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Barrier properties of polymer nanocomposites during cyclic sorption-desorption and stress-coupled sorption experiments

Suneetha Burla
West Virginia University

Barrier Properties of Polymer Nanocomposites during Cyclic Sorption-Desorption and Stress-Coupled Sorption Experiments

Suneetha Burla

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Dr. Rakesh K Gupta, Ph.D., Chair
Dr. Dady Dadyburjor, Ph.D.
Dr. Eung H Cho, Ph.D.

Department of Chemical Engineering
Morgantown, West Virginia
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ABSTRACT

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It is well known that layered silicate nanoparticles, when distributed within the matrix of a polymer, can retard the diffusion of small molecules and improve barrier properties. This has been demonstrated in both sorption and permeation experiments in the past. In order to assess the long-term retention of barrier properties of polymer-layered silicate nanocomposites, it becomes important to study their response to various environmental effects.

The main theme of this investigation is to study the effect of several water exposure cycles and exposure coupled with external tensile stress on the barrier properties of various polymers like vinyl ester, polyester and epoxy and their polymer-based nanocomposites. As expected, Montmorillonite clay decreased the diffusivity of moisture in the above polymers and retained its effect during the repeated cycles of sorption and desorption. However, in the presence of clay (5 wt%), diffusivities measured during absorption under external stress were larger than those without stress. SEM analysis on the 5 wt% clay loaded vinyl ester samples subjected to stress-coupled sorption revealed the presence of micro cracks which caused increase in diffusivities.

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DEDICATION

To my beloved parents...…..

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CHAPTER 1

INTRODUCTION

This chapter gives a short introduction to polymer layered silicate (PLS) nanocomposites and the effects of addition of nanoparticles to polymers on the barrier, mechanical and thermal properties of the polymers. It mentions the motivation for the study of polymers selected and lists the main objectives of this research project. Finally, it discusses several industrial applications of polymeric membranes, based on their barrier properties.

In addition to aerospace, marine and automotive applications, polymer composites are being increasingly used for structural applications such as construction of roads and bridges because of the durability of composites under harsh environmental conditions. Conventional structural materials are susceptible to corrosion and deteriorate when they come in contact with moisture or other deicing salt solutions. The growing concern over the deterioration of the infrastructure has prompted engineers to consider alternatives to conventional structural materials. Polymer composites offer superior resistance to corrosion, fatigue and other environmental effects when compared to metals and have other advantages such as lower density, high strength-to-weight ratio, high stiffness-to-weight ratio and ease of installation. Though the polymer composites may not corrode via the same mechanisms as metals, they undergo plasticization and degradation when exposed to moisture, caustic solutions, UV radiation etc. This results in deterioration of mechanical properties and reduction in the life of the composite structures. Polymer layered silicate nanocomposites, made by dispersing nano-sized particles, seem to provide a solution to this problem by reducing the diffusivity of moisture and other molecules in polymer composites. Nano materials, such as nanoclay, when distributed within the polymer matrix, act as physical barriers to the diffusing moisture by increasing the path of diffusion. Consequently, the nanocomposite would take a longer time before it is completely saturated with water. In addition, due to its hydrophilic nature, clay can help to sequester water molecules.

1.1 Introduction to Polymer Layered Silicate Nanocomposites

Nanotechnology is a new word which defines the creation of materials, devices and systems through the control of matter at the nanoscale (1 nm = 10^{-9} m) and has become one of the most powerful driving forces in technologies of the 21st century. PLS nanocomposites exhibit significant improvements in the properties such as modulus, strength, diffusivity and thermal stability by addition of only small amounts of organically modified layered silicates, when compared to their "neat" polymer constituents or their macrocomposite counterparts (Shah, 2001; Rana, 2003 and Ravindran, 2005). Such property enhancements are induced not only by the physical presence of the filler but also by the interaction of the polymer with the filler via altering the local properties of the polymer material. In this regard, PLS nanocomposites have been effective in modifying polymer properties due to the high surface area of contact and high aspect ratio (Cussler et al., 1988 and Alamgir et al., 2002). This large aspect ratio creates a tortuous path for a penetrant molecule resulting in improvement in barrier properties. More recent results indicate that chemical interactions may further improve the barrier properties of these systems (Ajit, 2004). The ever-growing industrial interest has stimulated the development of theoretical models to describe the transport process, but these may lack a correct microscopic description of the diffusion process.

1.2 Motivation for Study

Polymer-clay composites have been produced using a broad range of polymers, such as polystyrene, polypropylene, polyamide and epoxy. Some polymers are used in protective clothing application, electronic devices, cable materials and biomedical devices. A variety of major applications of polymers are in the fields of textiles, automobiles, food packaging, and consumer products etc, in which transport of small molecules across polymeric membranes plays an important role. This has drawn researchers' attention in the field of PLS nanocomposites and in the applications which demand stringent performance specifications and tolerances in properties and dimensions. The orientation and dispersion of layered silicate particles greatly influences the performance of the nanocomposites (Cussler, 2004 and Malwitz, 2003). Mechanical deformation is an important factor affecting the transport process through polymer nanocomposites as it can lead to changes in orientation and delamination of PLS in the polymer matrix.

Any application of polymer composites in an outdoor environment involves the interaction with moisture either in the form of atmospheric water vapor or rain. Also, the composites may have to come in contact with the chemicals and the solvents depending on the applications. Some examples include aviation turbine fuel, deicing liquids and paint strippers in aircraft applications; gasoline or motor fuel in automotive applications; and salt water in waterfront or seashore applications. This interaction can be continuous or periodic; periodicity can be either due to daily or seasonal changes in the atmospheric humidity, which can be regarded as harmonic or step wise changes caused by specific storage, operational or application conditions. Such environments may have a significant effect on the properties of the matrix resin and the composite. The effects of moisture on polymer composites have been investigated, but the focus of most experiments has been on the effects of a single cyclic absorption process (Chin et al., 1999 and Shah, 2002). The present study involves multiple sorption-desorption cycles to determine if cyclical aging introduces additional damage into the composite system.

However, in order to project the service life of composites, the knowledge of their performance and long time durability under conditions such as moisture, mechanical stress and stress coupled moisture becomes essential. A topic of practical interest is the effect of stress on moisture diffusion in polymers and composites. Most of the previous publications have dealt with the transport of moisture in polymers and polymer nanocomposites without stress. However, in many applications composite structures are subjected to internal and external stresses during much or all of their life. Some researchers have tried to understand the effect of stress on the water transport, but their investigation was restricted to polymers and polymer composites without any nano-sized particles (Fahmy, 1980; Marom, 1981; Weitsman, 1986 and Chipalkatti, 1986). The improvement of the barrier properties of the polymer-clay nanocomposites under zero-stress has been widely studied (Shah, 2001; Chen, 2002 and Rana, 2005). The number of studies addressing the effect of mechanical stress on the barrier properties of nanocomposites has been rather small (Liu, 2004). This is partly because the effects were considered inconsequential and also because of the limitations of the experimental techniques employed.

A more comprehensive understanding of stress effects may be gained by studying the diffusion behavior exhibited by both neat resins and their respective nanocomposites under conditions of zero tensile stress and uniaxial tensile stress. This research project aims at developing a new experimental technique designed to study stress-coupled diffusion in polymer nanocomposites. In addition, the investigation also involves study of diffusion during cyclic sorption-desorption of moisture in both neat resins and nanoclay composites.

1.3 Objectives of Research

- Structural characterization of polymer nanocomposites containing nanoclay using various techniques like SEM, TEM and XRD

- Measuring equilibrium moisture content and diffusivity of water in resins like vinyl ester, polyester, epoxy and their nanocomposites and establishing the mechanism of water diffusion through the polymers.

- Reducing the diffusion coefficient through polymers by dispersing nanoclay in the matrix and studying the effect of clay loading on the diffusion properties by varying the amount of clay.

- Conducting cyclic moisture sorption-desorption experiments to assess the effect of clay dispersion on the long term barrier properties.

- Conducting stress coupled moisture sorption experiments to study the effect of clay loading and stress on the transport properties.

To summarize, the transport of water through vinyl ester, polyester and epoxy resins and the effect of clay loading on transport properties will be studied gravimetrically, by performing transient water uptake experiments. Cyclic absorption-desorption experiments will be conducted to study the effect of cyclic changes in the concentration driving force on the diffusivity values. Stress-coupled diffusion experiments will be conducted to determine the effect of stress on moisture diffusion. Diffusion coefficient and equilibrium moisture content will be calculated from the data obtained which will provide insight into the rate and amount of water ingress into the sample.

1.4 Industrial Applications of Polymeric Membranes

In industry, polymeric membranes have been mainly used as barrier plastics, where resistance to diffusion of molecules plays an important role and as separation membranes, where selectivity and permeability are important factors. One particular industry where barrier properties of polymers play a significant role is the packaging industry. For example, for the packaging of carbonated soft drinks the package should not allow the permeation of carbon dioxide, oxygen or water. In the packaging of products containing fats and oils like fried snacks and meat, protection against the effects of oxygen and light is required.

An interesting exception to the simple barrier demands is the storage of blood platelets (Koros, 1990). Blood platelets are living cells that consume oxygen to live and generate carbon dioxide as a metabolic byproduct. The carbon dioxide generated presents a large problem as it tends to cause undesirable changes in the pH unless the carbon dioxide can escape. At the same time aqueous solution containing the platelets should not lose significant amounts of water by permeation. This case, therefore, illustrates the need for an advanced controlled atmosphere package which would allow relatively free exchange of oxygen and carbon dioxide while essentially preventing outward permeation losses of water.

Not only can the type of polymer be adjusted to the needs, but the macroscopic structure of the membrane can also be altered. As shown in Figure 1, one can use a variety of barrier structures besides that of a simple film to control the exchange of mass between the internal and external environment.

For example, in an application where there is a need for a barrier to oxygen an often used polymer is ethylene-vinyl alcohol (EvOH). EvOH has a very low permeability to oxygen in the dry state. The problem however is that it loses its barrier properties at high relative humidities, so in such cases an interface layer is placed on the EvOH membrane such that it is shielded from the humid environment.

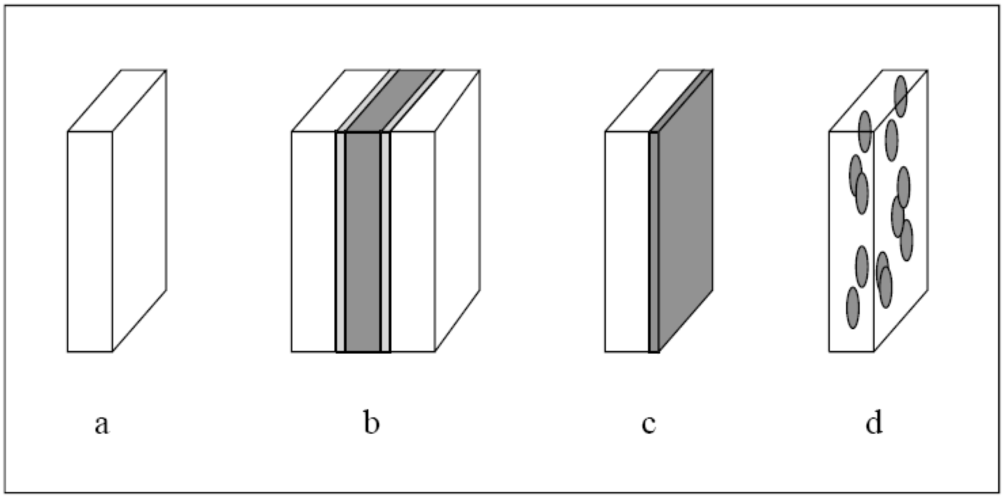


Figure 1 Primary types of barrier structures a) Monolithic, single polymer b) Laminate of two or more polymers, middle high barrier layer e.g. EvOH, covered with surface layers. These interact with the environment which could damage the middle layer. c) Reactively formed or coated laminate d) Polymer filled with inorganic platelets or higher barrier polymer lamellae to enhance the tortuosity of the path of the penetrants (Sok, 1994).

Another application which has large industrial interest is the selective separation of gases by use of membranes. In these cases there is a need for both high selectivity and high permeability. Silicone polymers have been used as selective membranes mainly because of the latter requirement. The enhancement of the selectivity usually has a negative influence on the rate of permeation, so for every application a new tradeoff has to be made. An interesting example of the enhancement of the selectivity is the use of polymer films containing metal complexes. The incorporation of cobalt-porphyrin complexes in a copolymer of poly (alkylmethacrylate) produces an increase in the selectivity (O_2/CO_2) from 3.4 to 12.8. The complex selectively absorbs (according to a Langmuir isotherm) and transports oxygen in the membrane (Nishide et.al., 1986 and Tsuchida, 1988).

Another class of applications is biomedical applications, for example the usage of polymers as contact lenses. Contact lenses are classified based on their mechanical strength and physical behavior as “hard”, to denote glassy polymers, or “soft” for rubbery polymers. For polymers used as contact lenses, surface wettability and flexure and high oxygen permeability are the important properties. Silicone films have been used as a material for contact lenses for the past three decades. Presently the polymer used in hard lenses is usually PMMA (polymethylmethacrylate) and most of the present soft contact lenses are prepared from poly (2-hydroxyethyl methacrylate) (PHEMA).

Controlled drug release is another biomedical application. Delivering the drugs at a controlled rate enhances their therapeutic efficacy and reduces their toxicities. Controlled release drug administration not only means prolongation in the duration of drug delivery, but also implies predictability and reproducibility. A number of therapeutic transdermal (through-skin) products employing silicone rubbers (including PDMS) are commercially available, for example for the controlled release of anesthetic vapors or steroids (Folkman, 1966 and Roseman, 1972).

The resins used in the present study are epoxy, polyester and vinyl ester and these have been widely used in automotive, marine, chemical, electrical and construction applications, mainly due to the ease of processing and composite manufacture, higher thermal stability, and chemical resistance. The construction applications involve construction of roads and bridges. Unsaturated polyester resins with styrene crosslinking agents are widely used, with applications in sanitation and in naval industries as composite matrix materials. The resistance of vinyl ester resins to degradation by corrosive and hostile environments has led to their use in many applications, such as in swimming pools, sewer pipes and solvent storage tanks. Epoxy resins, due to their excellent mechanical properties, are widely used as adhesives for bonding applications, including many in the construction, electronic packaging, aerospace, aircraft and automotive applications.

In all these and other applications modeling of the moisture transport can be of crucial importance to both a better understanding of the process or even the design of new polymer-based barrier films.

CHAPTER 2

LITERATURE REVIEW

This chapter gives a brief review of the polymers used as matrix materials in composites, the mechanism of mass transport in polymeric membranes, classification of the diffusion process and features of various diffusion processes. It also presents highlights of work done by various researchers on moisture diffusion through neat resins, composites and polymer layered silicate nanocomposites both with and without stress. It gives details of theoretical models describing the processes of diffusion and various factors affecting the mass transport process.

The knowledge of the performance of polymer layered silicate nanocomposites under different environmental conditions such as moisture, elevated temperatures and external stress has been of intense interest to scientists and engineers due to applications such as construction of roads and bridges, aerospace and other high performance applications. The mass transport process, however, is complex and so far no single theoretical framework or mathematical model has been able to explain the correct microscopic description of the phenomenon. In order to be transported through bulk polymers, small molecules must first be absorbed on the surface of the polymeric material. The dissolved molecules then diffuse through the polymer. Finally, the small molecules desorb on the other surface of the polymer.

2.1 The Polymer Matrix

Before looking at the mechanism of mass transport through membranes it is necessary to consider some features of the two principal microstructural conditions of polymeric materials, the glassy and rubbery state. It has been known for a long time that the mechanism of diffusion is very different in rubbery and glassy polymers. This is mainly due to the fact that glassy polymers are not in a true state of equilibrium. The difference in mechanism is reflected in the significant differences observed in the dependence of the diffusion coefficient, as well as the permeability and solubility coefficients, on the penetrant gas pressure or concentration in polymers and on the temperature (Stastna and De Kee, 1995). For example, the diffusion coefficients for light gases in rubbery polymers are often independent of concentration. By contrast, in glassy polymers the diffusion coefficients can be highly nonlinear functions of penetrant concentration and reach a constant value only at sufficiently high concentration. At temperatures below the glass transition temperature the polymer is in its glassy state and is hard and may be brittle, which is directly related to the restricted chain mobility. The intermolecular forces between the chains do not allow movements other than vibrations. Depending on the conditions during the formation of the glassy state (for example, the temperature gradient) the polymer is more or less trapped in a non-equilibrium state. In glassy polymers the penetrant diffusion is low but size selectivity is very good. Above the glass transition temperature the polymer is in its rubbery state. In this state the polymers are generally tough and flexible; this is associated with freer chain motion. Rubbery polymers have very short relaxation times (compared to glassy polymers) and respond very rapidly to external stresses. Thus a change in temperature causes an "immediate" adjustment to the new equilibrium state. A similar immediate adjustment occurs when small penetrants are absorbed in a rubbery polymer. Larger segments of the polymer are thought to participate in the penetrant diffusion process due to internal chain motions such as chain rotations, translations and stronger vibrational motions. The penetrant diffusion is much faster in a rubbery polymer than in a glassy polymer but size selectivity is lower. In both the glassy and rubbery states the polymer properties can be further modified by the presence of crystalline phases, by stress induced orientations or as a function of cross-link density. They tend to place additional constraints on the mobility of the amorphous phase through which diffusion takes place (It is partly because of these possible variations in polymer properties that there is such a wide range in experimental values of mass transport coefficients).

The basic equations governing the mass transport of one component through another component are described by Fick's laws. Fick's first law describes the flux to be linear with the concentration gradient and the proportionality constant is known as the diffusion coefficient. Fick's second law relates the concentration gradient with the change in the flux. The mass transport process that satisfies Fick's laws is called Fickian diffusion process (Case I). This kind of diffusion process has been modeled and solved systematically (Crank and Park,1968 and Crank, 1975).

Diffusion in polymers occurs by the transport of a penetrant via random molecular motion. In glassy polymers the diffusion process can be classified as follows (Alfrey et al., 1966 and Crank, 1968):

I. Case I- Fickian diffusion: the rate of diffusion of the penetrant is much smaller than the rate of the relaxation processes (polymer segment mobility).

II. Case II- the diffusion is much greater than the rate of the relaxation processes (polymer segment mobility).

III. Non-Fickian (anomalous) diffusion: the rates of diffusion and relaxation are comparable.

These different cases are usually differentiated by the shape of the sorption curves ($M_t/M_\infty=Kt^\alpha$) [Frisch et al., 1980]. M_t represents the mass of diffusant sorbed at time t, and M_∞ refers to the mass sorbed by the polymer at equilibrium. For Fickian diffusion, $\alpha = 1/2$, for non-Fickian systems, $\alpha=1$ and the diffusion process is considered to be anomalous for $\alpha \in (1/2, 1)$.

When Fick's first law is used in a mass balance, one obtains Fick's second law, whose

one-dimensional form is

$$\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial x^2} \qquad [2.1]$$

in which, c is the concentration of the diffusing species (in this case water), t is time, x is the position in the diffusing direction and D is the diffusion coefficient. Here D is taken to be a constant, but its value can depend on temperature and concentration of the diffusing species; it usually increases with increasing temperature.

When a dry sheet of polymer of uniform thickness (2*l*) is exposed to moisture, the sample mass increases due to water uptake and using appropriate boundary conditions for diffusion into a semi-infinite film exposed to an infinite bath of penetrant, Equation [2.1] can be solved to obtain moisture uptake (or mass gain) M_t to be

$$\frac{M_t}{M_\infty} = \left[1 - \Sigma\frac{8}{(2n+1)^2\pi^2}\exp\left[\frac{-D(2n+1)^2\pi^2 t}{4l^2}\right]\right] \qquad [2.2]$$

where $M_\infty$is the equilibrium increase in sample mass and 2*l* is the sample thickness.

The corresponding solution of Fick's Law at short times is

$$\frac{M_t}{M_\infty} = 2\left(\frac{Dt}{l^2}\right)^{1/2}\left\{\pi^{-1/2} + 2\sum_0^\infty (-1)^n \, ierfc\frac{nl}{\sqrt{(Dt)}}\right\} \qquad [2.3]$$

The diffusion coefficient can be calculated by simplifying the above equation (Crank, 1975). For $Dt/2l^2 < 0.05$, the above equation can be approximated to (Singh et al., 1991 for example)

$$\frac{M_t}{M_\infty} = 4\left(\frac{Dt}{\pi(2l)^2}\right)^{1/2} \qquad [2.4]$$

The diffusion coefficient can now be calculated from the initial slope of M_t / M_∞ Vs $t^{1/2}/2l$ plot. Alternately, the diffusion coefficient can be determined from (Crank, 1975)

$$D = \frac{0.049}{\left(t/4l^2\right)_{1/2}} \qquad [2.5]$$

where $(t/4l^2)_{1/2}$ is the value at $M_t/M_\infty = 0.5$.

In the case of desorption (during the final stages), the equivalent form of Equation [2.3] is given by the following (Crank, 1975)

$$\frac{d}{dt}\{\ln[M_t - M_\infty]\} = -\frac{\pi^2 D}{(2l)^2} \qquad [2.6]$$

and a plot of $\ln[M_t - M_\infty]$ versus time should approach a straight line, whose slope is given by the right hand side of Equation [2.6].

Gravimetric sorption involves exposing the specimen to a penetrant and monitoring the change in specimen mass with time. For liquid uptake experiments, a "blot-and-weigh" technique is often used. Mass uptake is referenced to the original mass of the specimen and is calculated by

$$M = \frac{M_t}{M_0} \times 100 \qquad [2.7]$$

Where M= Moisture Content (%)

M_t = Mass uptake of water at time t

M_0 =Dry weight of the sample

2.2 Mechanism of Diffusion of Water through Polymers and Polymer Nanocomposites

Diffusion of water through polymers may take place due to absorption and adsorption (Chin et al., 1999). Absorption is a capillary uptake of water by existing pores in the material and this process does not plasticize the matrix and generates little heat or swelling. Adsorption, on the other hand, is the process by which a solution is formed and generates heat (in the form of heat of solution) and results in swelling, as observed when a polymer is immersed in an organic solvent. In such a case, the term uptake or sorption should be used. Adsorption of water molecules takes place on the surface of the polymer, followed by the penetration of water into the polymer due to random molecular motion. For a polymer free of pores or voids, the process of water uptake is mainly due to adsorption. However in reality, no polymer is free of voids or pores, hence both adsorption and absorption take place simultaneously. Thus the entire process of water uptake is termed as a sorption process.

Moisture transport in polymers is related to molecular-sized holes (nanovoids) within the polymer matrix and to the polymer matrix-water affinity. There are two states of water in the water-absorbed epoxy system. The unbounded free water, filling the nanovoids, doesn't cause swelling. Hydrogen-bonded water, on the other hand, causes swelling of the polymer. Another study of moisture diffusion in plastic packaging by Cai et al. (2002) revealed that the water molecules inside the plastic materials were chemically bonded with polymers by hydrogen bonds in the microholes formed by the polymer-molecule chain. The amount of volume change due to moisture-induced swelling is significantly less than the volume of moisture absorbed, indicating that a large portion of absorbed water resides in the nanovoids. It is well accepted that the polarity of polymers affects the diffusion of water. However, it has not been established to what extent the topology has a significant effect on the moisture diffusion. The traditional theory suggests that the free volume affects the moisture absorption. However, studies have found no correlation between the topology (nanovoids size and total volume of nanovoids) and the moisture transport. Polar sites act as the bottleneck for transport through nanopores; the rate of formation and breakage of internal hydrogen bonds dictates the rate of the moisture transport. Furthermore, water in the nanopores may form hydrogen bonds with polymer chains and water transport is reduced. So far, the mobility of water in a polymer matrix and how absorbed water affects the mobility of polymer chains at temperature below and above T_g are not well known. The solvent absorption in any appreciable amount into polymeric films gives rise to a certain degree of swelling in the structure, which strongly influences the proportion between the amorphous and crystal phases of films (Junya, 2001). The presence of crystallites in a polymer reduces the effective cross-sectional area for diffusion and increase the effective path length. This may also result in restraints being imposed on the amorphous phase (Crank and Park, 1968).

Shah (2002) and Rana (2003) conducted moisture sorption experiments on vinyl ester nanocomposites and found significant improvement in the mechanical properties and reduction in diffusivities with increasing clay loading. The exfoliated clay particles improve barrier properties by physically impeding the movement of the penetrant molecules through the matrix. This mechanism is termed as "Tortuous Path" impedance. The clay platelets orient themselves in layers as shown in the schematic representation in Figure 2. Since the nanoparticles are dispersed through out the resin, the effective path of the diffusing molecule is longer, leading to a decrease in the diffusion coefficient and permeability. The addition of clay also showed an effect opposite to the above explained diffusion behavior as far as diffusivity through nanocomposites is concerned. Becker et al. (2004) have investigated the effect of nanoclay on the water uptake properties and thermal stability of high performance epoxy nanocomposites. Water sorption measurements showed an increase in diffusivity values with clay addition. The results also showed that the equilibrium water uptake of all nanocomposites was reduced when compared to neat epoxy system.

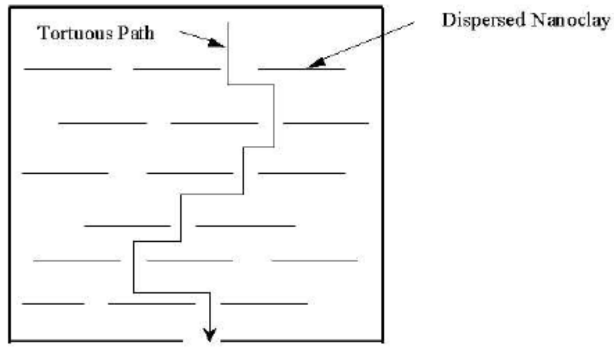


Figure 2 Schematic of the flow of a penetrant through a nanocomposite (Yano et al., 1993)

2.3 Stress Assisted Moisture Diffusion through Neat Resins, Composites and Polymer Layered Silicate Nanocomposites

Marom and Broutman (1981) studied the moisture penetration into composites under external stress. It was concluded that external stressing of composites results in increasing their rate of moisture absorption, their maximum moisture content and the diffusion coefficients. The results also indicate that the exposure of the composites to water produces a typical damage mechanism which enhances moisture take-up. Similar phenomenon was observed by Henson (1986) and Chipalkatti (1989).

Henson (1986) conducted moisture sorption and desorption experiments on neat epoxy and graphite epoxy under stress and concluded that both initial rate of diffusion and maximum moisture content increased in the presence of external stress. It was also proved that elastic strain, viscoelastic creep, and hygrothermal swelling generated during absorption in stressed coupons contributed significantly to the total deformation. Inspection of coupons under load revealed that an external stress increased both the crack density and the crack size, which might have accounted for the increased levels of moisture content found in the stressed coupons.

Chipalkatti (1989) investigated the stress and deformation coupled moisture transport in polymers. His results revealed that equilibrium moisture content and diffusion coefficient increased with applied stress.

2.4 Factors Affecting the Mass Transport Process

2.4.1. Temperature

Temperature plays a very important role in the diffusion of penetrant molecules through polymeric membranes. Diffusion, like reaction rates, may be thought of as an activated process following an expression of the Arrhenius form

$$D = D_O \exp(-E_D/RT) \quad [2.8]$$

where the activation energy E depends on the polymer and size of the penetrant. The break through time, time required for the penetrant to be detected on the opposite side of the membrane, is also dependent on the temperature according to Arrhenius form of relationship:

$$t_b = t_O \exp(E_B/RT) \quad [2.9]$$

where t_b and E_B are the breakthrough time and activation energy of breakthrough time respectively. The breakthrough time is the time taken in standard tests for permeation of a chemical through a protective barrier (such as a rubber glove) to be detected.

Sorption curves for the majority of the liquids show a systematic variation with temperature; i.e., sorption generally increases with increasing temperature. The sorption, diffusion, and permeation results increase with increasing temperature, and so, Arrhenius activation parameters for diffusion (E_D) and permeation (E_P) have been calculated with a general equation of the following type:

$$X = X_O \exp(-E_X/RT) \quad [2.10]$$

where X represents D or P and E_x represents E_D or E_P; RT is the usual energy term. The energy of activation is a function of the nature and size of the permeating liquid within the polymer matrix. With increasing temperature, the segmental motion of the polymer chain also increases; this creates additional free volume and, therefore, increases liquid transport (Aminabhavi et al., 1999).

The temperature dependence of the permeation and solubility can also be expressed by the following Arrhenius types of relationships:

$$J = J_O \exp\left(\frac{-E_J}{RT}\right) \quad [2.11]$$

$$S = S_O \exp\left(\frac{-H_S}{RT}\right) \quad [2.12]$$

where J is the flux and E_J is the apparent activation energy of permeation, and S is the solubility and H_S is the heat of sorption. H_S can be either positive or negative. The positive value of the heat of sorption suggests that the sorption process is endothermic, and sorption increases with increasing temperature, suggesting segmental movements of the polymer chain segments and thereby accommodating more solvent molecules at higher temperatures (Aminabhavi et al., 1999).When the sorption process is exothermic (heat of sorption is negative), the sorption decreases with increasing temperature (Chung et al., 2003). Such behavior can be explained in terms of thermodynamics by considering that the sorption of solvent molecules occurs at the liquid-polymer interface and it is generally assumed that there is a thermodynamic equilibrium at this interface. The process of sorption is a result of the equilibrium between the chemical tendency of mixing and the elasticity of the polymer network, which tends to limit the swelling. Therefore, depending upon the chemical nature of the solvent and the polymer, the sorption process could be endothermic or exothermic (Khinnavar and Aminabhavi, 1992).

2.4.2. Nature of the Polymer

According to the hole theory of diffusion, the rate of diffusion depends on the number and size distribution of pre-existing holes, and the ease of hole formation. The former depends on the ease and degree of packing of the chains and is related to the free volume and to the density (Hedenqvist et al., 1996). The ease of hole formation depends on the segmental chain mobility, i.e. the chain stiffness, and on the cohesive energy of the polymer. In addition, the degree of crystallinity and of crosslinking as well as additives such as fillers and plasticizers will affect the diffusion process. The dual type sorption behavior is typical of glassy polymers, appearing in polymers analyzed well below the glass-transition temperature, and it is due to localized adsorption on specific sites. Sorption is visualized as a process in which there are dual modes: either the penetrant molecules are normally dissolved and free to diffuse, or they are immobilized on particular sites of the polymeric matrix. In the case of organo layered silicates, in the absence of the polymeric matrix, we must assume that the dual behavior is due to adsorption on specific sites (Giuliana et al., 2003). It has been shown that the sorption and diffusion coefficients in the crystalline phase are substantially smaller than in the glassy or rubbery phases. As a result, it is generally assumed that the crystalline phase doesn't sorb, and hence, doesn't allow any penetrant to diffuse through it. In this case D depends on the volume fraction of the amorphous phase, α, the tortuosity of penetrant path, τ and the "blocking factor", B_1:

$$D = D_a \, \alpha n / B_1 \tau \qquad [2.13]$$

where D_a is the diffusion coefficient in a hypothetical, completely amorphous polymer, and n, approximately equal to 1, is an empirical parameter, dependent on the nature of the penetrant molecule (Chung et al., 2003). Hedenqvist et al. (2000) have studied the transport properties of hyperbranched and dendrimer-like star polymers and the results obtained confirmed that the transport properties were primarily controlled by the hydroxyl group concentration.

2.4.3. Nature of the Penetrant

Permeation through polymer membranes can occur from both the gas and the liquid phase. In gas permeation diffusion coefficients are independent of penetrant concentration in the membrane in contrast to vapor or liquid permeation. In latter case, membrane may be highly swollen by a penetrating liquid. This opens up the structures with the result that the absolute flux rates through the membrane can be 2 or 3 orders of magnitude larger than for a (noncondensible) gas. Thus in vapor or liquid permeation the diffusion coefficients are strong (typically exponential) functions of concentration.

If the available free volume spaces between polymer segments are bigger than the solvent molecule, then the liquid entering into these spaces may not cause significant change in volume. On the other hand, when the solvent molecules do not enter into the already available free volume, then the polymer segments tend to relax and thereby contribute toward swelling. In the absence of any such interactions between the polymer segments and solvent molecules at any time t, the mass uptake by the geomembrane may not be equivalent to the corresponding volume gain (Aminabhavi et al., 1999).

2.4.4. Mechanical Deformation

The effect of elongation depends on the nature and size of the penetrants, the barrier material, and, in addition, the magnitude and direction of the extension. Barrie and Platt (1961) investigated the diffusion of hydrocarbons into rubber cross linked with dicumyl peroxide and found that for an extension of up to 70%, no significant change in solubility and diffusivity was observed. At higher extensions, the permeability decreased with increasing extension. Several authors have observed that if the extension is less than a critical value, the effect of the extension on permeability is negligible. A decrease in permeability followed by an increase as the extension increases has also been reported (Liu et al., 2004). Wolf and Fu (1996) observed an increase in diffusion when the applied stress was above a critical value. Henson (1986) studied the stress effects on moisture transport in an epoxy resin and its composite. His results show that the maximum moisture content increases roughly with stress for the composite coupons, but grows non-linearly for the epoxy samples. Also, the diffusivity values increase with increasing stress level for both epoxy and composite coupons. The interaction between stress and moisture in epoxy can be attributed to the time dependent response of the resin and that in composite are apparently due mainly to damage.

2.4.5. Cyclical Aging

The issue of moisture ingress into polymer nanocomposites is of utmost concern. The time-scale of moisture diffusion is much slower than heat transfer, but the effects can be more dramatic. Absorbed moisture causes plasticization of the polymer matrix and reduces the glass transition temperature of the resin. This results in changes in modulus, strength, and strain to failure and fracture toughness. These effects may be reversible, but the swelling stresses induced by moisture uptake can cause permanent damage such as matrix cracking, hydrolysis etc. The effect of moisture on polymer nanocomposites has been extensively studied, but the focus has been on the effect of a single cyclic absorption process. The cyclical aging might introduce an additional damage into the composite system.

Garcia et al. (1998) have studied the effects of cyclic moisture aging on a glass/vinyl ester composite system and found that the material properties are reduced significantly after the first conditioning cycle, but damage does not continue to accumulate with exposure time. The initial damage is not recovered when the material is allowed to return to its initial moisture content, suggesting that there is permanent damage to the matrix or fiber and plasticization of the matrix material. Lee and Rockett (1992) found that in unsaturated polyester, vinyl ester and acrylic resins, the diffusion coefficient, D, calculated for absorption was much higher than that for desorption and reabsorption. Grinsted et al. (1992) performed experiments on poly-(methyl methacrylate) exposed to methanol and reported that the diffusivity increased with the number of cycles. Martin and Garcia (2000) studied the effect of water exposure cycles on particle-filled epoxy-based adhesives. Their results showed a marked increase in saturation level between absorption and reabsorption. This could be attributed to the re-development of hydrogen bonds, created between filler and resin, during reabsorption. The results of their work showed a depression in glass transition temperature with the number of cycles which is dependent on the moisture contained in the apparent free volume. Mauri et al. (1978) have determined moisture sorption and desorption in a number of graphite-reinforced epoxy and high temperature resistant polymer composites at different conditions of humidity and temperature. They observed that the sorption and desorption rates were roughly equivalent and the diffusion coefficients were independent of the relative humidity. They also found an increase of diffusivities with subsequent resorption cycles and this was thought to be due to microstructural damage. Chipalkatti (1989) studied the stress and deformation coupled cyclic moisture sorption-desorption in polymers (Nylon 6, 6 and Polycarbonate). His results revealed that equilibrium moisture content increased with applied stress and rose over repeated cycles of sorption-desorption. The diffusion coefficient was observed to increase with applied stress but decreased with time through repeated cycles. It was established that the effect of hysteresis and the effect of repeated cycles was largely thermo-reversible in the materials studied.

2.5 Models Describing the Phenomenon of Diffusion in Composites

A common model (Maxwell, 1881) describes the diffusion coefficient D of a small solute through a continuum partly filled with a suspension of impermeable spheres

$$D/D_O = \frac{1-\varphi}{1+\frac{\varphi}{2}} \qquad [2.14]$$

where D_o is the diffusion coefficient in the absence of the spheres and φ is the "loading," that is, the volume fraction of the spheres. This is a small effect: if φ equals 0.1, the diffusion drops about 15%.

According to Cussler et al. (1988), diffusion through polymers is described as the diffusion of small solute molecules through a continuum partly filled with a periodic suspension of impermeable flakes. They used Monte Carlo calculations of diffusion across membranes containing impermeable flakes to show the effects of tortuous paths around the flakes, of diffusion through slits between flakes, and of constricted transport from entering these slits. The flakes are so arranged that the diffusion is essentially two-dimensional. This diffusion depends strongly on the orientation of the flakes. If the flakes are all oriented parallel to the direction of the diffusion, the result is approximately

$$\frac{D}{D_O} = \frac{1-\varphi}{1+\varphi} \qquad [2.15]$$

For a membrane containing impermeable flakes oriented perpendicular to the diffusion, the simplest limit is

$$\frac{D}{D_O} = 1 + \left(\frac{\alpha^2\varphi^2}{1-\varphi}\right) \qquad [2.16]$$

Here φ is the volume fraction of the flakes and α is the aspect ratio, half the second longest dimension of the flakes divided by the shortest dimension (Eitzman, 1996; Carter and Kibler, 1978).

CHAPTER 3

EXPERIMENTAL PROCEDURE AND METHODS OF CALCULATION

The purpose of the experimental phase of this investigation was to study the effect of clay addition on repeated cycles of sorption and desorption in the absence of stress and on stress coupled moisture sorption in polymers. Specimens were monitored for moisture absorption and desorption, mechanical deformation, material property changes and damage accumulation. This chapter includes materials used in this study, chemistry of resins used, sample preparation, characterization methods, experimental set up for each type of experiment and methods of data analysis.

3.1 Materials

Commercial vinyl ester, polyester and epoxy were used in this study. All three matrices are thermosets suitable for fabricating FRP composites through pultrusion and resin transfer molding processes. Hetron 922 vinyl ester and AROPOL 2036 C polyester were obtained from Ashland Chemicals. Both the vinyl ester and polyester resins were dissolved in styrene. The epoxy used was Tyfo S Saturant Epoxy consisting of two components A and B obtained from FYFE Company LLC. Part A was epoxy resin, which is a modified bisphenol-A polyglycidyl ether and Part B was hardener, which is a modified polyamine. Nanocomposites were made using Cloisite 10A® clay obtained from Southern Clay Products.

Methyl ethyl ketone peroxide (9% active oxygen) was used as an initiator and 6% cobalt naphthenate was used as promoter in the preparation of vinyl ester and polyester samples. In case of polyester sample preparation, the reaction between initiator and promoter is very fast and hence an inhibitor was added to increase the gel time and to inhibit the resin from curing very quickly. 10% Hydroquinone in methanol was used as an inhibitor. All the chemicals were obtained from Sigma Aldrich Company.

3.2 Sample Preparation

Samples of neat vinyl ester were prepared by mixing together resin, catalyst and promoter in the quantities mentioned in Table 1, and then pouring the mixture into a

Teflon mold. The Teflon molds used are as shown in Figure 3. A similar procedure was followed for polyester except that inhibitor was added in addition to catalyst and promoter in case of polyester samples. To prevent oxygen inhibition of the free radical cross linking reaction and also to minimize styrene evaporation, the Teflon mold was sealed using another Teflon sheet. Typical dimensions of the samples used for sorption experiments were 5 cm x 1.25 cm and thicknesses varied between 0.07 cm and 0.1 cm. The cured samples are as shown in Figure 4. The resin was allowed to cure at room temperature for 24 hours and the samples were post cured for 3 hours in an oven maintained at 95 °C. Samples of neat epoxy were prepared by mixing 100 parts of component A by weight with 34.5 parts of component B by weight for about an hour to assure complete homogeneity of the mixture. The mixture was then poured into Teflon molds, cured for 24 hours at room temperature and post cured for 24 hours at 60 °C.

Figure 3 Teflon mold used to cast the samples

Figure 4 Cured neat vinyl ester samples

Table 1. Table showing catalyst, promoter, inhibitor quantities, curing temperature and post curing temperature used for different resins used in the study

Resin	Catalyst (wt %)	Promoter (wt %)	Inhibitor (wt %)	Curing		Post curing	
				Time(hrs)	Temp(^{o}C)	Time(hrs)	Temp(^{o}C)
Vinyl ester	1.25	0.3	-	24	25	3	95
Polyester	1.25	0.15	0.3	24	25	3	75
Epoxy	-	-	-	24	25	24	60

Nanocomposite samples for the diffusion experiments were prepared by mixing different weight percentages of Cloisite 10A® with resin in a sonicator (for about 20-30 minutes) until the mixture was completely homogenized. The mixture was then degased in a vacuum chamber to make sure that all the gas bubbles were completely removed and then promoter, initiator and inhibitor were added to the mixture in quantities mentioned in Table 1 and stirred for about 10 minutes. The mixture was then poured into Teflon molds, cured for 24 hours at room temperature and then post cured.

Vinyl ester samples for diffusion experiments under stress were prepared in a similar manner as mentioned above and holes of 0.7mm diameter were drilled at the two ends of the samples.

3.3 Characterization Methods

3.3.1. X-Ray Diffraction

X-ray diffraction was used to determine the basal spacing of the montmorillonite clay. These tests were performed on both clay and clay-polymer nanocomposites. The samples were prepared in a manner similar to those prepared for sorption experiments and were molded to disc shape with 40mm diameter and 3-5 mm thickness. The tests were conducted using PANalytical X'pert Pro PW3040-Pro X-Ray Diffractometer. The samples were scanned from 2θ of 0º to 12º. The slit settings on the tube side were 1/4º for scatter and 1/8º for divergence. Intercalation of the clay by the polymer chains would lead to an increase in the basal spacing, while exfoliation would cause the peak in the XRD graph to disappear.

3.3.2. Transmission Electron Microscopy

Samples used for TEM analysis were prepared in a manner similar to the preparation of samples for diffusion experiments. The pictures of samples and the molds used for the preparation of samples are shown in Figure 5(a). Characterization was done using JEOL 100CX Transmission Electron Microscope with an accelerating voltage of 80 kV. Ultra thin sections of the polymer/clay nanocomposite with a thickness of approximately 65 nm were cut parallel to the face of the sample using an ultra microtome equipped with a diamond knife.

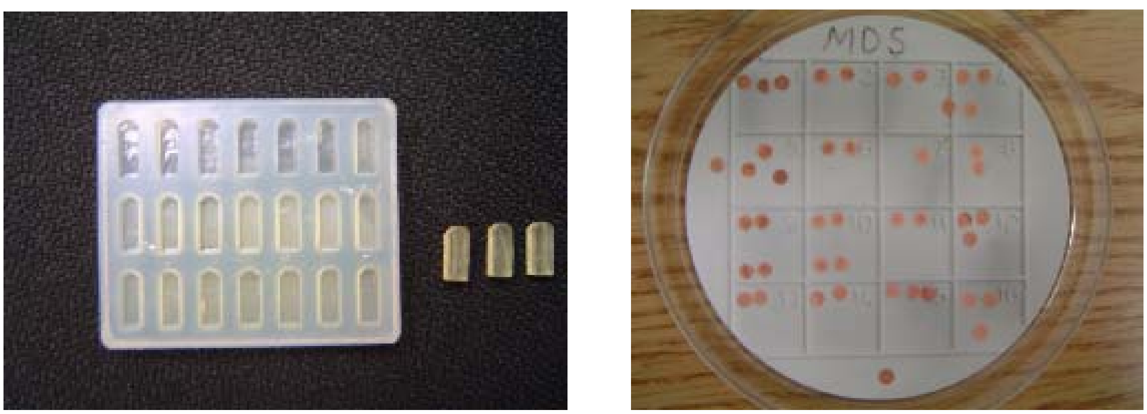


Figure 5 (a) Molds and Samples used for TEM analysis (b) Carbon coated Cu grids used in TEM analysis

A representative diagram of the sectioning is shown in Figure 6. The sections were transferred dry to carbon-coated Cu grids of 200 mesh shown in Figure 5(b). The contrast between the layered silicates and the polymer phase was sufficient for imaging, so heavy metal staining of sections prior to imaging was not required. The pictures obtained show the dispersion of nanoclay within the polymer.

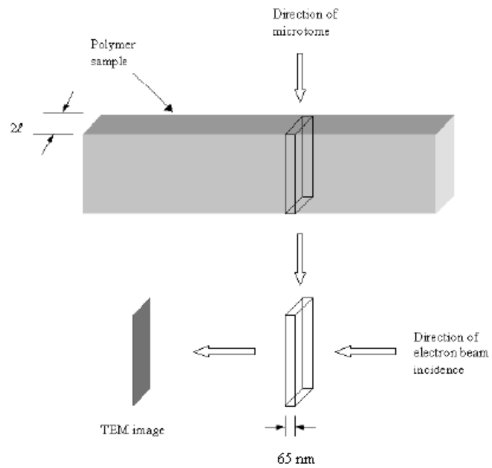


Figure 6 Schematic representation of sample microtoming for TEM analysis. Direction of electron beam incidence is the direction of view.

3.3.3. Scanning Electron Microscopy

Cyclical Aging could cause microcracking of the matrix and degradation of tensile stiffness and strength and changes in mode of failure. Also, it is highly likely that external stresses will enhance the accumulation of such damage and further affect stress-assisted diffusion. The presence and extent of such damage was monitored using scanning electron microscopy.

Scanning electron micrographs of freshly prepared samples (5 cm x 1.25 cm, thickness-(0.07-0.1) cm) with various clay loadings were taken and recognized as “Reference” samples. Samples were examined for the presence of microcracks after each cycle of sorption-desorption and also after the stress coupled diffusion experiments. A sample to be examined was fixed to an aluminum stub using double sided graphite tape. Then the sample was kept in 400 mm Hg vacuum for 15 minutes to ensure that there was no water inside the sample. The sample was then coated with a 30-40 nm gold layer in a sputter coater shown in Figure 7(a) to make the surface conductive. Then the sample was grounded to the aluminum tab using a copper tape shown in Figure 7(b).

Figure 7 (a) Gold sputter coater (b) Gold coated sample grounded with copper tape

The scanning electron microscope used was Hitachi S4700 cold fielding machine and the sputter coater was Gold-Pd SPI-MODULETM sputterer. Scanning electron micrographs of the samples obtained were compared with the micrographs of the “Reference” samples.

3.3.4. Cyclic Sorption-Desorption Experiments

Post-cured samples were immersed in a beaker containing distilled water at room temperature. Samples were periodically removed, blotted dry with Kimberly Clarke lint-free tissue, weighed and re-immersed in water. A Mettler electronic balance with an accuracy of 1 μg was used to measure the weight of the samples. Samples were weighed after every 30 minutes for the first 3 hours after immersion, every hour for the next 12 hours, every 12 hours for the next 2 days and every day until samples are completely saturated. Each experiment was continued until there was no mass gain reported over a period of 5 days. Data obtained for at least 4 - 5 samples were used to calculate the average diffusion coefficient of the material. The diffusion coefficients and equilibrium moisture contents were calculated from the sorption curve.

The completely saturated samples were, then, kept inside a controlled humidity chamber maintained at a humidity of 20% RH. Temperature of the humidity chamber was found to be 25 °C throughout the experiments. All the samples were weighed periodically to understand the desorption behavior of these samples. Here, the equilibrium was considered to have been attained when no weight loss was recorded over a period of 5 days. The above procedure was repeated for three repeated sorption-desorption cycles. Diffusion coefficients for desorption were calculated from the slope of the normalized weight- loss curves during later stages of desorption.

3.3.5. Equilibrium Moisture Content

The dependence of maximum moisture content of vinyl ester samples, both neat and clay loaded, on the relative humidity of the environment was determined experimentally. The samples were allowed to reach equilibrium moisture content in an air-sealed constant humidity chamber during exposure to four different relative humidities: 40%, 60%, 70% and 80%. The humidity of the chamber is varied by placing hot water in the chamber until required humidity is attained. Five samples each for all clay loadings were used for monitoring weight gain during exposures at all relative humidities. All the samples were weighed periodically until equilibrium was attained. The temperature of the chamber was at 27 ºC during these four exposures.

3.3.6. Stress Coupled Sorption Experiments

A stainless steel cylindrical load frame was used to apply a constant load for up to 36 specimens at a time as shown in the Figure 8. The frame consisted of twelve holes on its circumference. Twelve specimens parallel to each other were loaded and each specimen contained three samples in series linked using momentless steel wire in order to produce pure uniform uniaxial tension in all the samples. Each specimen containing three samples swiveled in series was latched to the frame using a die spring of known spring constant, nut and bolt. The load was applied on the specimens by tightening the spring. The ultimate tensile stress (UTS) of the fresh samples was determined (Rana, 2003) prior to the experiment and specimens were monitored for two different load levels of 8 lb_f (17% UTS) and 14 lb_f (30% UTS). Both neat and clay loaded samples were subjected to the same load levels. The entire load frame with samples mounted on it was then immersed in water for experiments in water and placed in a humidity chamber maintained at 60% RH for experiments at 60% RH shown in Figure 9. The moisture weight-gain measurements were performed by periodically removing three samples in series as explained in the previous section. Since initial weight measurements were more frequent than the later ones and to avoid periodic stress relaxations in the samples, all the samples for the initial period of 48 hours were not reloaded but kept for future characterization after weight gain measurement. Weight gain during the later stages of absorption was monitored by periodically weighing the samples and reloading them onto the load frame until equilibrium weight gain was attained.

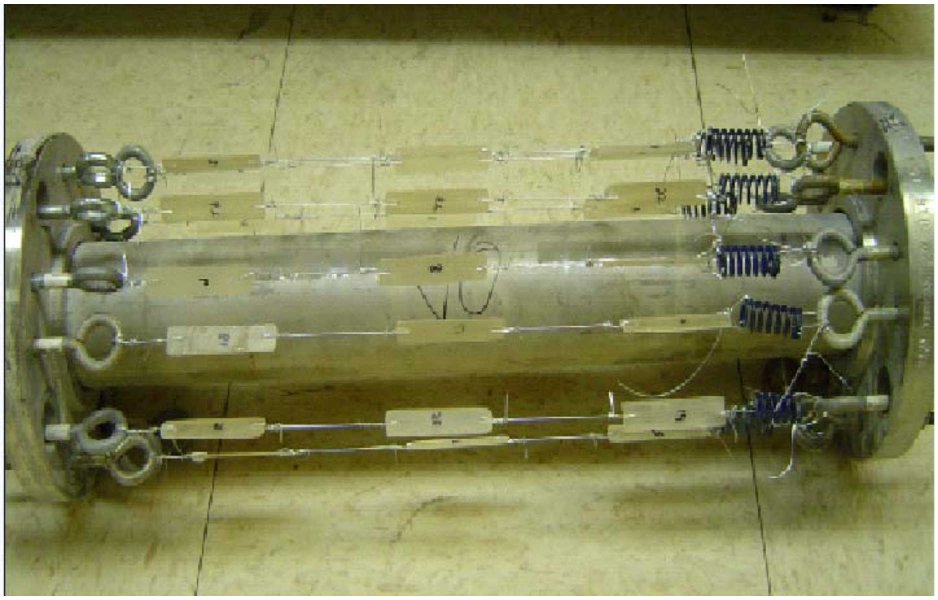


Figure 8 Assembly of the load frame loaded with samples for sorption under stress

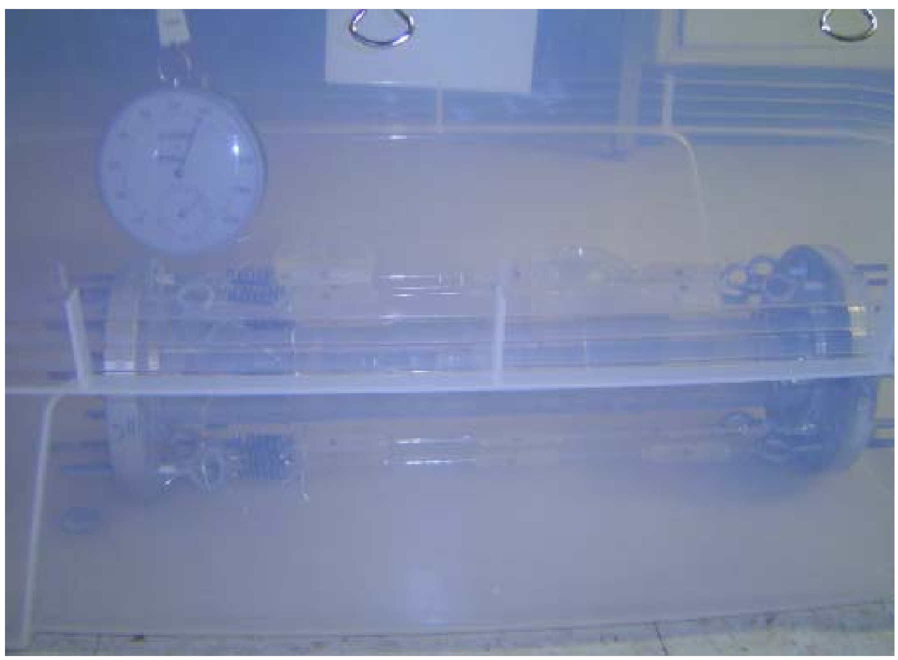


Figure 9 Experimental set up for sorption under stress at 60% RH

3.4 Method of Calculation of Diffusion Coefficient in Samples During Sorption

The diffusivity for the samples was calculated using Fick's law as described in the previous chapter.

Thickness of the sample=2*l* cm

Weight gain of the sample at time t=M_t gm

Weight gain of the sample at equilibrium=M_∞ gm

The diffusion coefficient, D can be calculated by rearranging the following Equation

$$\frac{M_t}{M_\infty} = 4\left(\frac{Dt}{\pi(2l)^2}\right)^{1/2} \qquad [3.1]$$

into the following equation

$$D = \frac{\pi \times (2l)^2}{16}\left(\frac{M_t / M_\infty}{\sqrt{t}}\right)^2 \qquad [3.2]$$

Where $\frac{M_t / M_\infty}{\sqrt{t}}$ is the slope of the straight line from the plot of M_t/ M_∞ versus $\sqrt{t}$ drawn up to $M_t/ M_\infty<0.5$ and the units of D are cm^2/sec.

3.5 Method of Calculation of Diffusion Coefficient in Samples During Desorption

The diffusion coefficient during desorption can be calculated by rearranging the following equation:

$$\frac{d}{dt}\{\ln[M_t - M_\infty]\} = -\frac{\pi^2 D}{(2l)^2} \qquad [3.3]$$

into the following equation

$$D = -\left(\frac{\ln[M_t - M_\infty]}{t}\right)\frac{(2l)^2}{\pi^2} \qquad [3.4]$$

Where $\left(\frac{\ln[M_t - M_\infty]}{t}\right)$ is the slope of the straight line from the plot of $\ln[M_t - M_\infty]$ versus t drawn during the last stages of desorption and the units of D are cm^2/sec.

3.6 Method of Calculation of Equilibrium Moisture Content

The moisture content within the samples was calculated using the following equation

$$M = \frac{M_t}{M_0} \times 100 \qquad [3.5]$$

Where M= Moisture Content (%)

M_t = Mass uptake of water at time t

M_0 =Dry weight of the sample

CHAPTER 4

RESULTS AND DISCUSSION

4.1 XRD Analysis

Figure 10 shows XRD scan on Cloisite 10A® and also on vinyl ester nanocomposite samples containing 0 wt%, 2 wt% and 5 wt% clay. The d spacing for clay can be calculated using the Bragg equation [4.1]

$$2d \sin\theta = \lambda \qquad [4.1]$$

where d is the λ average distance between the individual clay platelets, θ is half the diffraction angle and is the wavelength of the incident X-ray. The XRD pattern of the Cloisite 10A® montmorillonite clay contained a strong peak at 2θ=4.5º. The interlayer distance (d-space) of clay was found to be 3.9nm. This value matches with the interlayer distance of the nanoclay platelets determined using TEM. Similar results were reported by Shah (2001). No strong characteristic basal reflections (peaks) were observed for nanocomposites samples. The absence of such a peak indicates either exfoliation or breakdown of ordered structure of the clay. However, when the scans were observed on different scale on separate graph shown in Figure 11, very small peaks were seen for 2 wt% and 5 wt% Cloisite 10A® nanocomposites too, which become insignificant when seen on a combined XRD scan shown in Figure 10.

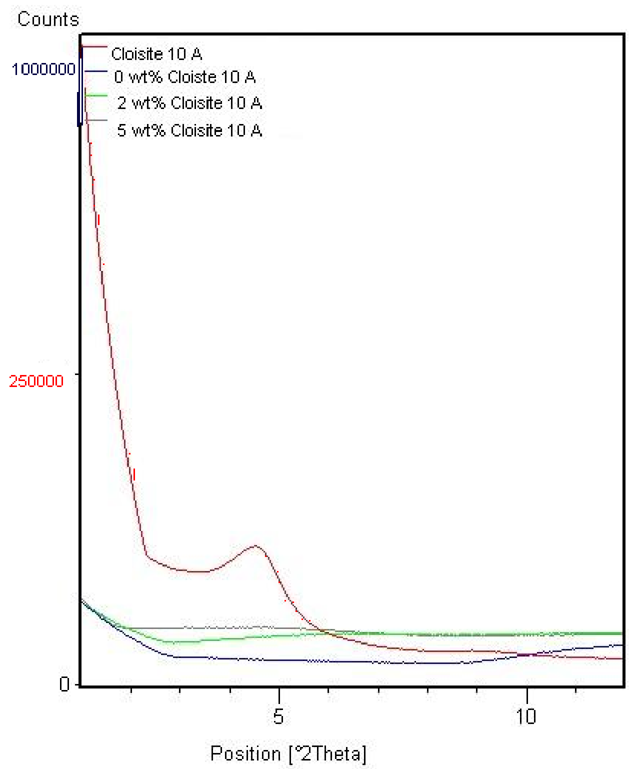


Figure 10 XRD scans on Cloisite 10A® and vinyl ester nanocomposites

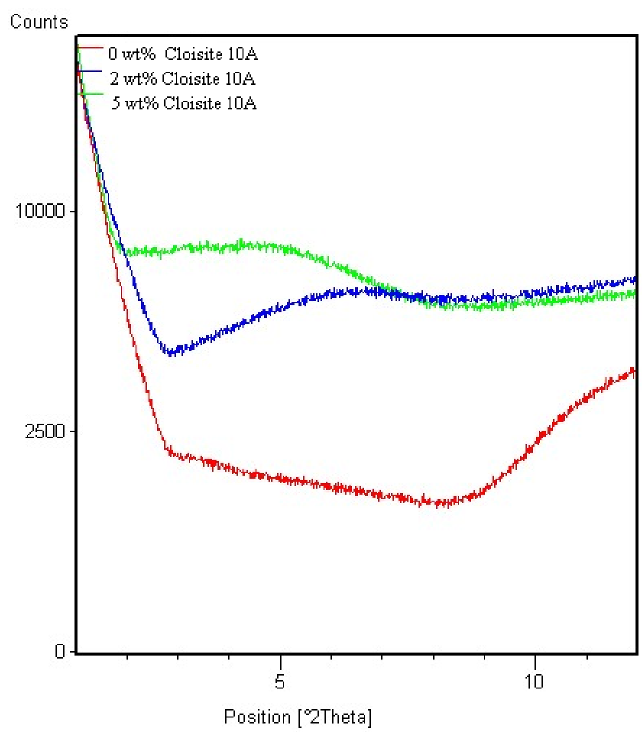


Figure 11 XRD scans on neat vinyl ester resin and vinyl ester nanocomposites

4.2 TEM Analysis

Analysis of TEM images of nanocomposite samples explains morphology of the various clay loaded polymer samples. Figure 12 to Figure 16 show TEM micrographs of vinyl ester nanocomposites, Figure 17 to Figure 20 show micrographs of polyester nanocomposites and Figure 22 to Figure 24 show micrographs of epoxy nanocomposites. TEM pictures at low magnification show that the clay particles are reasonably dispersed, uniformly distributed and randomly oriented. This is shown in representative pictures of 2 wt% and 5 wt% clay loaded vinyl ester, polyester and epoxy nanocomposites in Figure 12, Figure 13, Figure 14, Figure 17, Figure 18 and Figure 22. At higher magnifications of >100,000x, it was found that the clay particles existed both as clusters or aggregates and as individual platelets in the form of dark lines, as shown in Figure 15, Figure 16, Figure 19, Figure 20, Figure 21, Figure 23 and Figure 24. The aggregates consisted of about 2 to 20 expanded silicate sheets and the distance between the individual platelets in these aggregates was found to be in the range of 3 - 4 nm.

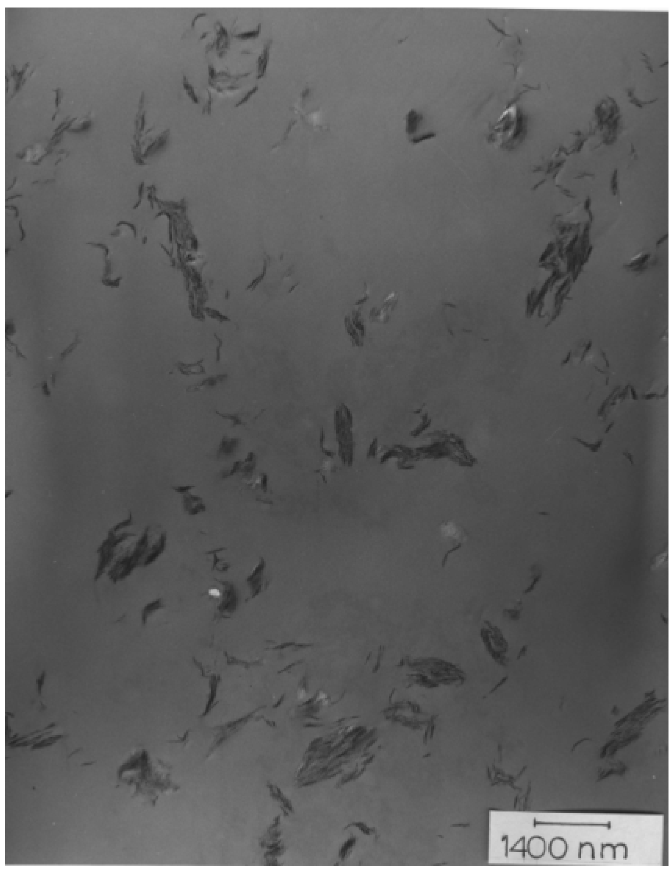


Figure 12 TEM image of 5 wt% clay loaded vinyl ester (14,400x)

Figure 13 TEM image of 2 wt% clay loaded vinyl ester (30,000x)

Figure 14 TEM image of 5 wt% clay loaded vinyl ester (30,000x)

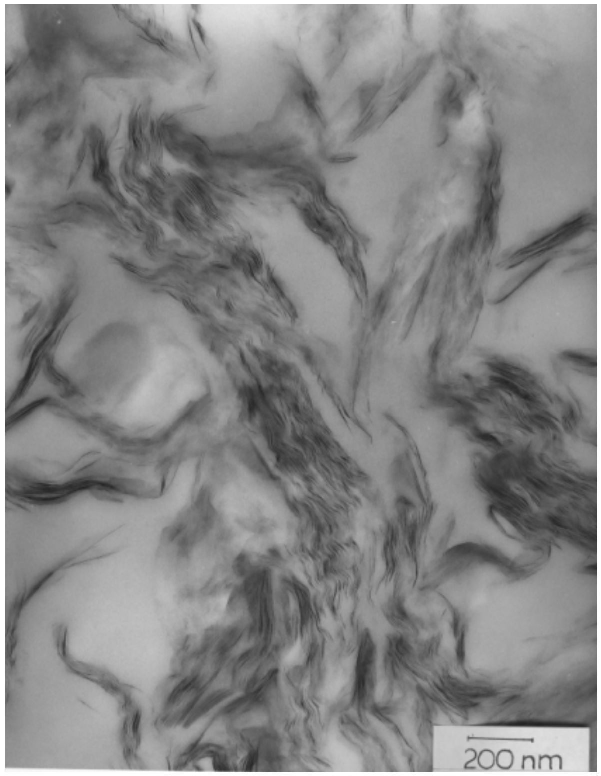


Figure 15 TEM image of 2 wt% clay loaded vinyl ester (108,000x)

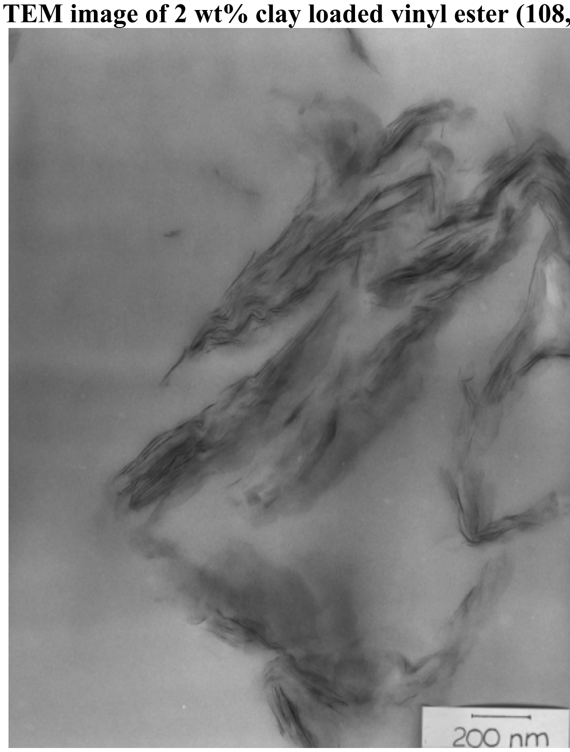


Figure 16 TEM image of 5 wt% clay loaded vinyl ester (108,000x)

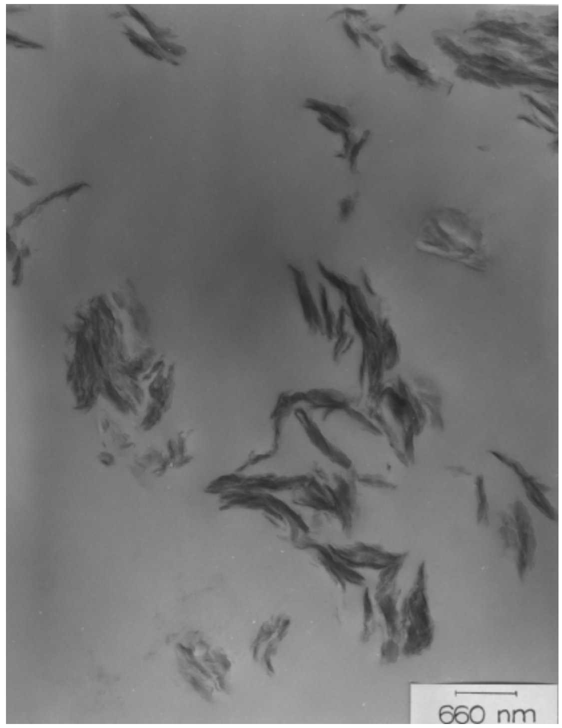


Figure 17 TEM image of 2 wt% clay loaded polyester (30,000x)

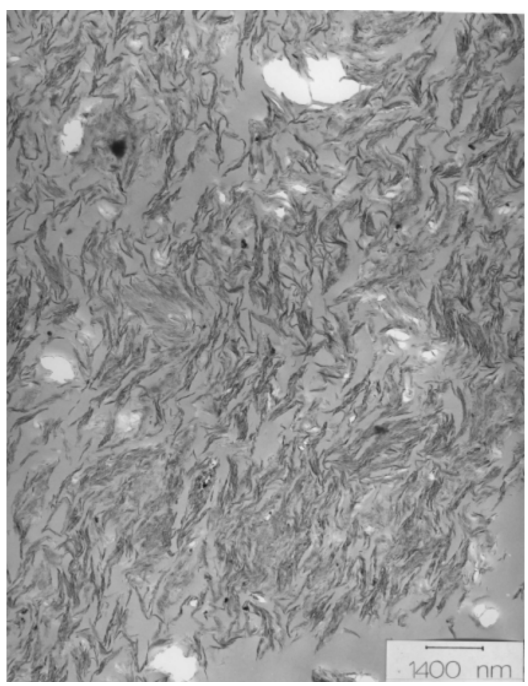


Figure 18 TEM image of 5 wt% clay loaded polyester (14,400x)

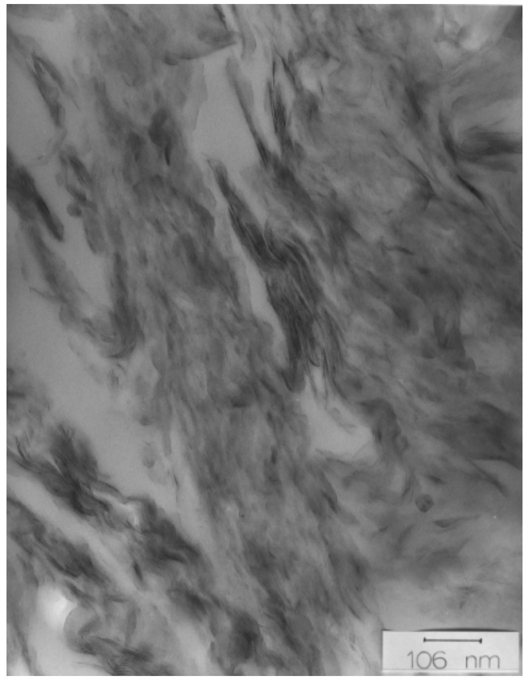


Figure 19 TEM image of 5 wt% clay loaded polyester (174,000x)

Figure 20 TEM image of 5 wt% clay loaded polyester (300,000x)

Figure 21 TEM image of 2 wt% clay loaded polyester (420,000x)

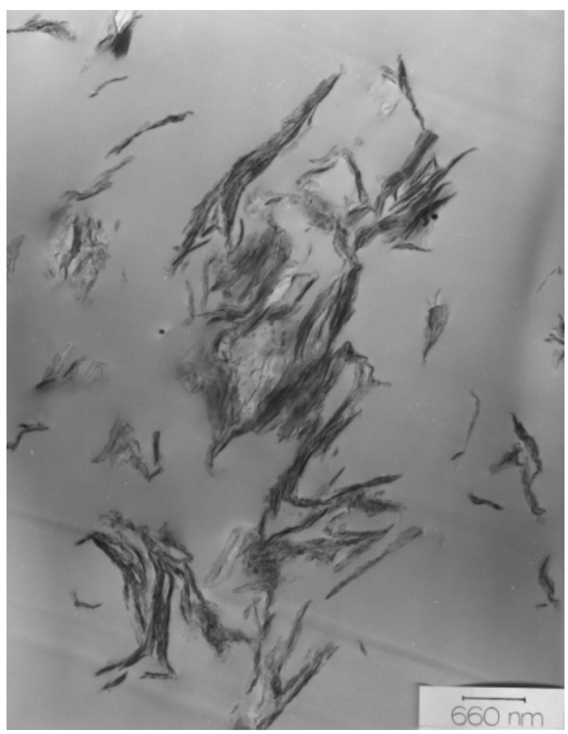


Figure 22 TEM image of 2 wt% clay loaded epoxy (30,000x)

Figure 23 TEM image of 2 wt% clay loaded epoxy (300,000x)

Figure 24 TEM image of 5 wt% clay loaded epoxy (300,000x)

The presence of clay in the form of both aggregates and individual platelets suggests that the samples are not completely exfoliated, and a better dispersion of clay can be obtained through improved mixing techniques. A possible explanation for the observed morphology may be the method of mixing/dispersing the clay used. The clay was ultrasonically mixed with resin using a sonicator at room temperature. It is possible that in regions where the clay platelets started to expand and peel away, the local viscosity greatly increased. There was no possibility of lowering the viscosity as the mixing was done at room temperature, and there might be loss of styrene at higher temperatures. The shear produced by the ultrasonic waves was not enough to break these regions of high concentrations of clay. Also, there might be chances of these ultrasonic waves not being able to penetrate into the regions of high viscosity. The clay in the low concentration regions was completely exfoliated and that in the high concentration regions remained as aggregates or clusters and was not effectively dispersed to the lower concentration zones. Thus the problem could possibly be solved by increasing the shear, which could improve the dispersion of the clay particles. Other suggestion would be ultrasonic mixing coupled with manual/mechanical stirring to prevent the excess build up of local clay concentration.

The TEM pictures explain the morphology of the corresponding nanocomposites of the polymers used in the study as a combination of exfoliated, intercalated and stacked structure.

4.3 Cyclic Sorption-Desorption Experiments with Distilled Water at Room Temperature

4.3.1. Experiments with Vinyl ester

Graphs of moisture uptake versus time and moisture content (%) versus time were plotted for all the vinyl ester samples containing different percentages of clay to show the trends at each of the three cycles of absorption (in water) and desorption (at 20% Relative Humidity). It was seen that the samples never quite reached the initial dry weight and retained some of the moisture. This is because desorption was done at 20% RH. The sample was in equilibrium with air at 20% RH at the beginning of the next cycle of sorption-desorption. The data from each cycle of absorption-desorption for different weight percentages of clay were plotted to demonstrate the effect of cyclical aging and clay addition on the equilibrium moisture content. The raw data for cyclic sorption-desorption experiments with neat vinyl ester samples is given in Appendix D in Table 12 and Table 13.

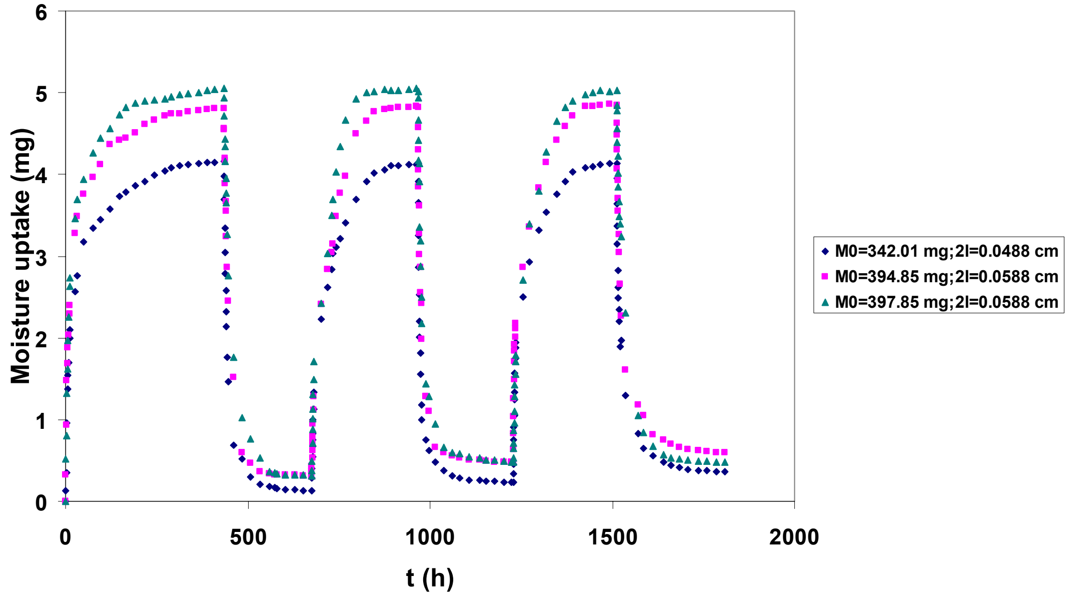


Figure 25 Moisture uptake (mg) versus t (h) for neat vinyl ester samples during cyclic absorption (water) - desorption (20%RH) at 25 °C

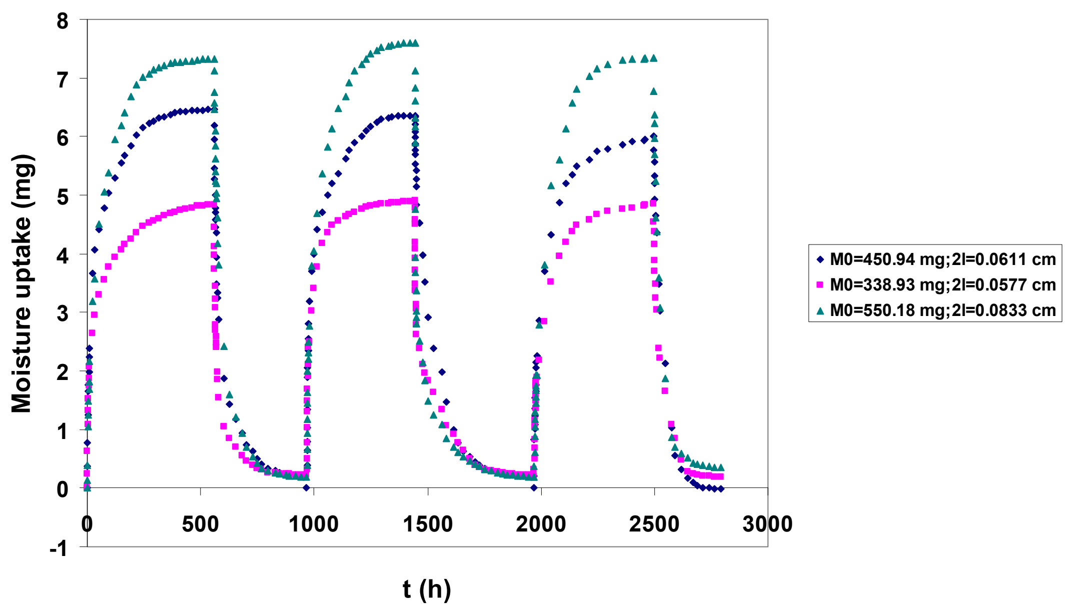


Figure 26 Moisture uptake (mg) versus t (h) for vinyl ester samples containing 2 wt% Cloisite 10A® during cyclic absorption (water) - desorption (20%RH) at 25 °C

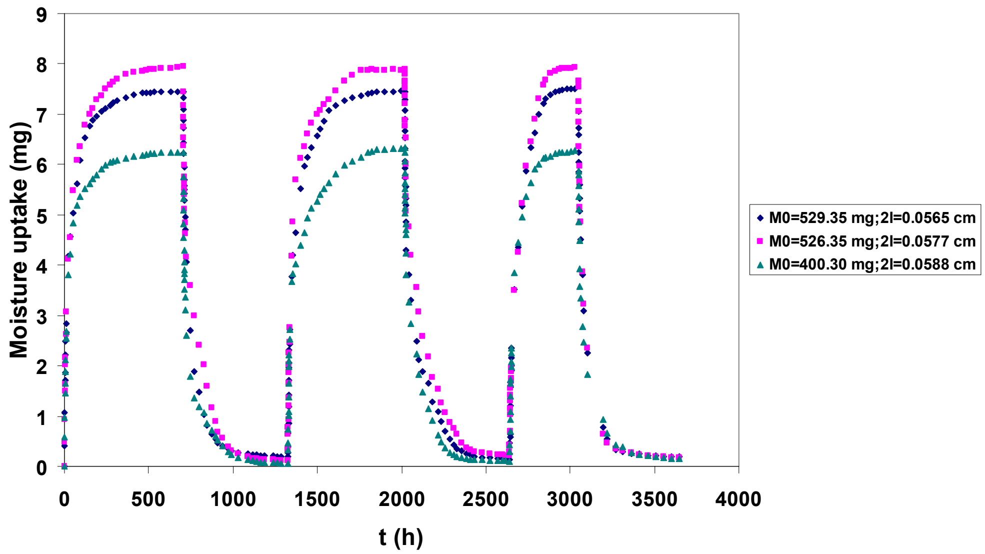


Figure 27 Moisture uptake (mg) versus t (h) for vinyl ester samples containing 5 wt% Cloisite 10A® during cyclic absorption (water) - desorption (20%RH) at 25 °C

Figure 25, Figure 26 and Figure 27 show moisture uptake versus time for neat vinyl ester samples and vinyl ester samples containing 2 wt% and 5 wt% clay respectively, during three cycles of sorption-desorption at 25 °C. For a given cycle of sorption-desorption, the time taken by the samples to reach equilibrium during absorption and desorption for clay loaded samples was more than that for the neat vinyl ester samples.

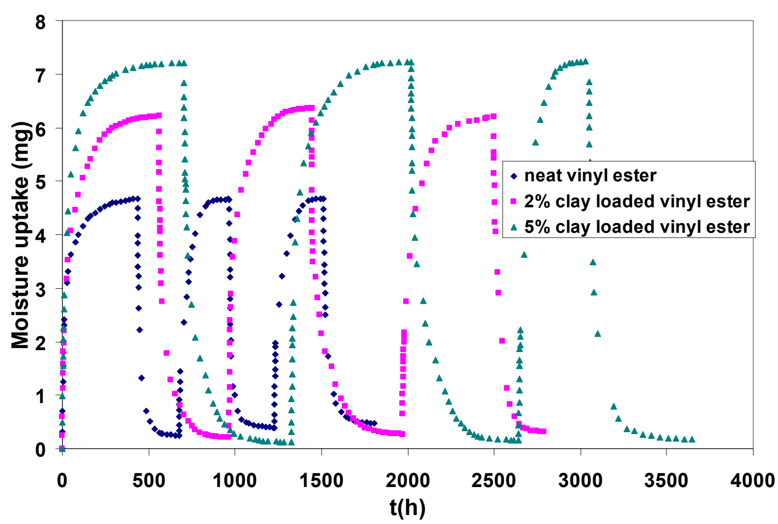


Figure 28 Average moisture uptake (mg) versus t (h) for vinyl ester samples containing different clay loadings during cyclic absorption (water) - desorption (20%RH) at 25 °C

Figure 28 shows average moisture uptake data for neat vinyl ester resin samples and those containing clay during cyclic sorption-desorption. It can be seen from the figure that the equilibrium moisture uptake for clay loaded samples was more than that for the neat vinyl ester samples. It was also observed that the cycling did not alter the equilibrium moisture content of the samples for given clay loading.

Using the mass uptake data of the samples, moisture content (%) for all the samples was determined and the graphs are shown in the following figures. Figure 29, Figure 30 and Figure 31 show moisture content versus time for neat vinyl ester samples, 2 wt% clay loaded and 5 wt% clay loaded vinyl ester samples respectively.

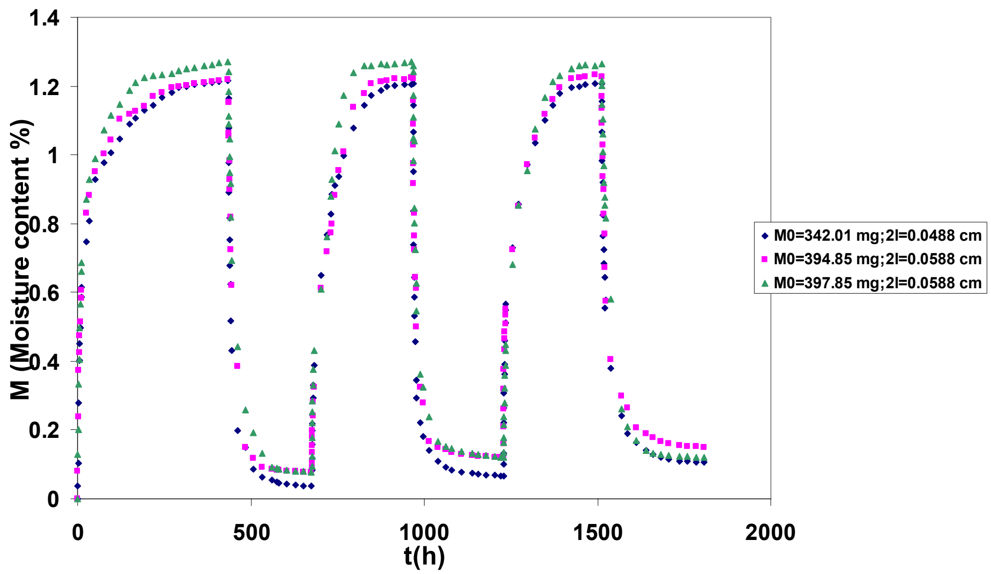


Figure 29 Moisture content versus t for neat vinyl ester samples during absorption (water)-desorption (20%RH) at 25 °C

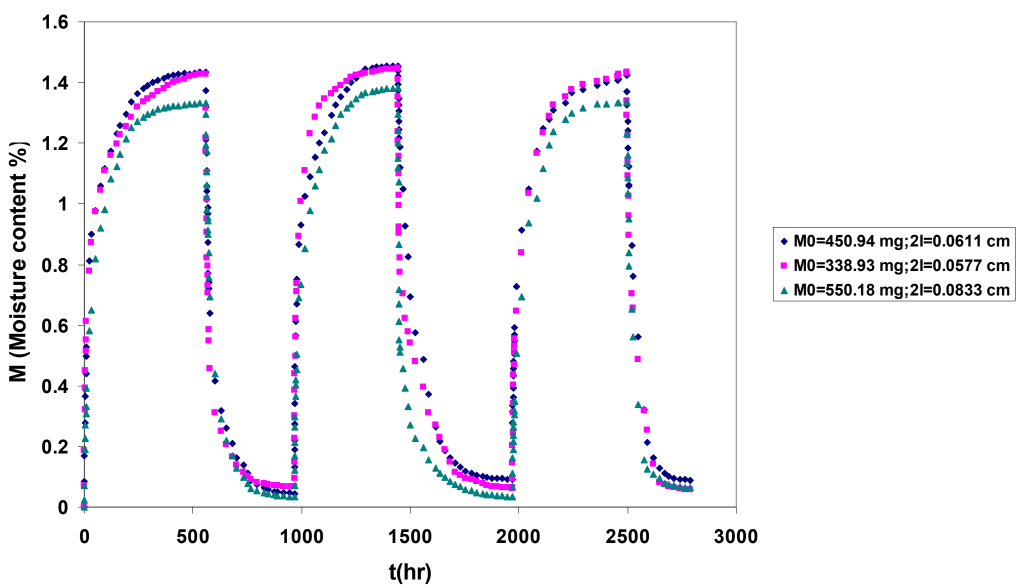


Figure 30 Moisture content versus t for vinyl ester samples containing 2 wt% Cloisite 10A® during absorption (water)-desorption (20%RH) at 25 °C

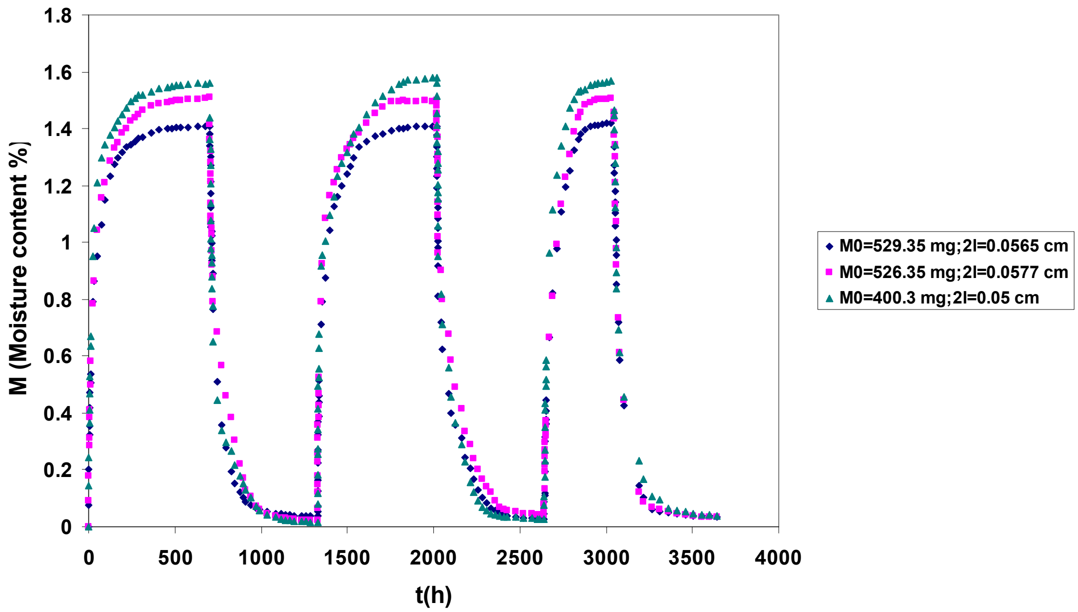


Figure 31 Moisture content versus t for vinyl ester samples containing 5 wt% Cloisite 10A® during absorption (water)-desorption (20%RH) at 25 °C

It can be clearly seen from the figures that for given clay loading, the samples reached same equilibrium moisture content during three cycles of sorption-desorption. Figure 32 shows average moisture content versus time plotted for vinyl ester samples containing different weight percentages of clay.

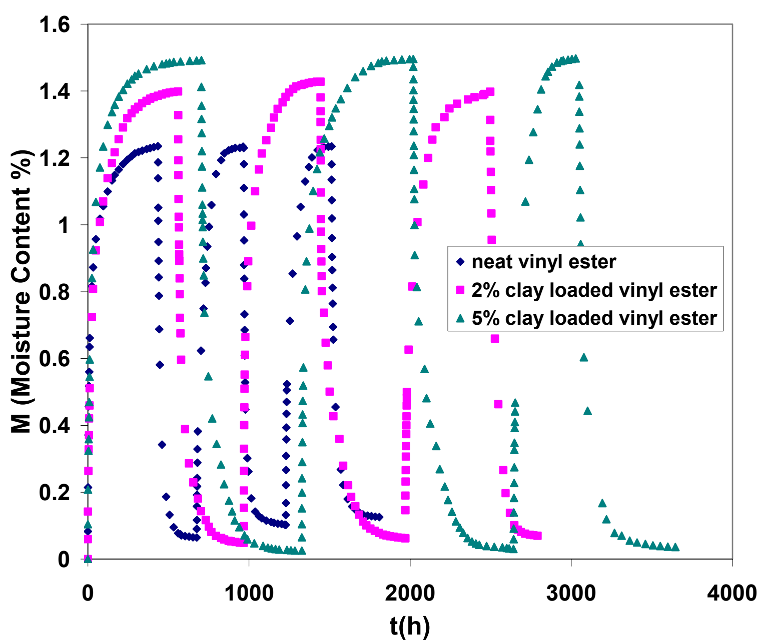


Figure 32 Average moisture content versus time for vinyl ester samples containing different clay loadings

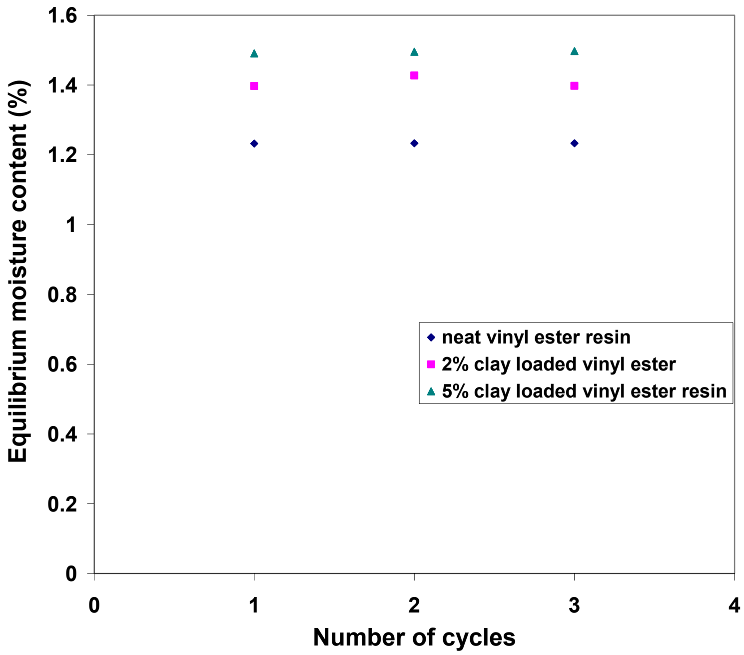


Figure 33 Comparison of equilibrium moisture content for vinyl ester samples containing different clay loadings obtained during cyclic sorption-desorption

Figure 33 shows comparison of equilibrium moisture content for vinyl ester samples containing different weight percentages of clay during three cycles of sorption-desorption. The equilibrium moisture content was found to be 1.23% for neat vinyl ester resin samples, 1.4% for 2 wt% clay loaded vinyl ester samples and 1.5% for 5 wt% clay loaded vinyl ester samples. It was observed that cycling did not affect the equilibrium moisture content for a given clay percentage i.e., the samples reached the same equilibrium moisture content at the end of the second and third cycles as that in the first cycle. But, for a given cycle, the equilibrium moisture content and the time taken to reach equilibrium increased with the increasing amount of clay. Similar results have been reported by Shah (2001) and Rana (2003). They observed non-linear increase in equilibrium moisture content with increased clay loading.

The reason for increasing equilibrium moisture content with increasing clay loading is due to the natural tendency of clay to adsorb water. The clay platelets preferentially absorbed the water molecules until they were saturated and hindered further ingress of water molecules by effectively increasing the diffusion path and tortuosity. Once the platelets were completely saturated, the water molecules would then follow a tortuous path to diffuse. Also, the presence of nanoparticles in an intercalated nanocomposite decreases the segmental mobility of polymer chains confined to regions between clay platelets. As a result, the water diffusion slows down (decrease in the diffusivity values), and the penetrating water molecules form aggregates or clusters in the nanocomposite. These clusters are mainly formed in neighborhoods of clay particles. According to free volume theory, clustering of water molecules implies an increase in the total mass uptake by the polymer matrix. This is shown by the water uptake by Cloisite 10A® in a humid environment of 60% RH at 25 °C in the Figure 34. Measured quantity of Closite 10A® is placed inside the humidity chamber and is periodically removed to measure the weight gain until equilibrium. The weight gain data is then used to calculate change in moisture content of the clay with time. Figure 34 clearly shows that the Cloisite 10A® absorbs moisture with time.

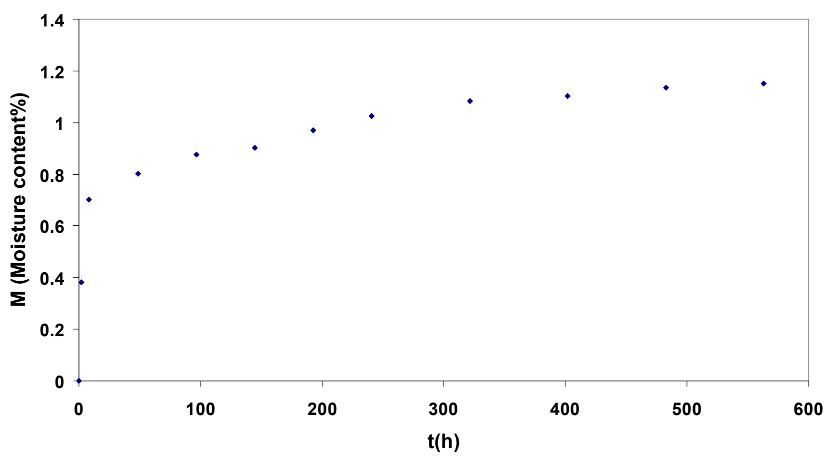


Figure 34 Moisture content versus t for Cloisite 10A® during exposure at 60% RH at 25 °C

A graph of M_t/M_∞ versus $t^{1/2}$ for absorption experiment was plotted for all the vinyl ester samples during three cycles of sorption-desorption where M_t and M_∞ were masses uptake of water at time t and at equilibrium respectively.

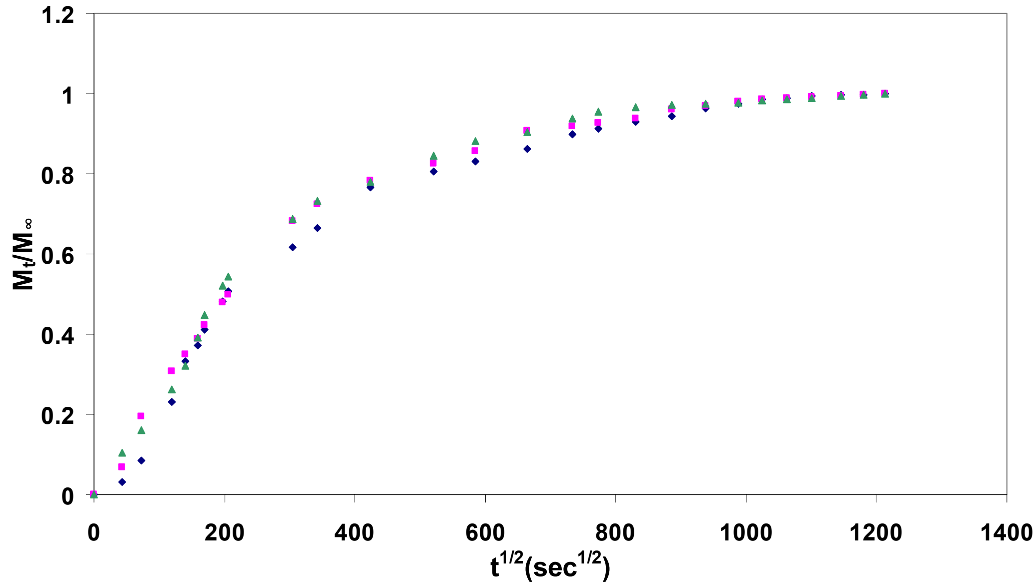


Figure 35 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 0 wt% Cloisite 10A® at 25 °C during first cycle of absorption

Figure 35, Figure 36 and Figure 37 show graphs of M_t/M_∞ versus $t^{1/2}$ for neat vinyl ester samples during first, second and third cycles of absorption. The plots show a linear initial uptake for the samples indicating that diffusion followed a Fickian process. From the initial slopes of these curves, absorption diffusion coefficients for all the cycles were calculated according to the method explained in Section 3.4.

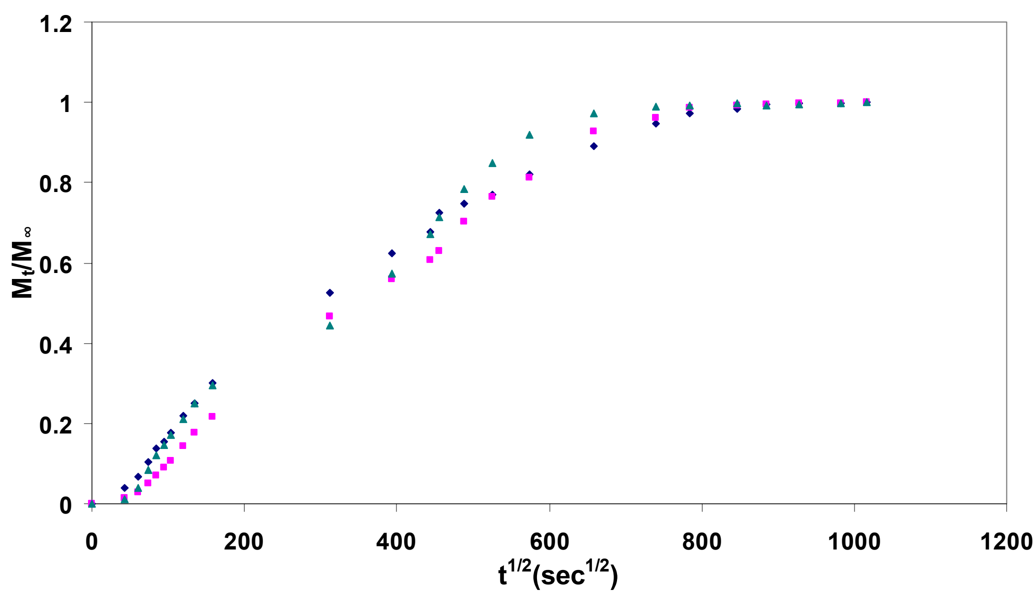


Figure 36 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 0 wt% Cloisite 10A® at 25 °C during second cycle of absorption

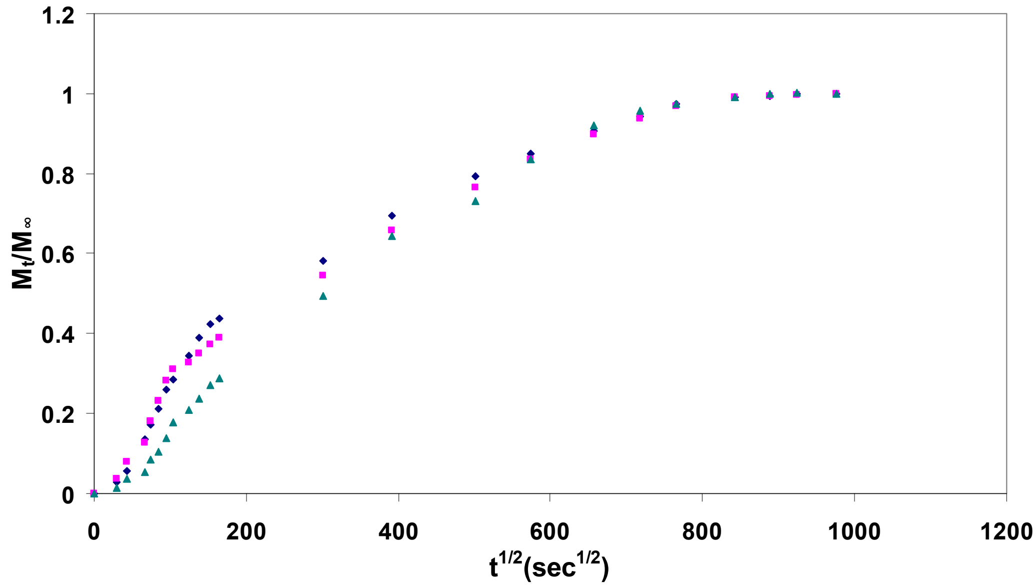


Figure 37 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 0 wt% Cloisite 10A® at 25 °C during third cycle of absorption

The diffusivity of water in neat vinyl ester resin during first cycle of absorption was found to be 4.15 x 10^{-9} cm^2/s and this is comparable to the value reported by others (Chin et al., 1999; Verghese et al., 1999; Rana, 2003 and Ravindran, 2005). The absorption diffusivities decreased slightly with subsequent cycles. The absorption diffusivities were found to be 1.53 x 10^{-9} cm^2/s for second cycle and 2.37 x 10^{-9} cm^2/s during third cycle. This could possibly be due to improved curing and greater crosslinking between the polymer chains with time and subsequent reabsorption. This improved curing and crosslinking with moisture absorption was also reported by other researchers in the past (Startsev, 1985 and Ravindran, 2005). Water was found to activate postcure of the epoxy materials for a whole class of epoxy compounds. In epoxy polymers, the residue of the groups that are capable for reaction but have not reacted is preserved. When polymers absorb water, the polar physical bonds become weak and the intensity of molecular motion increases. This in turn increases the probability of a contact between the groups that have not reacted, and therefore, of creating chemical bonds.

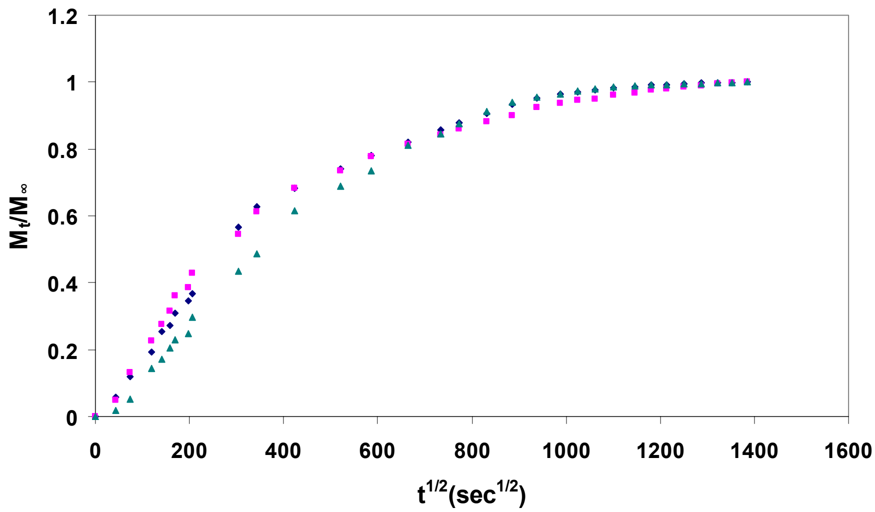


Figure 38 **M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 2 wt% Cloisite 10A® at 25 °C during first cycle of absorption**

Figure 38, Figure 39 and Figure 40 show graphs of M_t/M_∞ versus $t^{1/2}$ during first, second and third cycles of absorption respectively for vinyl ester samples containing 2 wt% Cloisite 10A®. The graphs show linear initial uptake indicating Fickian diffusion during three cycles of absorption. From the initial slopes of these curves, diffusion coefficients were calculated as explained in Section 3.4. The raw data for cyclic sorption-desorption experiments with vinyl ester samples containing 2 wt% Cloisite 10A® is given in Appendix D in Table 14 and Table 15.

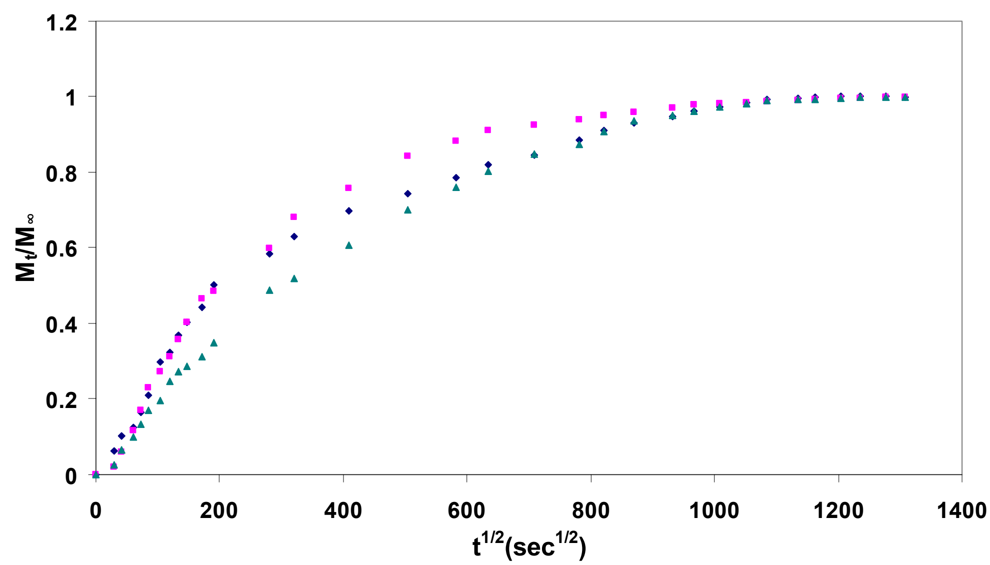


Figure 39 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 2 wt% Cloisite 10A® at 25 °C during second cycle of absorption

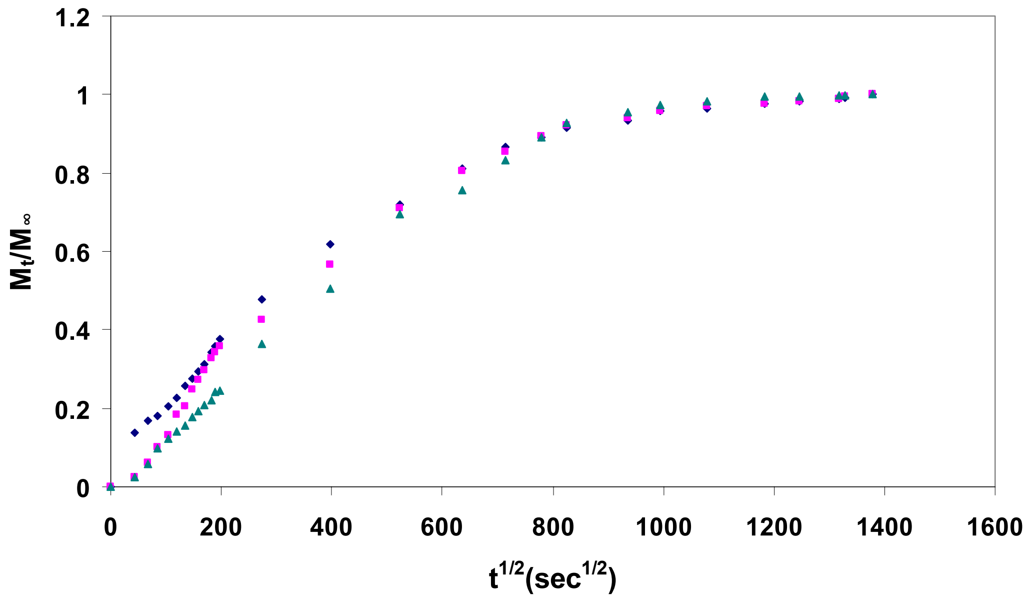


Figure 40 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 2 wt% Cloisite 10A® at 25 °C during third cycle of absorption

The average diffusivities were found to be 2.63 x 10^{-9} cm^2/s for first cycle, 2.54 x 10^{-9} cm^2/s for second cycle and 2.23 x 10^{-9} cm^2/s for third cycle of absorption.

Similar graphs of M_t/M_∞ versus $t^{1/2}$ for samples containing 5 wt% Cloisite 10A® during first, second and third cycles of absorption were drawn and are given in Appendix C in Figure 123, Figure 124 and Figure 125 respectively. The graphs showed linear initial uptake indicating Fickian diffusion during three cycles of absorption. From the initial slopes of these curves, diffusion coefficients were calculated as explained in Section 3.4. The average diffusivities were found to be 2.04 x 10^{-9} cm^2/s for first cycle, 2.12 x 10^{-9} cm^2/s for second cycle and 1.53 x 10^{-9} cm^2/s for third cycle of absorption.

Also, graphs of ln (M_t-M_∞) versus t for desorption experiment were plotted for all the samples during three cycles of sorption-desorption. From the slopes drawn during the final stages of desorption curves, desorption coefficients were calculated according to the method explained in Section 3.5.

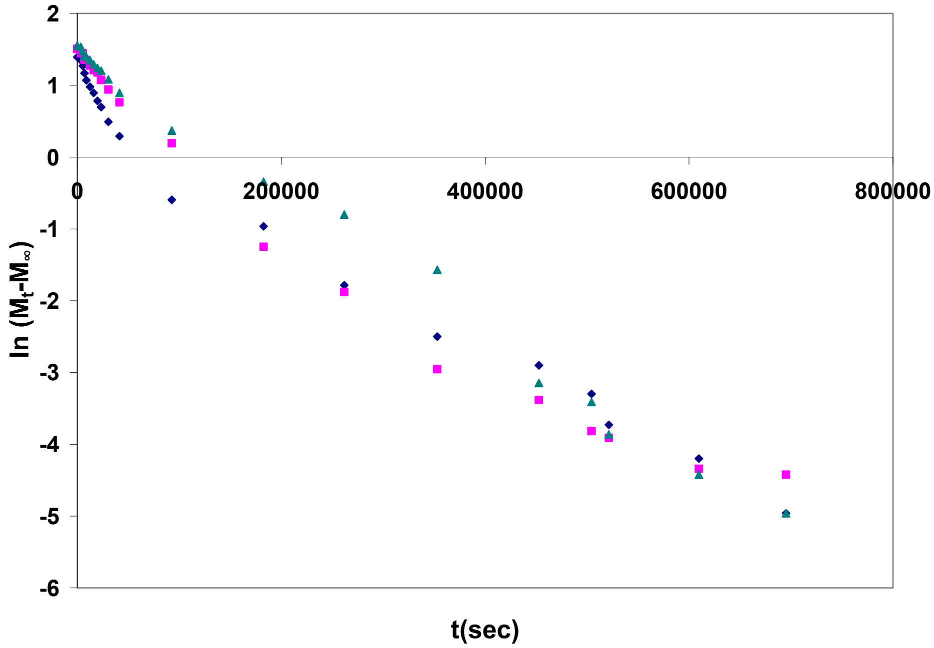


Figure 41 ln (M_t-M_∞) versus t for vinyl ester samples containing 0 wt% Cloisite 10A® at 25 °C during first cycle of desorption

Figure 41, Figure 42 and Figure 43 show ln (M_t-M_∞) versus time for neat vinyl ester samples during first, second and third cycles of desorption respectively. The plots show linear curves during the final or later stages of desorption indicating that the diffusion followed Fickian process during desorption.

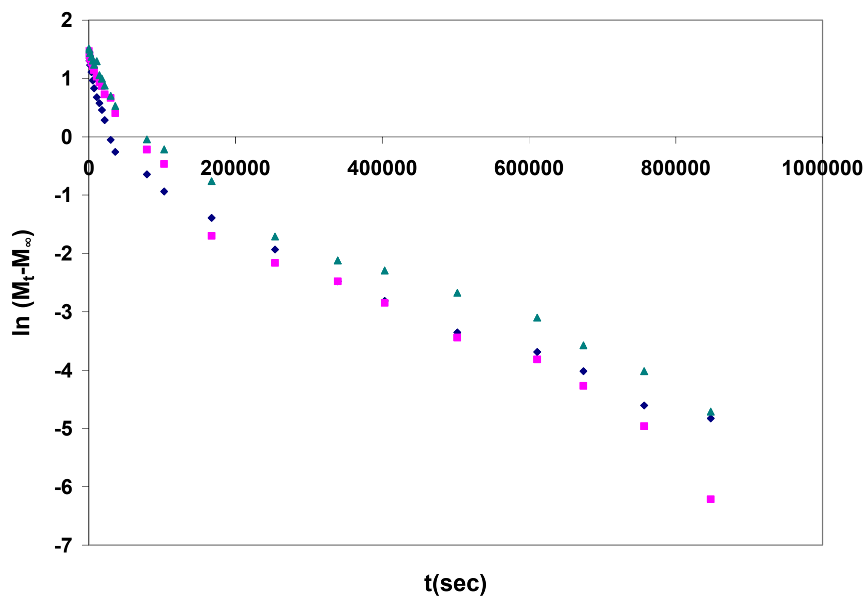


Figure 42 ln (M_t-M_∞) versus t for vinyl ester samples containing 0 wt% Cloisite 10A® at 25 °C during second cycle of desorption

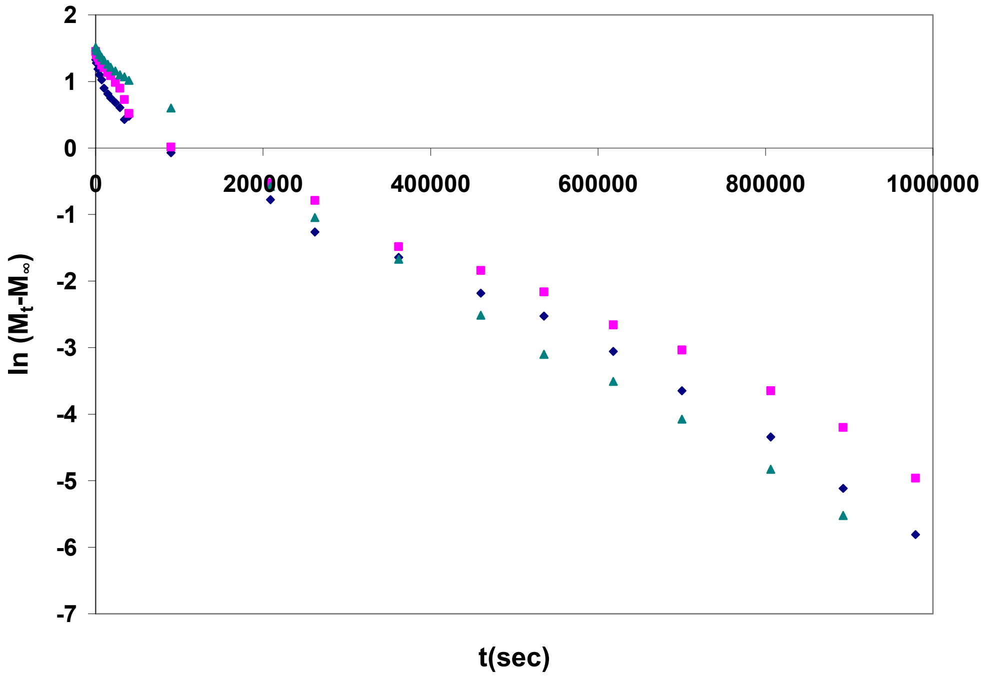


Figure 43 ln (M_t-M_∞) versus t for vinyl ester samples containing 0 wt% Cloisite 10A® at 25 °C during third cycle of desorption

The diffusivities can be calculated from these curves as explained in the Section 3.5. The diffusivities of water in neat vinyl ester resin during desorption were found to be 2.15 x 10^{-9} cm^2/s for first cycle, 1.8 x 10^{-9} cm^2/s for second cycle and 2.02 x 10^{-9} cm^2/s for third cycle. This indicates constant desorption diffusivity of water through neat vinyl ester during cyclic sorption-desorption.

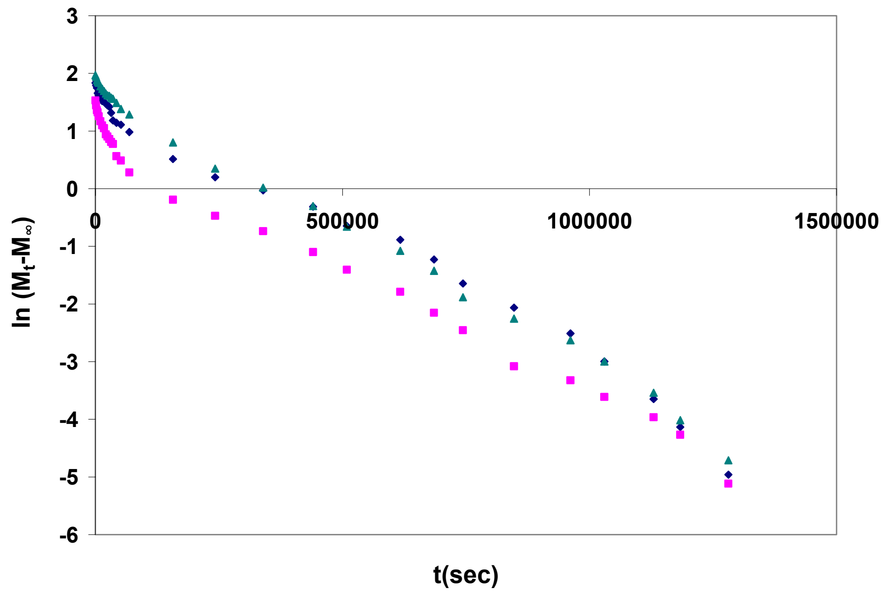


Figure 44 ln (M_t-M_∞) versus t for vinyl ester samples containing 2 wt% Cloisite 10A® at 25 °C during first cycle of desorption

Figure 44, Figure 45 and Figure 46 show ln (M_t-M_∞) versus time for samples containing 2 wt% Cloisite 10A® during three cycles of desorption. The graphs show linear curves during later stages of desorption for all the samples indicating Fickian diffusion during desorption.

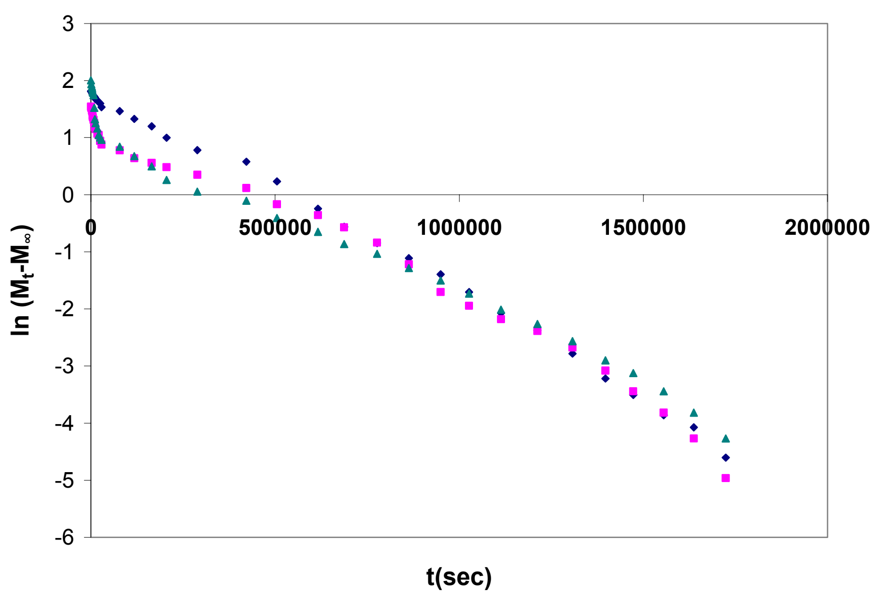


Figure 45 ln (M_t-M_∞) versus t for vinyl ester samples containing 2 wt% Cloisite 10A® at 25 °C during second cycle of desorption

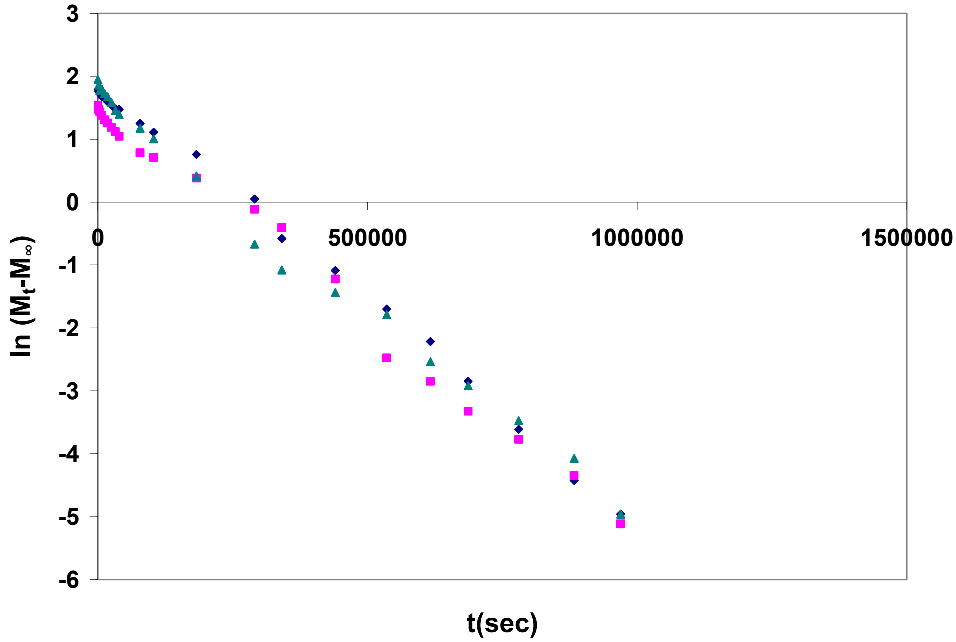


Figure 46 ln (M_t-M_∞) versus t for vinyl ester samples containing 2 wt% Cloisite 10A® at 25 °C during third cycle of desorption

The average diffusivities were found to be 2.02 x 10^{-9} cm^2/s for first cycle, 1.77 x 10^{-9} cm^2/s for second cycle and 2.53 x 10^{-9} cm^2/s for third cycle of desorption.

Similar graphs of ln (M_t-M_∞) versus time for samples containing 5 wt% Cloisite 10A® during first, second and third cycles of desorption were drawn and are given in Appendix C in Figure 126, Figure 127 and Figure 128 respectively. The raw data for cyclic sorption-desorption experiments with vinyl ester samples containing 5 wt% Cloisite 10A® is given in Appendix D in Table 16 and Table 17. The graphs show linear curves during later stages of desorption for all the cycles indicating Fickian diffusion during desorption. The diffusivities can be calculated from these curves as explained in the Section 3.5. The average diffusivities were found to be 1.18 x 10^{-9} cm^2/s for first cycle, 1.08 x 10^{-9} cm^2/s for second cycle and 0.92 x 10^{-9} cm^2/s for third cycle of desorption.

The clay loaded samples exhibited similar trend to the neat resin samples in that the diffusivity values during second and third absorption cycle decreased when compared to diffusivity during first cycle.

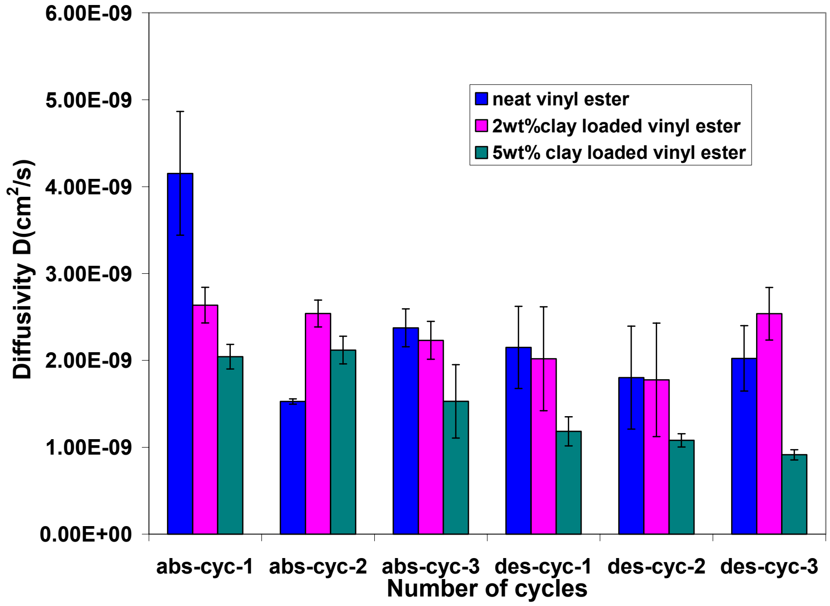


Figure 47 Variation of average diffusivity with number of cycles for vinyl ester samples containing different wt percentages of Cloisite 10A® at 25 °C during three cycles of desorption

It can be clearly seen from the plot of Diffusivity versus Number of cycles in Figure 47 that the diffusivity decreased with increasing amount of clay for a given cycle of sorption-desorption. Also, after the first absorption cycle, the diffusivity seemed to level off and remained constant during second and third cycles of sorption-desorption. The clay platelets preferentially absorbed the water molecules until they were saturated and hindered further ingress of water molecules by effectively increasing the diffusion path and tortuosity. Once the platelets were completely saturated, the water molecules would then follow a tortuous path to diffuse, thus reducing the diffusion coefficient. Also, the presence of nanoparticles in an intercalated nanocomposite decreases the segmental mobility of polymer chains confined to regions between clay platelets. As a result, the water diffusion slows down (decrease in the diffusivity values), and the penetrating water molecules form aggregates or clusters in the nanocomposite. The decrease in diffusivity with addition of nanoparticles has been widely reported in literature (Petrovicova et al., 2000; Bharadwaj, 2001; Shah, 2001 and Rana, 2003). Addition of 2 wt% clay reduces the diffusion coefficient by approximately 36% and a decrease in diffusivity by about 50% can be observed by addition of 5 wt% clay. The results for diffusion coefficients, absorption diffusivity (D_a), desorption diffusivity (D_d) and equilibrium moisture content (EMC) are tabulated in Table 2.

Table 2. Results of Cyclic Sorption-Desorption Experiments for Vinyl ester Samples at 25 °C

Wt% Cloisite 10A®	Cycle-1			Cycle-2			Cycle-3		
	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)
0	4.15±0.7	1.23±0.03	2.15±0.47	1.53±0.03	1.23±0.03	1.8±0.59	2.37±0.21	1.23±0.02	2.02±0.37
2	2.63±0.2	1.39±0.05	2.02±0.59	2.54±0.15	1.43±0.04	1.77±0.65	2.23±0.21	1.39±0.05	2.53±0.30
5	2.04±0.14	1.49±0.07	1.18±0.16	2.12±0.16	1.49±0.08	1.08±0.07	1.53±0.42	1.49±0.07	0.92±0.58

4.3.2. Experiments with Polyester

Similar sets of experiments were done with neat polyester samples and polyester samples loaded with 2 wt% and 5 wt% clay. Graphs of moisture uptake versus time and moisture content (%) versus time were plotted for all polyester samples containing different percentages of clay to show the scatter at each of the three cycles of absorption and desorption. As seen in the vinyl ester samples, polyester samples also never quite reached the initial dry weight and retained some of the moisture. The data from each cycle of absorption-desorption for different weight percentages of clay are plotted to demonstrate the effect of cyclical aging and clay addition on the equilibrium moisture content. The raw data for cyclic sorption-desorption experiments with neat polyester samples is given in Appendix D in Table 18 and Table 19.

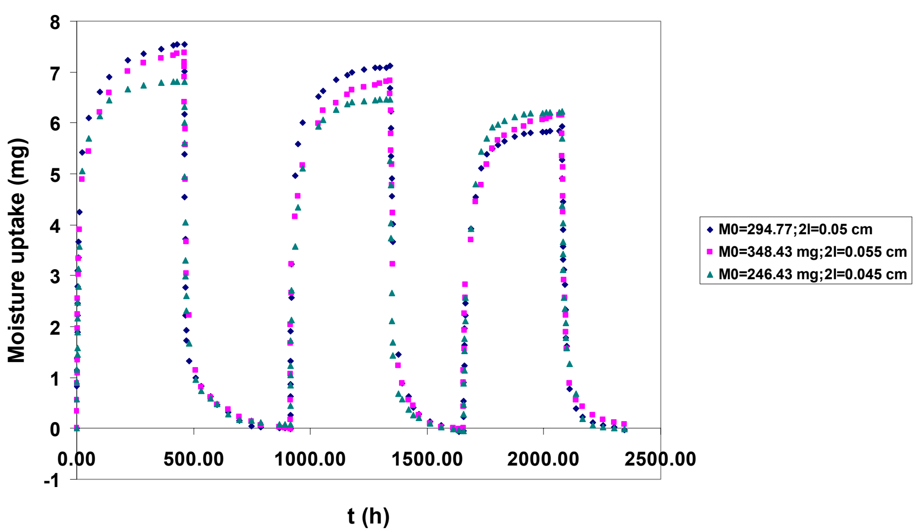


Figure 48 **Moisture uptake (mg) versus t (h) for neat polyester samples during cyclic absorption (water) - desorption (20%RH) at 25 °C**

Figure 48, Figure 49 and Figure 50 show moisture uptake versus time for neat polyester samples and polyester samples containing 2 wt% and 5 wt% clay respectively, during three cycles of sorption-desorption at 25 °C. For a given cycle of sorption-desorption, the time taken by the samples to reach equilibrium during absorption and desorption for clay loaded samples was more than that for the neat polyester samples, maximum being for 5 wt% clay loaded samples.

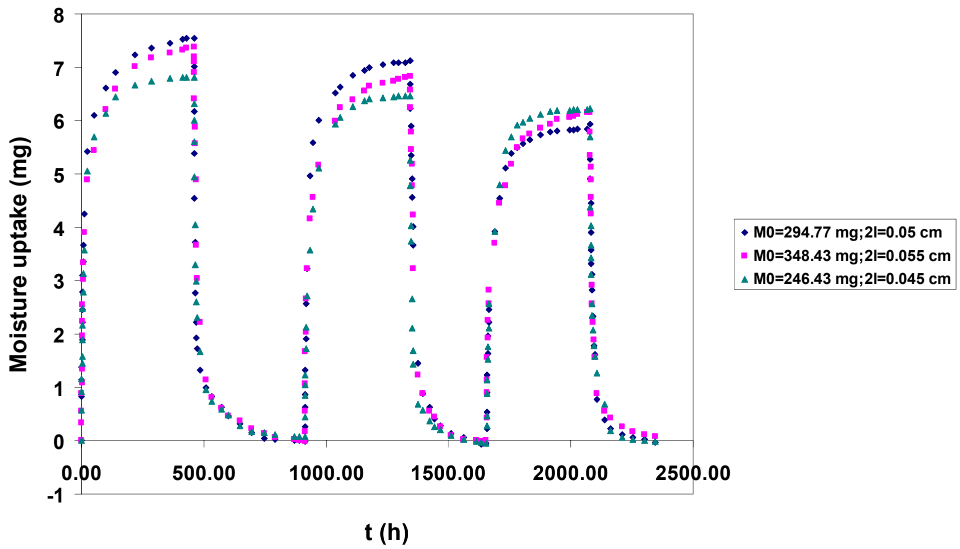


Figure 49 Moisture uptake (mg) versus t (h) for polyester samples containing 2 wt% Cloisite 10A® during cyclic absorption (water) - desorption (20%RH) at 25 °C

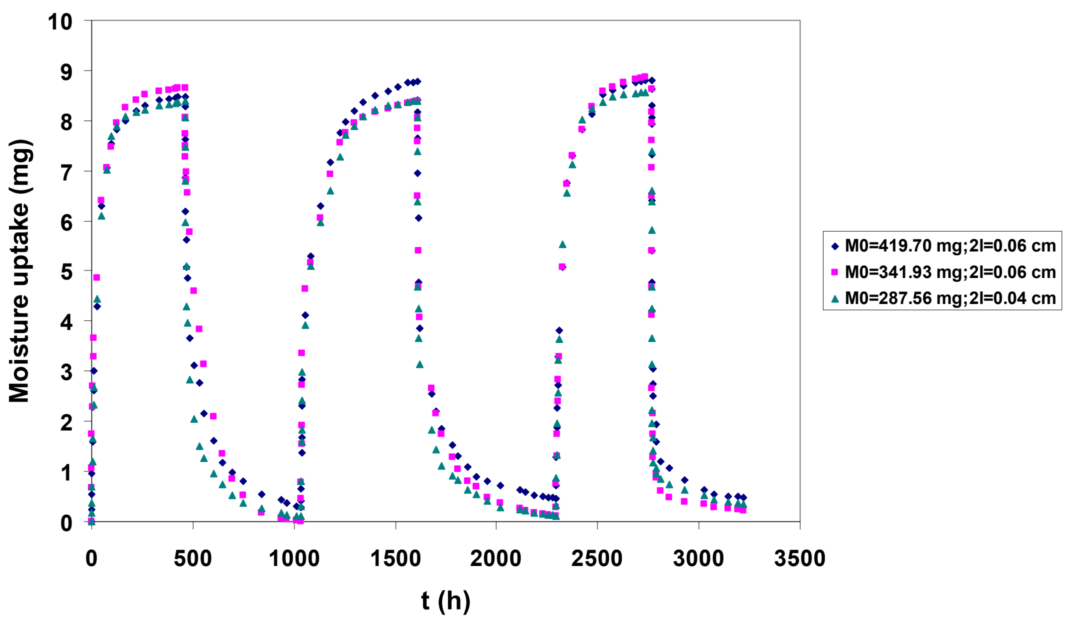


Figure 50 Moisture uptake (mg) versus t (h) for polyester samples containing 5 wt% Cloisite 10A® during cyclic absorption (water) - desorption (20%RH) at 25 °C

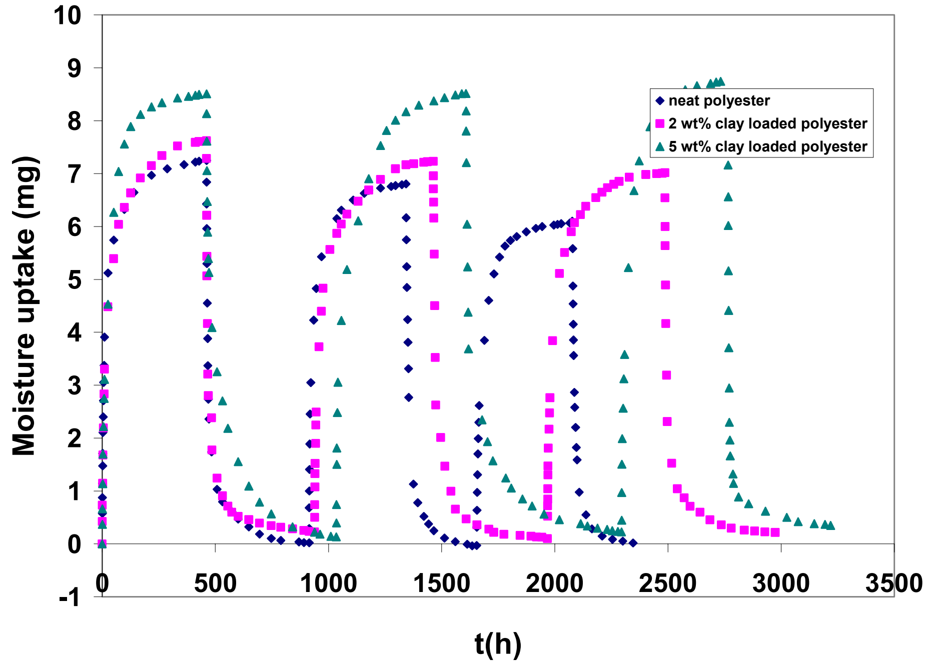


Figure 51 Average moisture uptake (mg) versus t (h) for polyester samples containing different clay loadings during cyclic absorption (water) - desorption (20%RH) at 25 °C

Figure 51 shows average moisture uptake data for neat polyester resin samples and those containing clay during cyclic sorption-desorption. It can be seen that the equilibrium moisture uptake for clay loaded samples was more than that for the neat polyester samples. It was also observed that the cycling did not alter the equilibrium moisture content of the samples for given clay loading.

The moisture uptake data for neat polyester resin samples and those containing clay depicted that the equilibrium moisture uptake increased with increase in clay loading. The moisture uptake of the neat polyester samples decreased slightly with subsequent cycling. This could have happened because of the polymer degradation due to hydrolysis. This was practically observed during the experiments as the polymer samples became soft and weak.

Using the mass uptake data of the samples, moisture content (%) for all the samples was determined and the graphs are shown in the following figures. Figure 52, Figure 53 and Figure 54 show moisture content versus time for neat polyester samples, 2 wt% clay loaded and 5 wt% clay loaded polyester samples respectively.

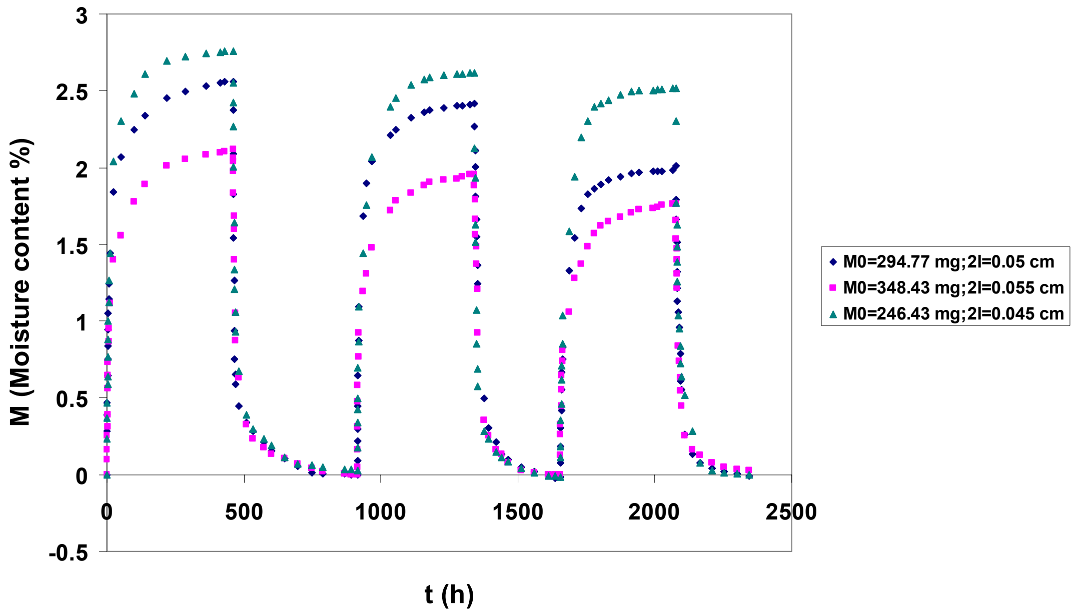


Figure 52 Moisture content versus t for neat polyester samples during absorption (water)-desorption (20%RH) at 25 °C

Figure 52 shows that moisture content of neat polyester samples decreased with the number of cylces. This again could have happened due to the polymer degradation.

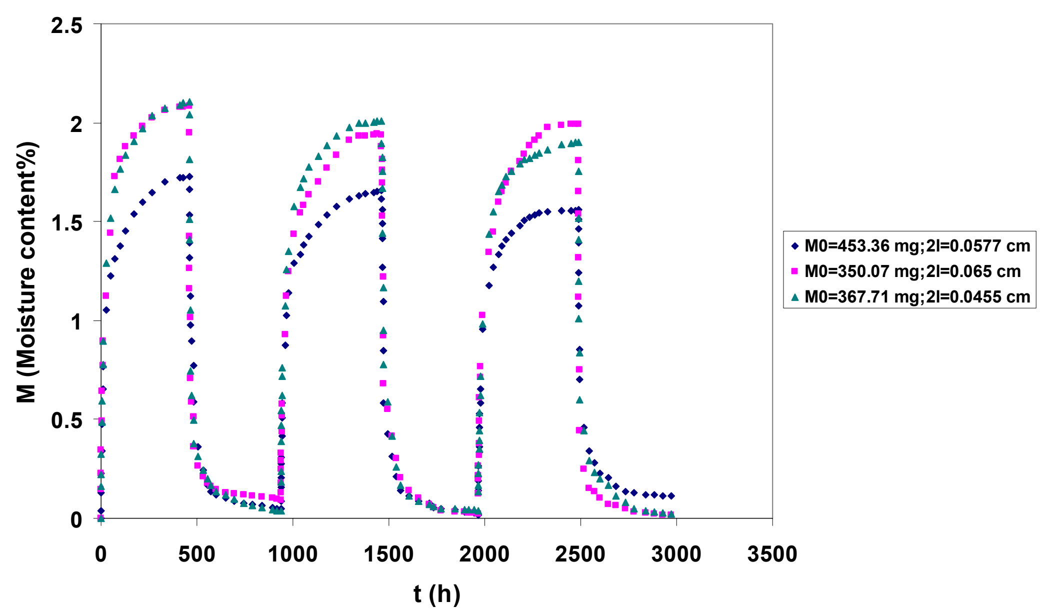


Figure 53 Moisture content versus t for polyester samples containing 2 wt% Cloisite 10A® during absorption (water)-desorption (20%RH) at 25 °C

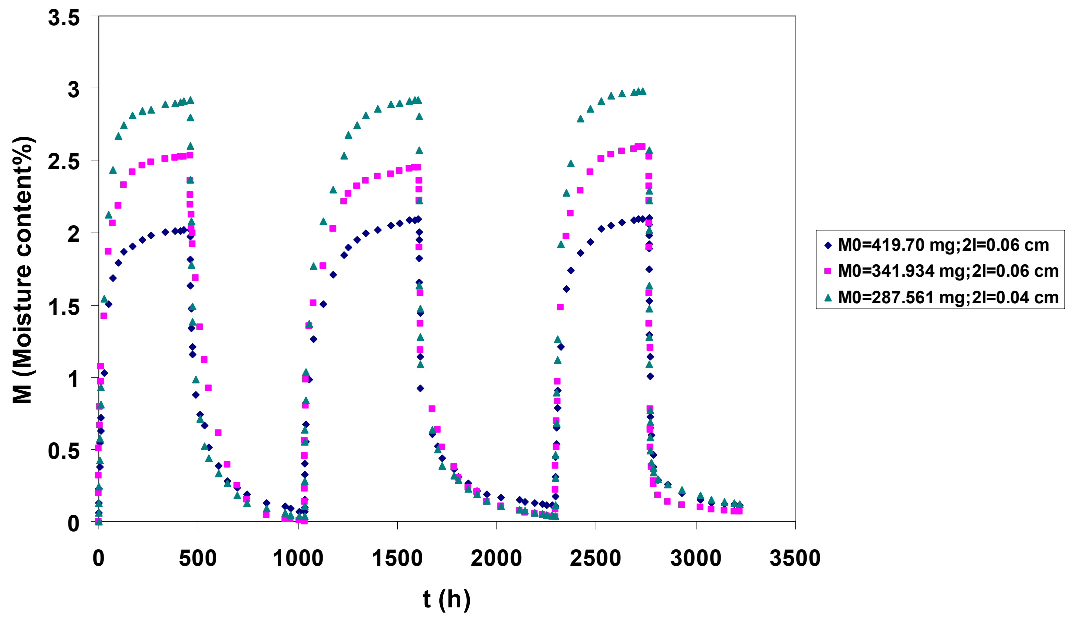


Figure 54 Moisture content versus t for polyester samples containing 5 wt% Cloisite 10A® during absorption (water)-desorption (20%RH) at 25 °C

It can be clearly seen from the Figure 53 and Figure 54 that for given clay loading, the samples reached same equilibrium moisture content during three cycles of sorption-desorption.

Figure 55 shows average moisture content versus time plotted for polyester samples containing different weight percentages of clay.

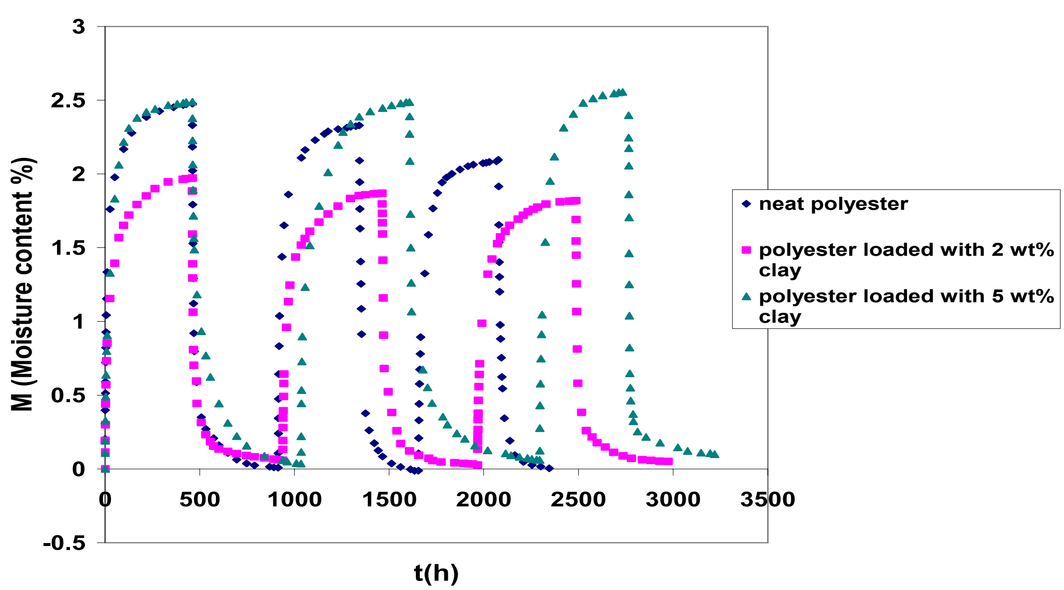


Figure 55 Average moisture content versus time for polyester samples containing different clay loadings

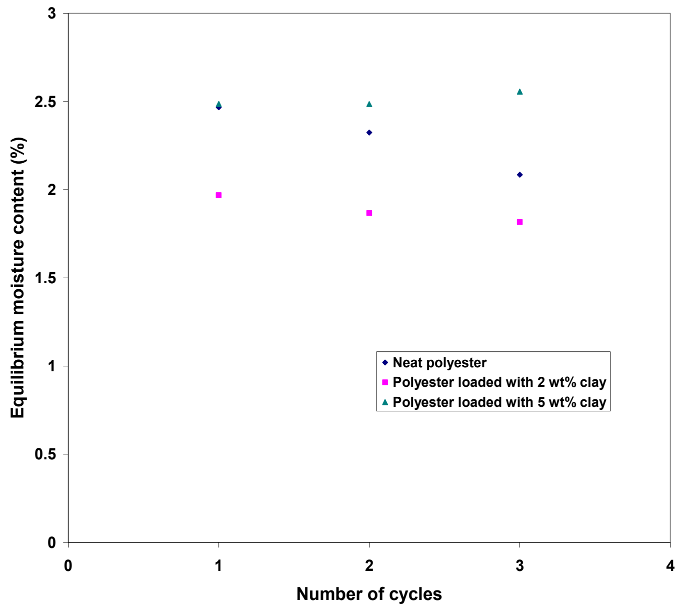


Figure 56 Equilibrium moisture content for polyester samples containing different clay loadings obtained during cyclic sorption-desorption

Figure 56 shows equilibrium moisture content for polyester samples containing different weight percentages of clay during three cycles of sorption-desorption. The average equilibrium moisture content was found to be 2.46% for neat polyester resin samples, decreased to 2.32% during second cycle and 2.08% during third cycle. It was found to be approximately 1.9% for 2 wt% clay loaded polyester samples and 2.4% for 5 wt% clay loaded polyester samples during three cycles. The equilibrium moisture content of the neat polyester resin samples during the first absorption cycle was found to be about 2.46%, which is comparable to the findings of other researchers (Gopalan, 1989, 2.4%). The equilibrium moisture content of the neat polyester samples seemed to decrease with cycling and cycling had no effect on the equilibrium moisture content of polyester samples loaded with clay. The equilibrium moisture content of 2 wt% clay loaded samples decreased and that of 5 wt% clay loaded samples remained same as compared to neat polyester resin.

Graphs of M_t/M_∞ versus $t^{1/2}$ for neat polyester samples, 2 wt% and 5 wt% clay loaded polyester samples, during first, second and third cycles of absorption were drawn and are given in Appendix C in Figure 129, Figure 130, Figure 131, Figure 135, Figure 136 and Figure 137 respectively. The graphs show linear initial uptake indicating Fickian diffusion during three cycles of absorption. From the initial slopes of these curves, diffusion coefficients were calculated as explained in Section 3.4. The raw data for cyclic sorption-desorption experiments with polyester samples containing 2 wt% and 5 wt% Cloisite 10A® is given in Appendix D in Table 20, Table 21, Table 22 and Table 23 respectively.

The diffusivity of water in neat polyester resin during first absorption cycle was found to be 4.26 x 10^{-9} cm^2/s and this is comparable to the value reported by others (Chin et al., 1999, Marais et.al., 1999 and Verghese et al., 1999). It was found that the corresponding diffusivities of water in neat polyester resin decreased slightly with subsequent cycles. This could be possible due to improved curing and greater crosslinking between the polymer chains with time and subsequent reabsorption. This improved curing and crosslinking with moisture absorption was also previously reported in the past. Similar results were reported by Lee and Rockett (1992) and Grinsted et al. (1992) where, diffusion coefficient, D, calculated for absorption was much higher than that for desorption and reabsorption. It was also observed that the cycling did not alter the equilibrium moisture content of the samples containing clay. The average diffusivities for neat polyester were found to be 4.26 x 10^{-9} cm^2/s for first cycle, 4.76 x 10^{-9} cm^2/s for second cycle and 2.71 x 10^{-9} cm^2/s for third cycle of absorption. The average absorption diffusivities for 2 wt% clay loaded polyester samples were found to be 3.05 x 10^{-9} cm^2/s for first cycle, 2.74 x 10^{-9} cm^2/s for second cycle and 2.77 x 10^{-9} cm^2/s for third cycle of absorption. The average absorption diffusivities for 5 wt% clay loaded polyester samples were found to be 2.45 x 10^{-9} cm^2/s for first cycle, 1.68 x 10^{-9} cm^2/s for second cycle and 2.42 x 10^{-9} cm^2/s for third cycle of absorption.

Graphs of ln (M_t-M_∞) versus time for neat polyester samples, 2 wt% and 5 wt% clay loaded polyester samples, during first, second and third cycles of desorption were drawn and are given in Appendix C in Figure 132, Figure 133, Figure 134, Figure 138, Figure 139 and Figure 140 respectively. The graphs show linear curves during later stages of desorption for all the cycles indicating Fickian diffusion during desorption. The diffusivities can be calculated from these curves as explained in the Section 3.5. The average desorption diffusivities were found to be 1.13 x 10^{-9} cm^2/s for first cycle, 1.25 x 10^{-9} cm^2/s for second cycle and 1.61 x 10^{-9} cm^2/s for third cycle of desorption. The average desorption diffusivities for 2 wt% clay loaded polyester were found to be 1.08 x 10^{-9} cm^2/s for first cycle, 1.08 x 10^{-9} cm^2/s for second cycle and 1.6 x 10^{-9} cm^2/s for third cycle of desorption. And, the average desorption diffusivities for 5 wt% clay loaded polyester were found to be 1.06 x 10^{-9} cm^2/s for first cycle, 1.57 x 10^{-9} cm^2/s for second cycle and 1.08 x 10^{-9} cm^2/s for third cycle of desorption.

A decrease in absorption diffusivity for all the samples during second and third absorption cycle was observed when compared to diffusivity during first cycle. The reduced diffusivity signifies improved curing and greater crosslinking between the polymer chain molecules during cyclic sorption-desorption. After the first absorption cycle, the diffusivity seemed to level off and remained constant during second and third cycles of sorption-desorption.

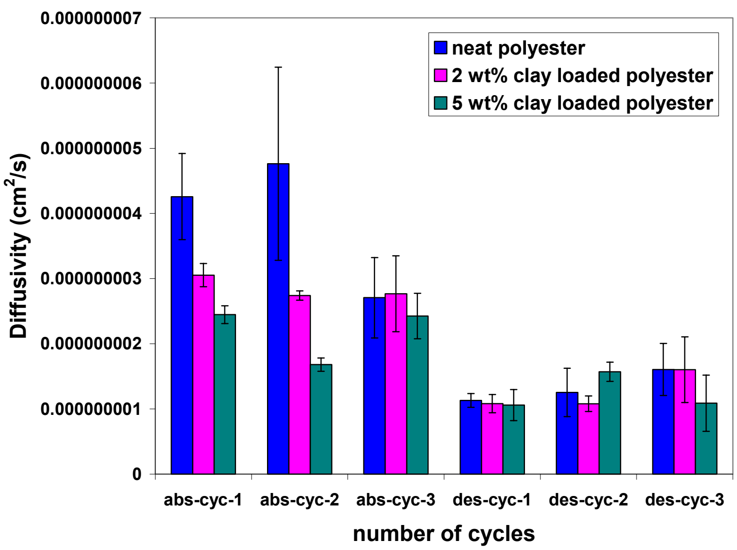


Figure 57 **Variation of diffusivity with number of cycles for polyester samples containing different wt percentages of Cloisite 10A® at 25 °C during three cycles of desorption**

Figure 57 shows the variation of diffusivity values for samples containing different weight percentages of clay with number of cycles of sorption-desorption. The clay loaded samples exhibited similar trend to the neat resin samples in that the diffusivity values during second and third absorption cycle decreased when compared to diffusivity during first cycle.

The equilibrium moisture content values obtained were consistent with the findings in the literature (Gopalan, 1989) and the decrease in the equilibrium moisture content with increased clay loading was also reported (Ole Becker, 2004). Addition of 2 wt% clay reduces the diffusion coefficient by approximately 28% and a decrease in diffusivity by about 42% can be observed by addition of 5 wt% clay. The results for diffusion coefficients, absorption diffusivity (D_a) and desorption diffusivity (D_d) and equilibrium moisture content (EMC) are tabulated in Table 3.

Table 3. Results of Cyclic Sorption-Desorption Experiments for Polyester Samples at 25 °C

Wt% Cloisite10A ®	Cycle-1			Cycle-2			Cycle-3		
	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)
0	4.26±0.6	2.46±0.33	1.13±0.1	4.76±0.14	2.32±0.33	1.25±0.37	2.71±0.61	2.08±0.38	1.61±0.39
2	3.05±0.17	1.96±0.21	1.08±0.14	2.74±0.07	1.86±0.18	1.08±0.12	2.77±0.58	1.81±0.22	1.6±0.5
5	2.45±0.13	2.48±0.44	1.06±0.23	1.68±0.1	2.48±0.41	1.57±0.14	2.42±0.35	2.55±0.44	1.08±0.43

4.3.3. Experiments with Epoxy

Similar set of experiments were done with neat epoxy samples and epoxy samples loaded containing 2 wt% and 5 wt% clay. Graphs of moisture uptake versus time and moisture content (%) versus time were plotted for all epoxy samples containing different percentages of clay to show the scatter at each of the three cycles of absorption and desorption. As seen in the vinyl ester and polyester samples, epoxy samples also never quite reached the initial dry weight and retained some of the moisture. The data from each cycle of absorption-desorption for different weight percentages of clay are plotted to demonstrate the effect of cyclical aging and clay addition on the equilibrium moisture content. The raw data for cyclic sorption-desorption experiments with neat epoxy samples is given in Appendix D in Table 24 and Table 25.

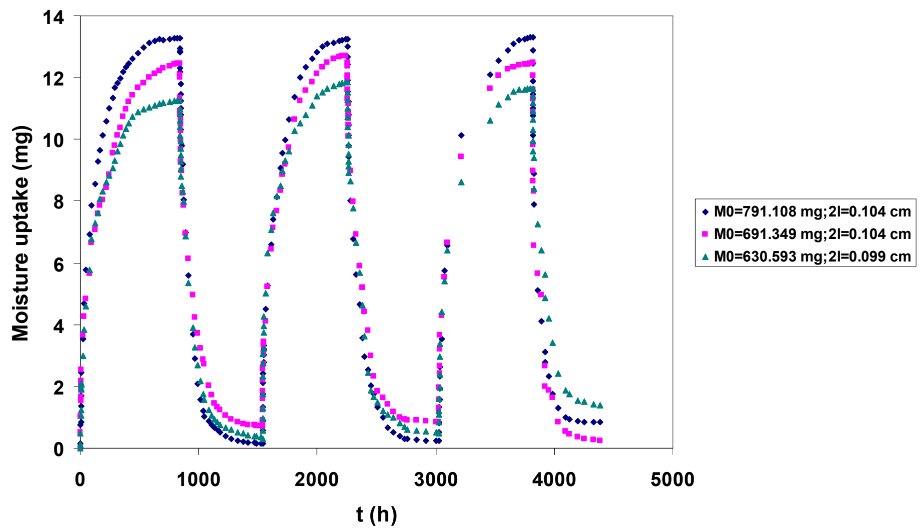


Figure 58 Moisture uptake (mg) versus t (h) for neat epoxy samples during cyclic absorption (water) - desorption (20%RH) at 25 °C

Figure 58, Figure 59 and Figure 60 show moisture uptake versus time for neat epoxy samples and epoxy samples containing 2 wt% and 5 wt% clay respectively, during three cycles of sorption-desorption at 25 °C. For a given cycle of sorption-desorption, the time taken by the samples to reach equilibrium during absorption and desorption for clay loaded samples was more than that for the neat epoxy samples, maximum being for 5 wt% clay loaded samples.

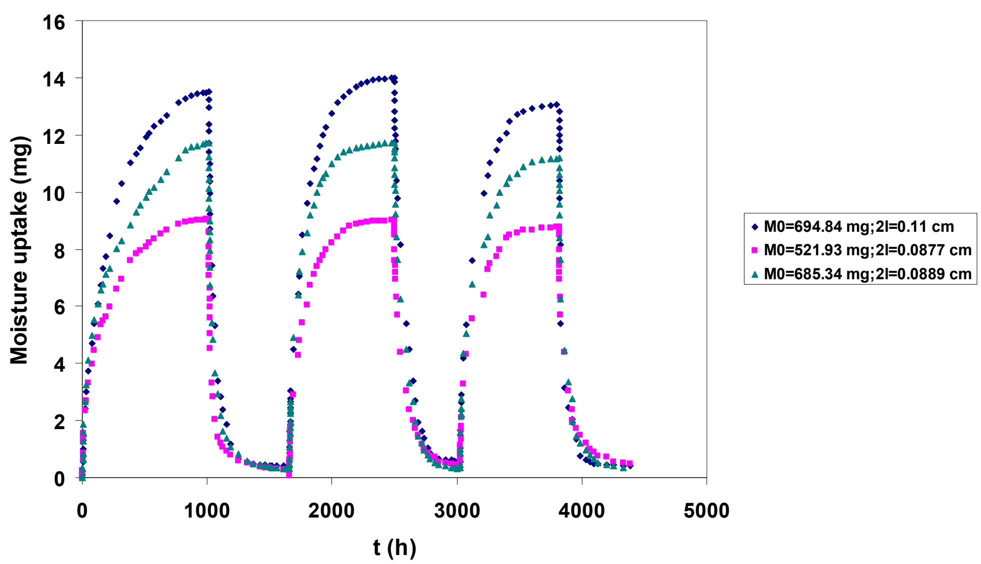


Figure 59 Moisture uptake (mg) versus t (h) for epoxy samples containing 2 wt% Cloisite 10A® during cyclic absorption (water) - desorption (20%RH) at 25 °C

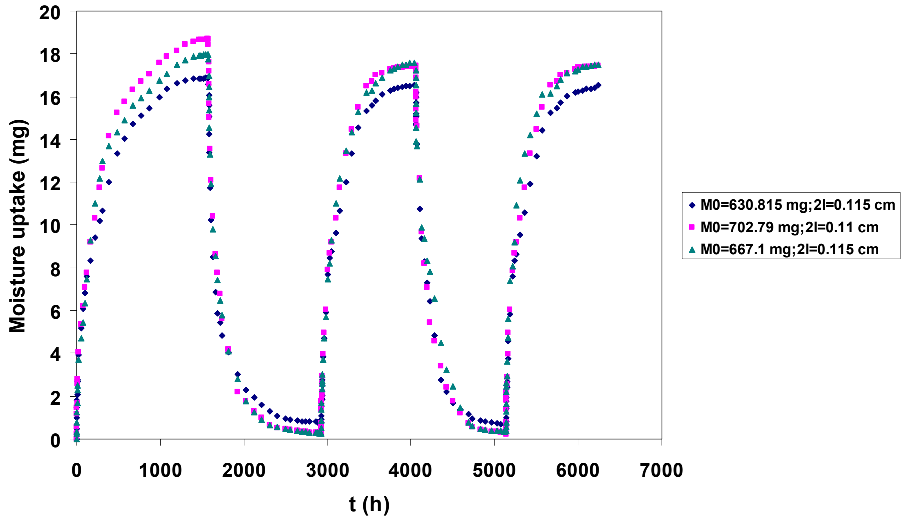


Figure 60 Moisture uptake (mg) versus t (h) for epoxy samples containing 5 wt% Cloisite 10A® during cyclic absorption (water) - desorption (20%RH) at 25 °C

Figure 61 shows average moisture uptake data for neat polyester resin samples and those containing clay during cyclic sorption-desorption. It can be seen from the figure that the equilibrium moisture uptake for 2 wt% clay loaded samples was less and 5 wt% clay loaded samples was more than that for the neat epoxy samples. It was also observed that the cycling did not alter the equilibrium moisture content of the samples for given clay loading.

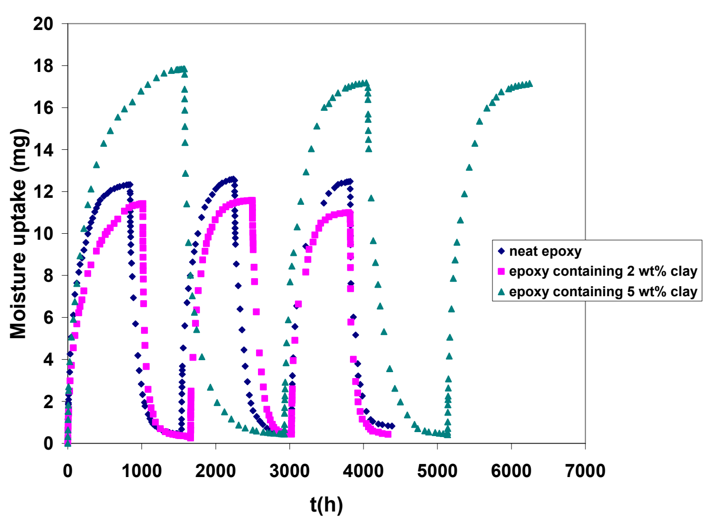


Figure 61 Average moisture uptake (mg) versus t (h) for epoxy samples containing different clay loadings during cyclic absorption (water) - desorption (20%RH) at 25 °C

Using the mass uptake data of the samples, moisture content (%) for all the samples was determined and the graphs are shown in the following figures. Figure 62, Figure 63 and Figure 64 show moisture content versus time for neat epoxy samples, 2 wt% clay loaded and 5 wt% clay loaded polyester samples respectively.

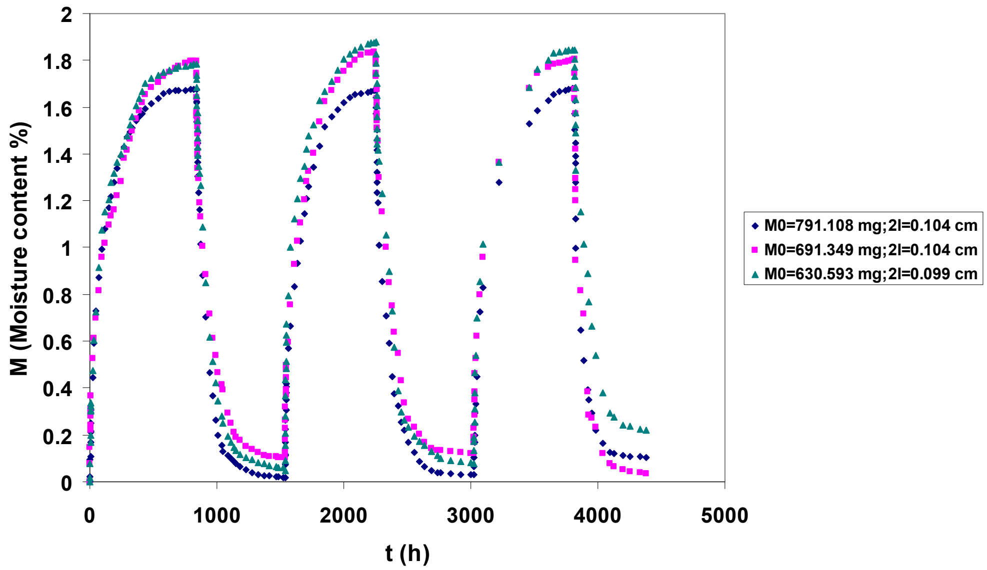


Figure 62 Moisture content versus t for neat epoxy samples during absorption (water)-desorption (20%RH) at 25 °C

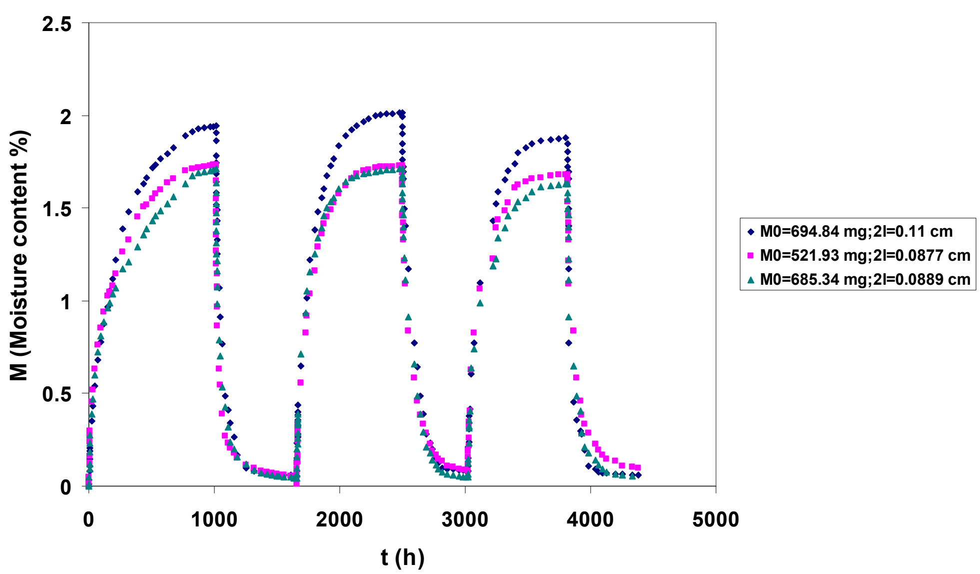


Figure 63 Moisture content versus t for epoxy samples containing 2 wt% Cloisite 10A® during absorption (water)-desorption (20%RH) at 25 °C

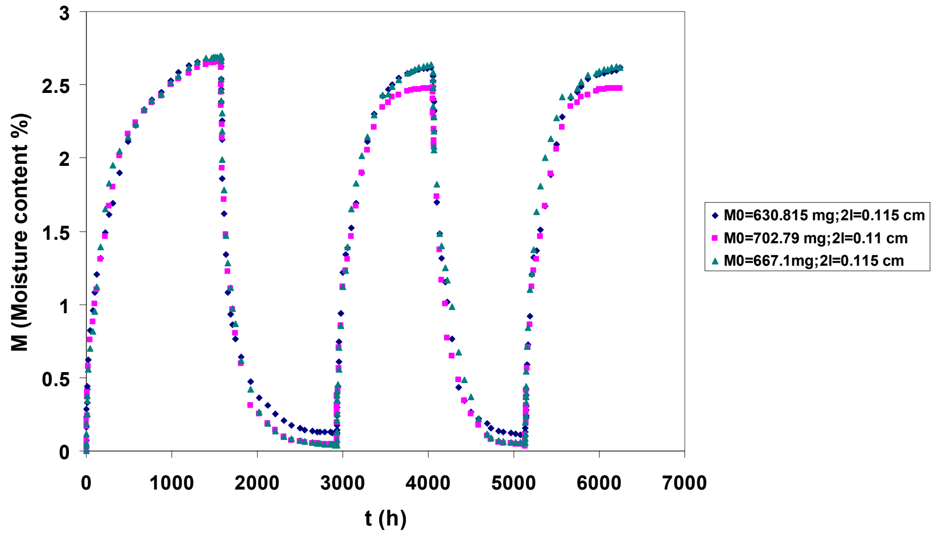


Figure 64 Moisture content versus t for epoxy samples containing 5 wt% Cloisite 10A® during absorption (water)-desorption (20%RH) at 25 °C

It can be clearly seen from the above figures that for given clay loading, the samples reached same equilibrium moisture content during three cycles of sorption-desorption.

Figure 65 shows average moisture content versus time plotted for epoxy samples containing different weight percentages of clay.

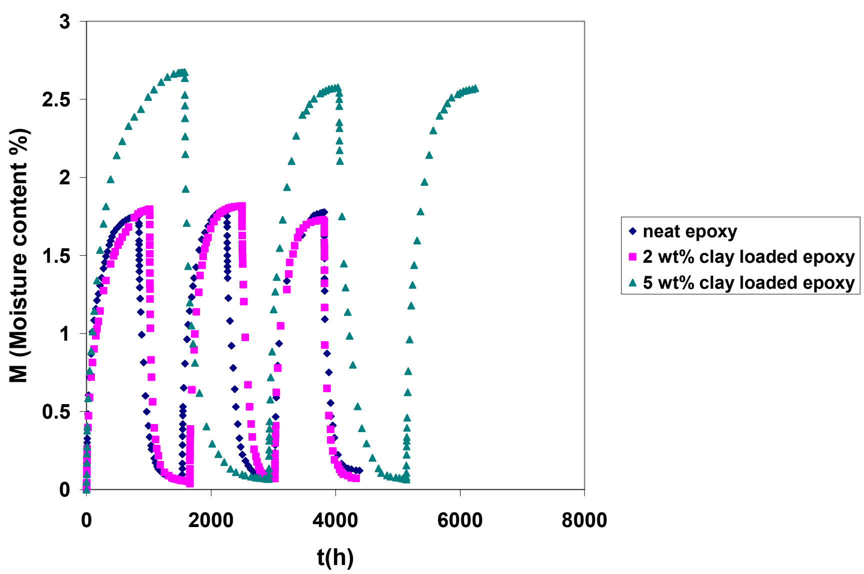


Figure 65 Average moisture content versus time for epoxy samples containing different clay loadings

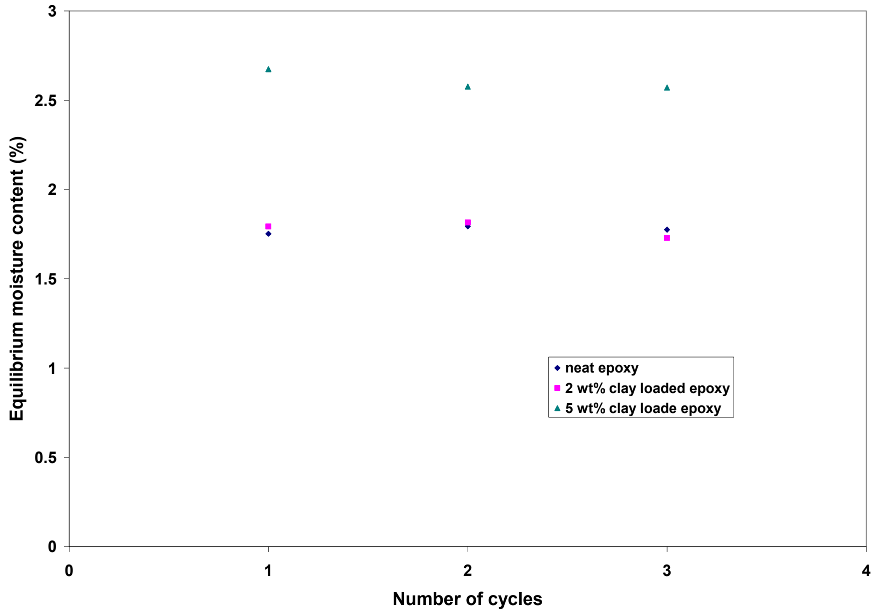


Figure 66 Equilibrium moisture content for epoxy samples containing different clay loadings obtained during cyclic sorption-desorption

Figure 66 shows equilibrium moisture content for epoxy samples containing different weight percentages of clay during three cycles of sorption-desorption. The equilibrium moisture content was found to be 1.75% for neat epoxy samples, 1.79% for 2 wt% clay loaded epoxy samples and 2.67% for 5 wt% clay loaded epoxy samples during three cycles. The equilibrium moisture content of the neat epoxy samples seemed to remain constant with cycling. The equilibrium moisture content of 2 wt% clay loaded samples remained same and that of 5 wt% clay loaded samples increased as compared to neat epoxy resin.

Graphs of M_t/M_∞ versus $t^{1/2}$ for neat epoxy , 2 wt% and 5 wt% clay loaded epoxy samples during first, second and third cycles of absorption were drawn and are given in Appendix C in Figure 147, Figure 148, Figure 149, Figure 153, Figure 154 and Figure 155. The graphs show linear initial uptake indicating Fickian diffusion during three cycles of absorption. From the initial slopes of these curves, diffusion coefficients were calculated as explained in Section 3.4. The raw data for cyclic sorption-desorption experiments with epoxy samples containing 2 wt% and 5 wt% Cloisite 10A® is given in Appendix D in Table 26, Table 27, Table 28 and Table 29 respectively.

The diffusivity of water in neat epoxy resin during first absorption cycle was found to be 2.03 x 10^{-9} cm^2/s and this is comparable to the value reported by others (Chin et al., 1999, 0.5 x 10^{-9} cm^2/s and Becker et.al., 2004, 4.3 x 10^{-9} cm^2/s). The average diffusivities for neat epoxy were found to be 2.03 x 10^{-9} cm^2/s for first cycle, 2.33 x 10^{-9} cm^2/s for second cycle and 2.28 x 10^{-9} cm^2/s for third cycle of absorption. The average absorption diffusivities for 2 wt% clay loaded epoxy samples were found to be 1.15 x 10^{-9} cm^2/s for first cycle, 1.79 x 10^{-9} cm^2/s for second cycle and 2.02 x 10^{-9} cm^2/s for third cycle of absorption. The average absorption diffusivities for 5 wt% clay loaded epoxy samples were found to be 1.1 x 10^{-9} cm^2/s for first cycle, 1.71 x 10^{-9} cm^2/s for second cycle and 1.99 x 10^{-9} cm^2/s for third cycle of absorption.

Graphs of ln (M_t-M_∞) versus time for neat epoxy , 2 wt% and 5 wt% clay loaded epoxy samples during first, second and third cycles of desorption were drawn and are given in Appendix C in Figure 156, Figure 157, Figure 158, Figure 162 and Figure 163 respectively. The graphs show linear curves during later stages of desorption for all the cycles indicating Fickian diffusion during desorption. The diffusivities can be calculated from these curves as explained in the Section 3.5. The average desorption diffusivities for neat epoxy were found to be 3.9 x 10^{-9} cm^2/s for first cycle, 2.27 x 10^{-9} cm^2/s for second cycle and 3.81 x 10-9 cm^2/s for third cycle of desorption. The average desorption diffusivities for 2 wt% clay loaded epoxy were found to be 3.16 x 10-9 cm^2/s for first cycle, 3.19 x 10^{-9} cm^2/s for second cycle and 2.48 x 10^{-9} cm^2/s for third cycle of desorption. The average desorption diffusivities for 5 wt% clay loaded epoxy were found to be 2.54 x 10^{-9} cm^2/s for first cycle and 3.68 x 10^{-9} cm^2/s for second cycle of desorption.

The diffusivity seemed to remain constant for neat epoxy samples during three cycles of sorption-desorption. For clay loaded samples, an increase in absorption diffusivity during second and third absorption cycle was observed when compared to diffusivity during first cycle. The increased diffusivity signifies damage occurred to the samples during cyclic sorption-desorption.

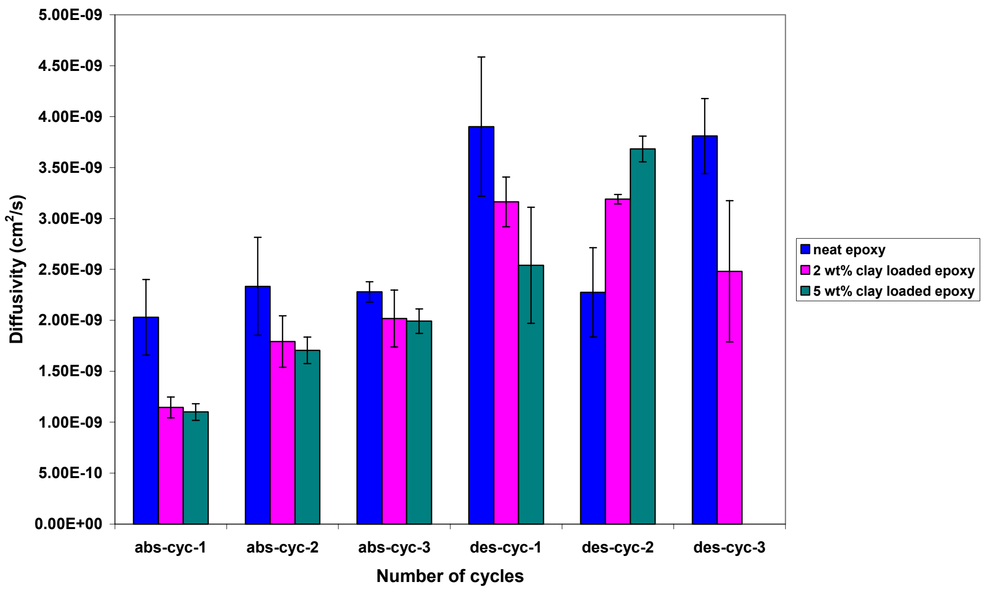


Figure 67 Variation of diffusivity with number of cycles for epoxy samples containing different wt percentages of Cloisite 10A® at 25 °C during three cycles of desorption

Figure 67 shows the variation of diffusivity values for samples containing clay with number of cycles of sorption-desorption. For a given cycle, diffusivity decreased with the addition of clay but increased with increase in the number of cycles.

Table 4. Results of Cyclic Sorption-Desorption Experiments for Epoxy Samples at 25 °C

Wt% Cloisite 10A®	Cycle-1			Cycle-2			Cycle-3		
	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)
0	2.03±0.37	1.75±0.06	3.9±0.68	2.33±0.48	1.79±0.1	2.27±0.43	2.28±0.09	1.77±0.08	3.81±0.37
2	1.15±0.10	1.79±0.12	3.16±0.24	1.79±0.25	1.81±0.17	3.19±0.47	2.02±0.28	1.73±0.13	2.48±0.69
5	1.1±0.08	2.67±0.01	2.54±0.57	1.71±0.13	2.57±0.08	3.68±1.26	1.99±0.12	2.57±0.08	-

The results of cyclic sorption-desorption experiments with neat epoxy and clay loaded epoxy samples at 25 °C are summarized in Table 4. It can be seen that absorption rate and corresponding diffusion coefficient significantly increase with subsequent resorption cycles in epoxy nanocomposites loaded with 2 wt% clay and 5 wt% clay where as increase is not very significant in case of neat epoxy samples. This increase was thought to be due to microstructural damage such as microcracking. This was confirmed with the help of SEM images (Figure 103, Figure 104, Figure 105 and Figure 106) taken on the samples subjected to cyclic sorption and desorption. Equilibrium moisture content also increased with the increasing clay content, increase being more significant in 5 wt% clay loaded samples.

When moisture is being absorbed into a dry laminate, the outer regions tend to swell isotropically, but, the inner moisture-free core will restrain swelling. This non-uniform swelling through the thickness of the laminate would yield high stresses at the surface of the laminate that can result in crack formation (Shirrell, 1978). Martin et al. (2000) studied the effect of water exposure cycles on diffusion properties of a particle-filled epoxy-based adhesive. They have observed an increased saturation level between absorption and reabsorption. They have also reported an increased diffusion coefficient during desorption and subsequent absorption. They attributed the difference to the hydrogen bond formation during the previous hygrothermal aging history. Hydrogen bonds are created between the filler and the resin during the initial hygrothermal aging process within specimens. The bonding strength between the filler and the resin is disrupted even when the water has been extracted during desorption. Thus, during reabsorption, the hydrogen bond formations are in a sense, re-developed to a greater extent at the interface between the fillers and the resin.

Table 5 gives a summary of results of cyclic sorption-desorption experiments for polyester, vinyl ester and epoxy resins. It can be observed that for a given percentage clay, equilibrium moisture content for polyester was greater than that of either vinyl ester or epoxy. The chemical structure and morphology of a polymer are known to affect moisture uptake.

Table 5. Summarized Results of Cyclic Sorption-Desorption Experiments for Polyester, Vinyl ester and Epoxy

Wt%	Polyester			Vinyl ester			Epoxy		
Cloisite 10A®	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)	D_ax10^9 (cm^2/s)	EMC (%)	D_dx10^9 (cm^2/s)
0	4.26±0.6	2.46±0.33	1.13±0.1	4.15±0.7	1.23±0.03	2.15±0.47	2.03±0.37	1.75±0.06	3.9±0.68
2	3.05±0.17	1.96±0.21	1.08±0.14	2.63±0.2	1.4±0.05	2.02±0.59	1.15±0.1	1.79±0.12	3.16±0.24
5	2.45±0.13	2.48±0.44	1.06±0.23	2.04±0.14	1.5±0.16	1.18±0.16	1.1±0.08	2.67±0.01	2.54±0.57

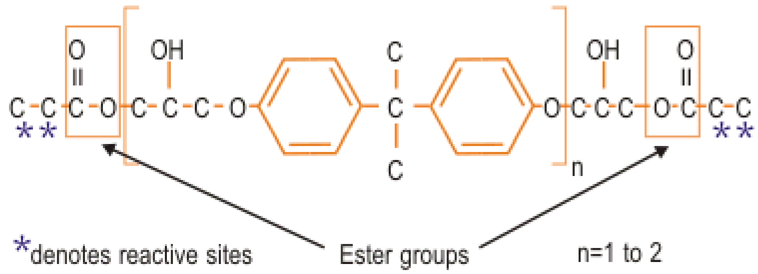


Figure 68 Idealized chemical structure of a typical epoxy based vinyl ester

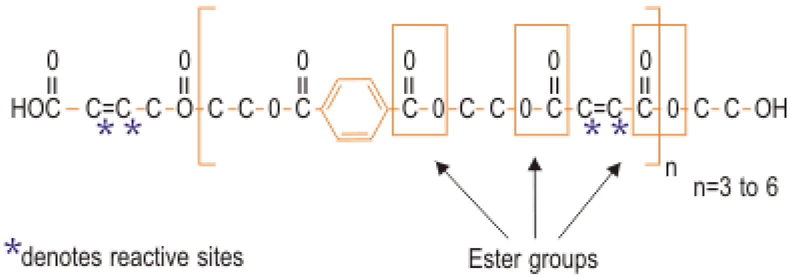


Figure 69 Idealized chemical structure of a typical epoxy based polyester

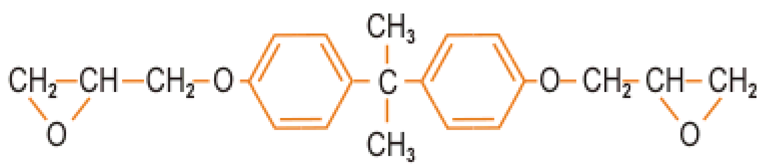


Figure 70 Idealized chemical structure of a typical epoxy (diglycidyl ether of bisphenol-A)

Vinyl ester resins are similar in their molecular structure to polyesters, but differ primarily in the location of their reactive sites and ester groups. Figure 68, Figure 69 and Figure 70 show idealized chemical structures of typical vinyl ester, polyester and epoxy respectively. In case of vinyl ester, the reactive sites and ester groups are present only at the end of the molecular chains whereas in polyester these are present not only at the end of the molecular chain but also within the molecular chain. Also, vinyl ester molecule contains fewer ester groups, which are susceptible to water degradation and less prone to damage by hydrolysis. Epoxy has a long chain molecular structure similar to vinyl ester with reactive sites at both ends. However, in epoxy, epoxy groups instead of ester groups form these reactive sites. The absence of ester groups means that the epoxy resin has particularly good water resistance.

4.3.4. Interaction of Water with Polymers During Cyclic Sorption-Desorption

Startsev et al. (1995) conducted a wide range of investigation on the influence of water on the properties of various classes of polymers and polymeric composite materials. Polymeric materials when exposed to a humid environment undergo plasticization due to water ingress, and this results in a reduction in strength, modulus and glass transition temperature. At low temperature (30-50 K below 273 K), water crystallizes and acts as a hard dispersed filler instead of a plasticizer. Interaction of water with polymers causes irreversible effects due to structural relaxation and activation by a chemical reaction. Under the influence of water, the mobility of polymeric chains increases creating a more perfect polymer structure as a result of exfoliation of the system. Also, water is a peculiar catalyst of the post curing chemical reaction. Water, while plasticizing a polymer in a humid climate, can speed up chemical reactions of destruction. With the development of structural reconstructions, chemical reactions, and formation of defects, the rate of moisture ingress and the maximum rates of water sorption alter.

4.4 Sorption Experiments with Neat and Clay loaded Vinyl ester Samples at Different Relative Humidities (%RH)

To determine the dependence of equilibrium moisture content (EMC) and diffusivity on relative humidity (RH) of exposed environment, neat vinyl ester samples and those containing 2 wt% and 5 wt% clay were exposed to four different relative humidities 40%RH, 60%RH, 70%RH and 80%RH. Graphs of moisture content versus time were plotted for all the samples and equilibrium moisture content was determined from the maximum or equilibrium value attained by the samples for a given relative humidity.

4.4.1. EMC at 40% Relative Humidity

Figure 71, Figure 72 and Figure 73 show respective graphs of moisture content (%) versus time for neat vinyl ester samples and those containing 2 wt% and 5 wt% Cloisite 10A® exposed to 40% RH at 25 °C.

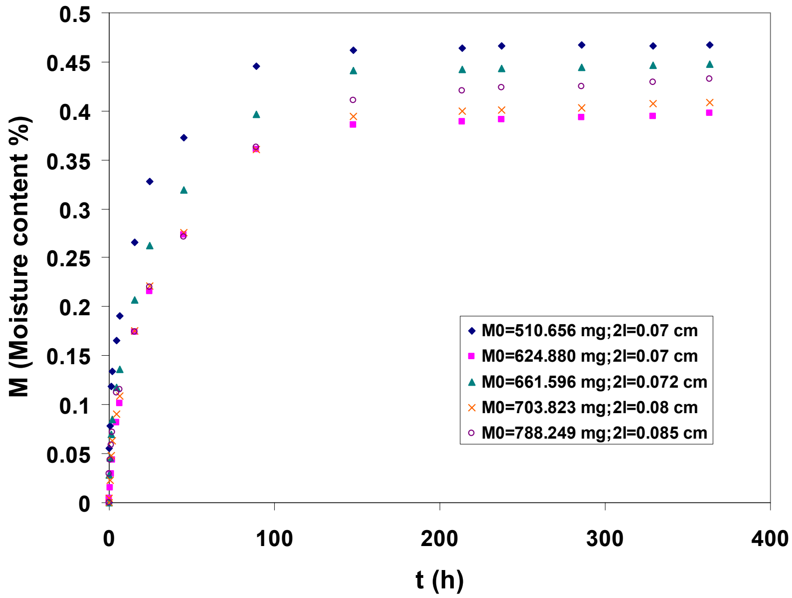


Figure 71 Moisture content versus t for neat vinyl ester samples exposed to 40%RH at 25 °C

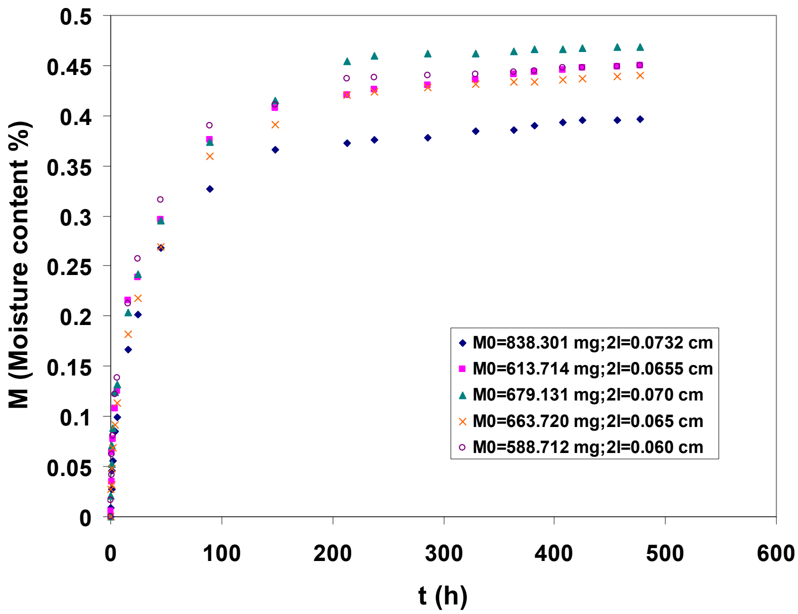


Figure 72 Moisture content versus t for 2wt% clay loaded vinyl ester samples exposed to 40%RH at 25 °C

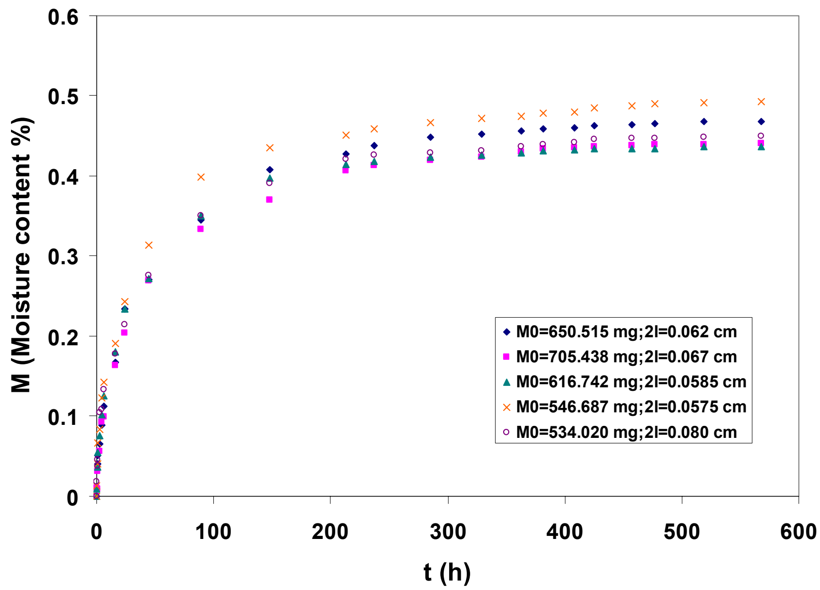


Figure 73 Moisture content versus t for 5 wt % clay loaded vinyl ester samples exposed to 40%RH at 25 °C

Figure 74, Figure 75 and Figure 76 show M_t/M_∞ versus $t^{1/2}$ for neat vinyl ester samples and those containing 2 wt% and 5 wt% clay exposed to 40% RH at 25 °C respectively. The figures show initial linear uptake indicating Fickian diffusion. The average diffusion coefficients calculated from the slopes of the curves are found to be 4.17 x 10^{-9} cm^2/s for neat vinyl ester samples, 2.73 x 10^{-9} cm^2/s for 2 wt% clay loaded samples and 2.52 x 10^{-9} cm^2/s for 5 wt% clay loaded samples. The vinyl ester samples exposed at 40% RH at 25 °C exhibited trend of decrease in diffusivity of moisture in vinyl ester with addition of clay. The raw data for sorption experiments with neat vinyl ester samples and those containing 2 wt% and 5 wt% Cloisite 10A® exposed to 40% RH at 25°C is given in Appendix D in Table 30, Table 31 and Table 32 respectively.

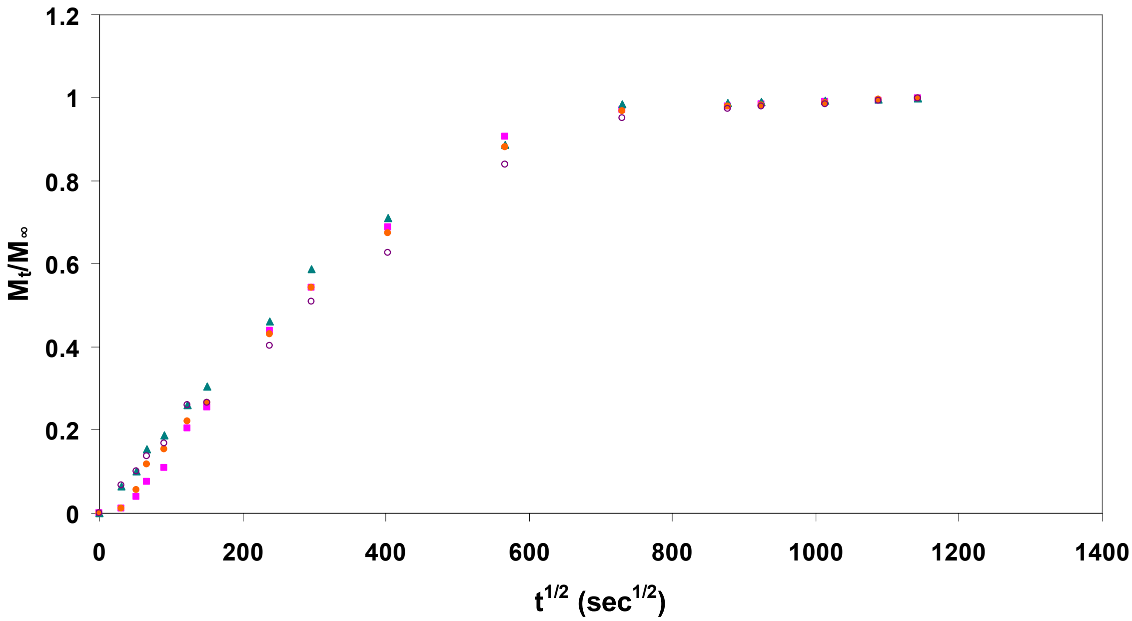


Figure 74 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 0 wt% Cloisite 10A® exposed to 40% RH

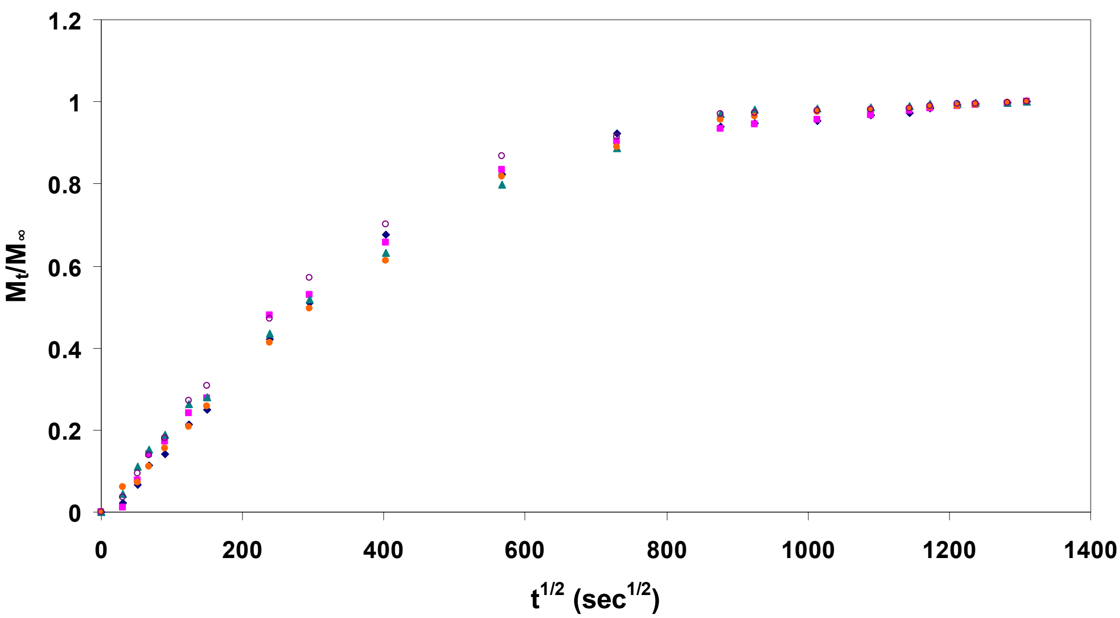


Figure 75 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 2 wt% Cloisite 10A® exposed to 40% RH

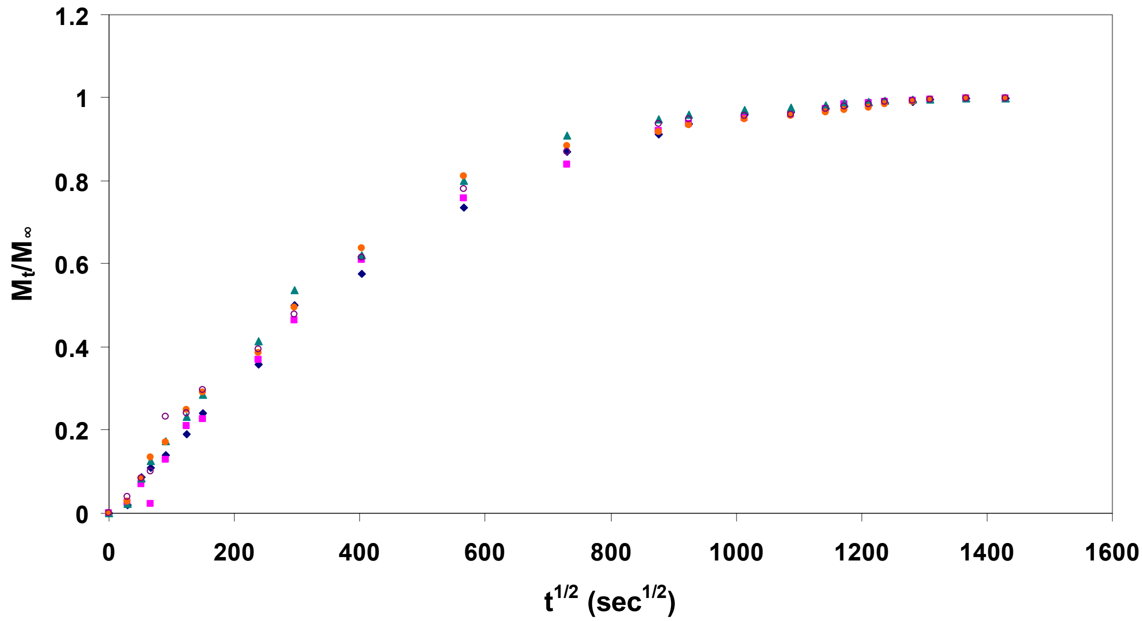
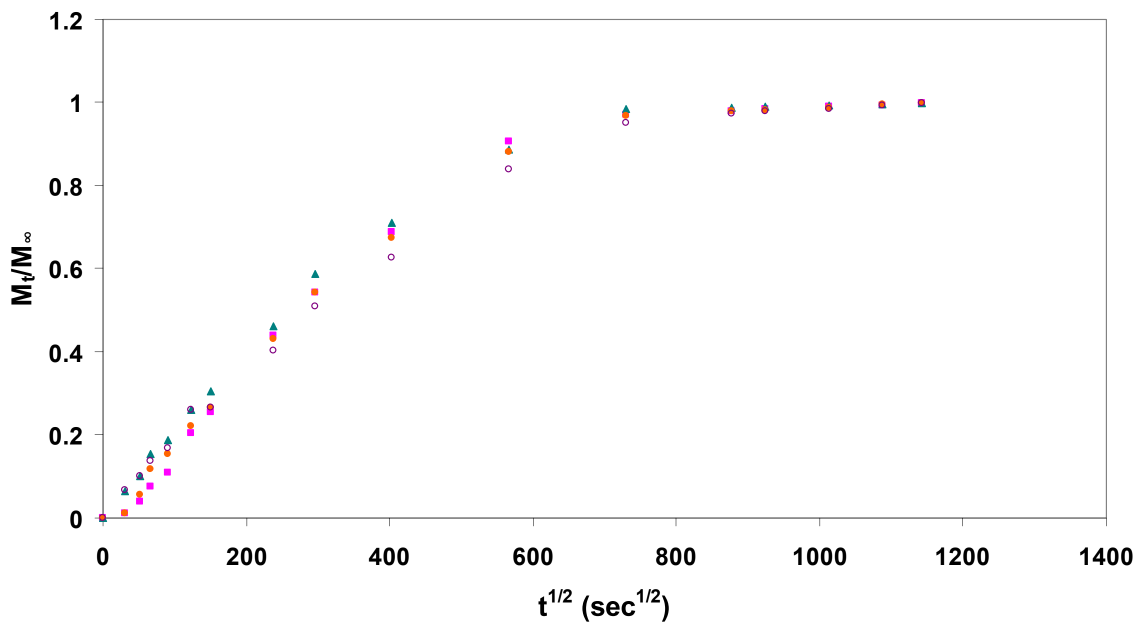


Figure 76 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 5 wt% Cloisite 10A® exposed to 40% RH

4.4.2. EMC at 60% Relative Humidity

Similar graphs of moisture content versus time were drawn for neat vinyl ester samples and clay loaded vinyl ester samples at 60% RH and are given in Appendix C in Figure 164, Figure 165 and Figure 166 respectively. The graphs showed that the average moisture content for neat, 2 wt% and 5 wt% clay loaded samples was 0.59% at 60% RH.

Graphs of M_t/M_∞ versus $t^{1/2}$ for neat vinyl ester samples and those containing 2 wt% and 5 wt% Cloisite 10A® were plotted and are given in Appendix C in Figure 167, Figure 168 and Figure 169 respectively. The graphs showed a linear initial uptake indicating Fickian diffusion and the diffusion coefficients were found to be 3.98 x 10^{-9} cm^2/s for neat vinyl ester samples, 2.66 x 10^{-9} cm^2/s for 2 wt% clay loaded samples and 2.31 x 10^{-9} cm^2/s for 5 wt% clay loaded samples. The raw data for sorption experiments with neat vinyl ester samples and those containing 2 wt% and 5 wt% Cloisite 10A® exposed to 60% RH at 25°C is given in Appendix D in Table 33, Table 34 and Table 35 respectively.



4.4.3. EMC at 70% Relative Humidity

Similar graphs of moisture content versus time were drawn for neat vinyl ester samples and clay loaded vinyl ester samples at 70% RH and are given in Appendix C in Figure 170, Figure 171 and Figure 172. The graphs showed that the average moisture content for neat, 2 wt% and 5 wt% clay loaded samples was 0.8% at 70% RH.

Graphs of M_t/M_∞ versus $t^{1/2}$ for neat vinyl ester samples and those containing 2 wt% and 5 wt% Cloisite 10A® were plotted and are given in Appendix C in Figure 173, Figure 174 and Figure 175 respectively. The graphs showed a linear initial uptake indicating Fickian diffusion and the diffusion coefficients were found to be 4.18 x 10^{-9} cm^2/s for neat vinyl ester samples, 2.99 x 10^{-9} cm^2/s for 2 wt% clay loaded samples and 2.72 x 10^{-9} cm^2/s for 5 wt% clay loaded samples. The raw data for sorption experiments with neat vinyl ester samples and those containing 2 wt% and 5 wt% Cloisite 10A® exposed to 70% RH at 25°C is given in Appendix D in Table 36, Table 37 and Table 38 respectively.

4.4.4. EMC at 80% Relative Humidity

Similar graphs of moisture content versus time at 80% RH were drawn for neat vinyl ester samples and clay loaded vinyl ester samples and are given in Appendix C in

Figure 176, Figure 177 and Figure 178 respectively. The graphs showed that the average moisture content for neat, 2 wt% and 5 wt% clay loaded samples was 0.9% at 80% RH.

Graphs of M_t/M_∞ versus $t^{1/2}$ for neat vinyl ester samples and those containing 2 wt% and 5 wt% Cloisite 10A® were plotted and are given in Appendix C in Figure 179, Figure 180 and Figure 181 respectively. The graphs showed a linear initial uptake indicating Fickian diffusion and the diffusion coefficients were found to be 4.18×10^{-9} cm^2/s for neat vinyl ester samples, 2.92×10^{-9} cm^2/s for 2 wt% clay loaded samples and 2.43×10^{-9} cm^2/s for 5 wt% clay loaded samples. The raw data for sorption experiments with neat vinyl ester samples and those containing 2 wt% and 5 wt% Cloisite 10A® exposed to 80% RH at 25°C is given in Appendix D in Table 39, Table 40 and Table 41 respectively.

Equilibrium moisture content (EMC) and the diffusivity values calculated using M_t/M_∞ versus $t^{1/2}$ curves for respective vinyl ester samples at various humidities are summarized in Table 6. The equilibrium moisture content (%) and Diffusivity as a function of relative humidity (%RH) for vinyl ester samples containing different amounts of clay are given in Figure 77 and Figure 78 respectively. For a given wt% clay, the diffusivity remained constant with increase in relative humidity and the equilibrium moisture content increased with increasing level of RH. Reduction in diffusivity value with increase in wt% clay was also observed at all RH levels, while equilibrium moisture content almost remained constant with increasing clay loading. Hoppel et al. (2000) investigated the moisture absorption characteristics of different composite materials. It was shown that moisture absorption in composites is a strong function of environmental conditions as well as material parameters (void volume fraction) and that the equilibrium moisture content is a linear function of the exposed relative humidity. Alfred and George (1979) observed similar phenomenon in moisture absorption of graphite-epoxy composite and maximum moisture content depended on the relative humidity but was insensitive to temperature.

Table 6. Variation of Equilibrium Moisture Content and Diffusivity with Relative Humidity if Exposed Environment

Wt% Cloisite 10A®	40% RH		60%RH		70%RH		80%RH	
	EMC	Dx10^9 (cm^2/s)	EMC	Dx10^9 (cm^2/s)	EMC	Dx10^9 (cm^2/s)	EMC	Dx10^9 (cm^2/s)
0	0.43±0.02	4.17±0.68	0.59±0.01	3.98±0.34	0.8±0.01	4.18±0.26	0.9±0.17	4.18±0.62
2	0.44±0.02	2.73±0.5	0.61±0.01	2.66±0.19	0.87±0.02	2.99±0.02	0.91±0.07	2.92±0.27
5	0.46±0.02	2.52±0.8	0.61±0.01	2.31±0.12	0.9±0.01	2.72±0.72	0.91±0.1	2.43±0.41

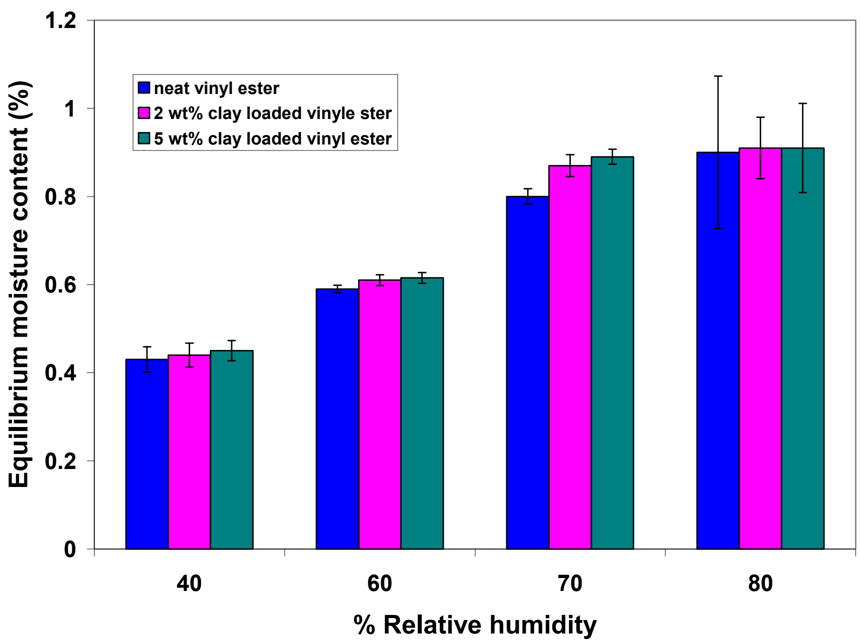


Figure 77 Variation of equilibrium moisture content with variation in relative humidity (%) for vinyl ester samples containing different wt percentages of Cloisite 10A® at 25 °C

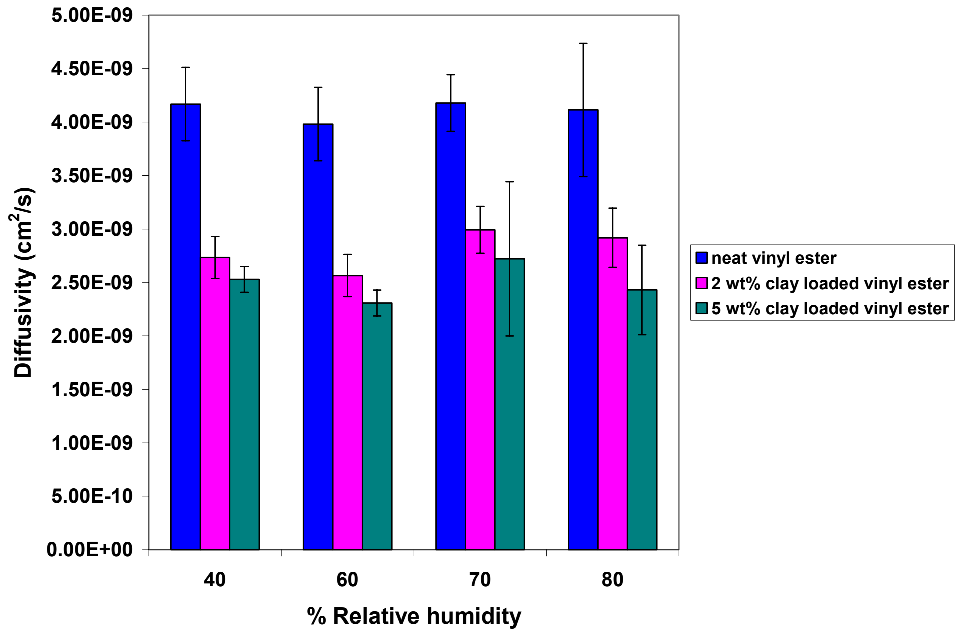


Figure 78 Variation of Diffusivity with variation in relative humidity (%) for vinyl ester samples containing different wt percentages of Cloisite 10A® at 25 °C

4.5 Sorption Experiments with Vinyl ester under Stress

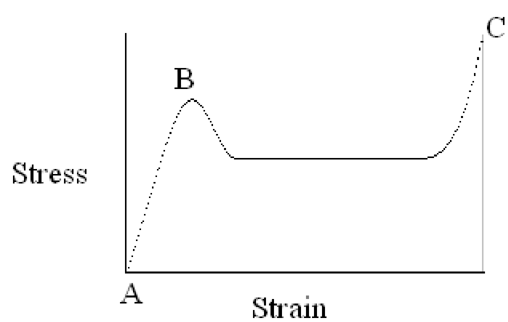


Figure 79 Typical stress strain curve in a polymer

Figure 79 shows typical stress-strain curve of a polymer. The initial linear part AB represents elastic deformation, and any changes in material dimensions in this region are reversed to the original dimensions upon the removal of applied stresses. This linear relationship is given by Hooke's law. The slope of the initial curve for elastic deformation gives Young's Modulus. The part BC represents plastic deformation where the material does not revert to its original dimensions when the applied stress is removed. Point C represents the failure of the material and the stress corresponding to C is called Ultimate Tensile Strength (UTS). Figure 80 shows stress-strain curve of neat vinyl ester (Rana, 2003). The slope of the straight line part of the curve gives Young's Modulus and the average value of which was found to be 4162 psi (28.7 GPa) and the average Ultimate tensile strength was found to be 2712 psi (18.7 MPa).

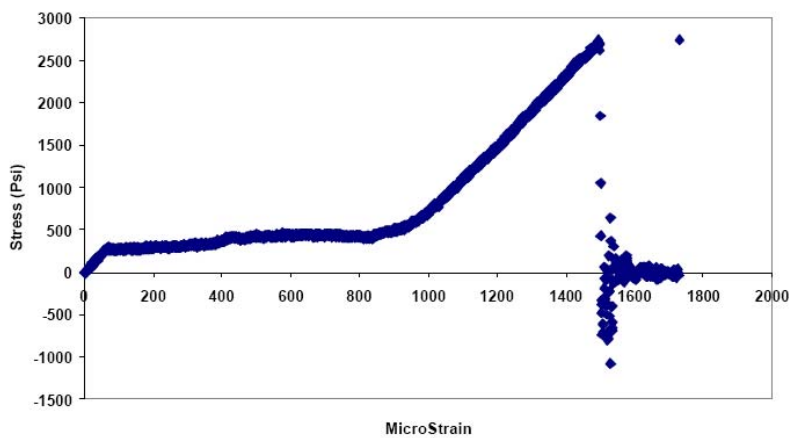


Figure 80 Stress Strain Curve for a Representative Neat Vinyl ester (Rana, 2003)

Sorption experiments under two different load levels, a load of 8 lb_f corresponding to a stress of 3.3 MPa (approximately 17% Ultimate tensile stress, UTS) and 14 lb_f corresponding to a stress of 5.78 MPa (approximately 30% UTS), were done with neat vinyl ester samples and those containing 5wt% clay. The experiments were conducted in two different environments, in water and at 60% RH. Two different stresses were applied by applying a load on the samples with the help of die springs. Twelve specimens parallel to each other were loaded to the same stress level and each specimen had an independent nut-bolt-and-spring arrangement for stress application, such that application or removal of stress on one specimen did not affect the stress acting on the other. The stress was applied on 12 parallel specimens attached to the load frame, each specimen consisting of 3 samples in series. Graphs of moisture uptake versus time and moisture content (%) versus time were plotted for vinyl ester samples with and without clay. The data for all the samples were plotted to demonstrate the effect of stress and clay addition on the equilibrium moisture content and diffusivity. During the initial stages of absorption (until M_t/M_∞ =0.6, approximately 2 days), moisture uptake of the samples was monitored by unloading three different samples at regular intervals of time and measuring the weight gain of the samples. Removal of samples did not affect the stress acting on the other samples. After the weight-gain measurement, these samples were not reloaded onto the load frame but kept aside for any further characterization. At later stages, the moisture uptake was monitored by unloading the samples to measure weight gain and reloading the samples. The masses uptake after initial period of absorption (approximately after 100 hrs), were the average masses uptake for ten different samples taken until equilibrium.

4.5.1. Sorption Experiments under Stress in Water

Figure 81 shows moisture uptake versus time for neat vinyl ester samples immersed in water and subjected to 17% UTS at 25 °C. Using the moisture uptake data, moisture content versus time was plotted as shown in Figure 82. The equilibrium moisture content of the neat vinyl ester samples under a stress of 17% UTS is about 1.15%. This is less than the equilibrium moisture content of the neat resin samples without any stress (1.24%). The raw sorption data of vinyl ester samples containing 0 wt% Cloisite 10A immersed in distilled water subjected to 17% UTS at 25 °C is given in Appendix D in Table 42 .

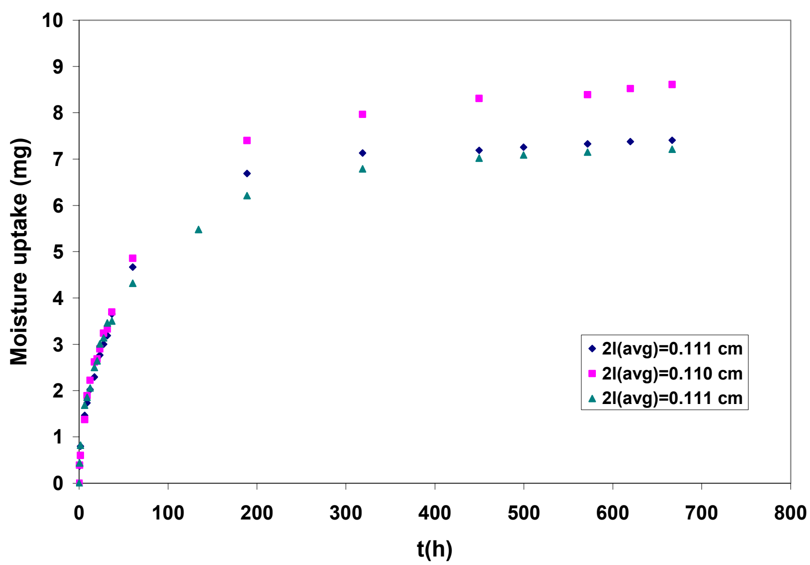


Figure 81 Moisture uptake (mg) versus t (h) for neat vinyl ester samples immersed in water and subjected to 17% UTS at 25 °C

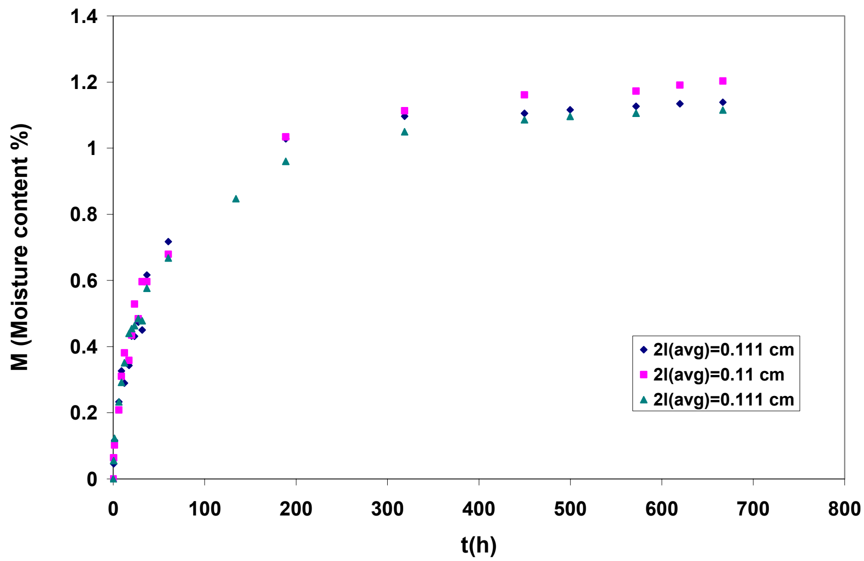


Figure 82 Moisture content versus t for neat vinyl ester samples immersed in water and subjected to 17%UTS at 25 °C

Figure 83 shows M_t/M_∞ versus $t^{1/2}$ for the samples plotted using the moisture content data. The linear initial uptake clearly shows that the diffusion under 17% UTS followed Fickian process. The average diffusivity calculated from the slope of the initial uptake curve was found to be 4.06 x 10^{-9} cm^2/s, which is comparable to the diffusivity without stress (4.15 x 10^{-9} cm^2/s).

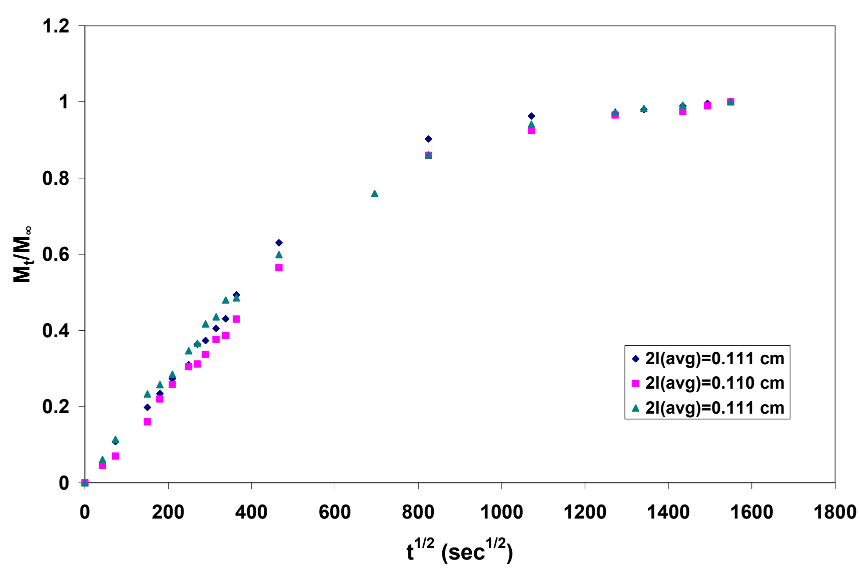


Figure 83 M_t/M_∞ versus $t^{1/2}$ for neat vinyl ester samples immersed in water and subjected to 17% UTS at 25 °C

Figure 84, Figure 85 and Figure 86 show plots of corresponding moisture uptake versus time, moisture content (%) versus time and M_t/M_∞ versus $t^{1/2}$ for neat vinyl ester samples immersed in water and subjected to 30% UTS.

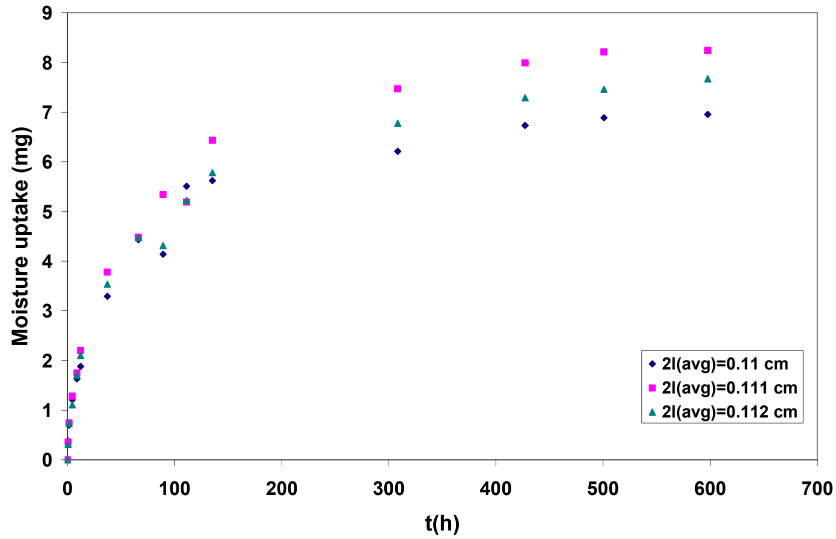


Figure 84 Moisture uptake (mg) versus t (h) for neat vinyl ester samples immersed in water and subjected to 30% UTS at 25°C

The average equilibrium moisture content of the samples is about 1.15%, which is same as that of the samples subjected to 17% UTS. This indicates that the increase in stress level did not affect the equilibrium moisture content of neat vinyl ester samples immersed in water. The raw sorption data of vinyl ester samples containing 0 wt% Cloisite 10A immersed in distilled water subjected to 30% UTS at 25 °C is given in Appendix D in Table 44.

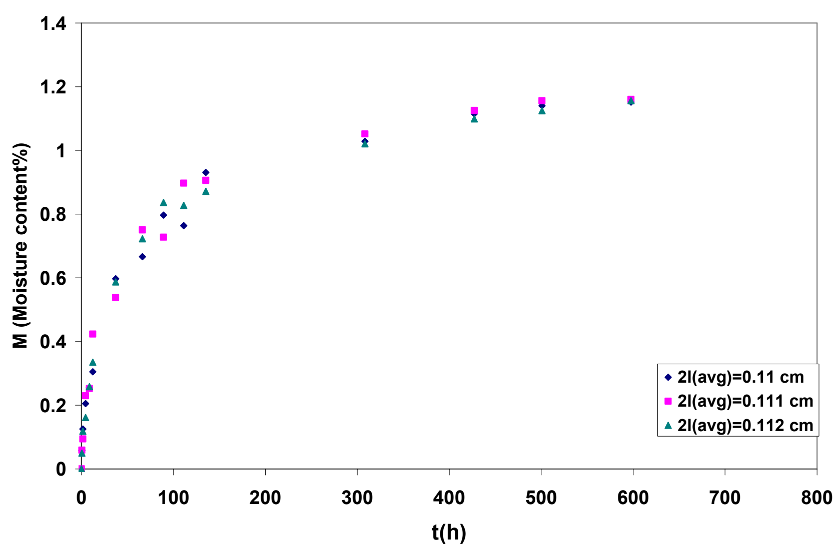


Figure 85 Moisture content versus t for neat vinyl ester samples immersed in water and subjected to 30%UTS at 25 °C

The linear initial uptake curve of M_t/M_∞ versus $t^{1/2}$ plot in Figure 86 shows that the diffusion under 30% UTS followed Fickian diffusion. The diffusivity was found to be 4.12 x 10^{-9} cm^2/s.

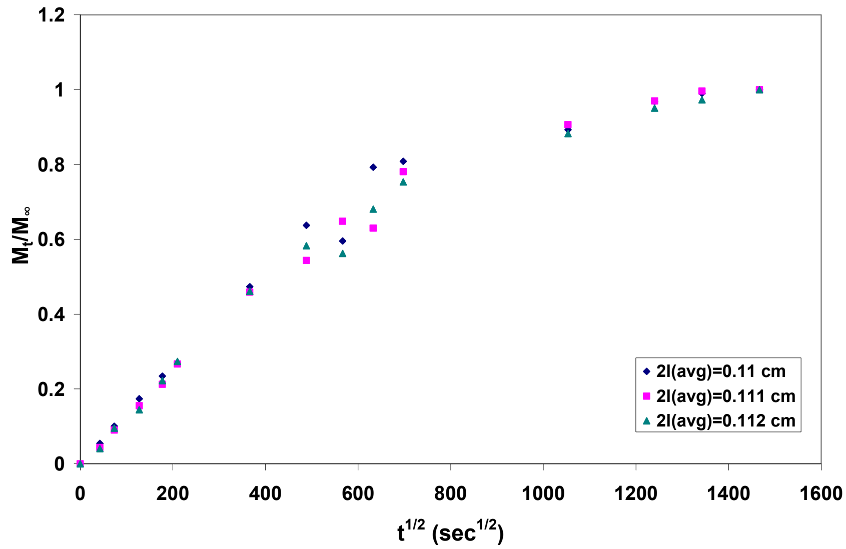


Figure 86 M_t/M_∞ versus $t^{1/2}$ for neat vinyl ester samples immersed in water and subjected to 30% UTS at 25 °C

The diffusivities of neat vinyl ester were found to be 4.15 x 10^{-9} cm^2/s without any stress, 4.06 x 10^{-9} cm^2/s under 17% UTS and 4.12 x 10^{-9} cm^2/s under 30% UTS. The diffusivity of water in neat vinyl ester samples seemed to remain constant with the increase in the stress level.

Figure 87, Figure 88 and Figure 89 show corresponding plots of moisture uptake versus time, moisture content (%) versus time and M_t/M_∞ versus $t^{1/2}$ for 5 wt% clay loaded vinyl ester samples immersed in water and subjected to 17% UTS. The average equilibrium moisture content of vinyl ester samples containing 5 wt% clay and subjected to 17% UTS was about 1.22%. The raw sorption data of vinyl ester samples containing 5 wt% Cloisite 10A immersed in distilled water subjected to 17% UTS at 25 °C is given in Appendix D in Table 43.

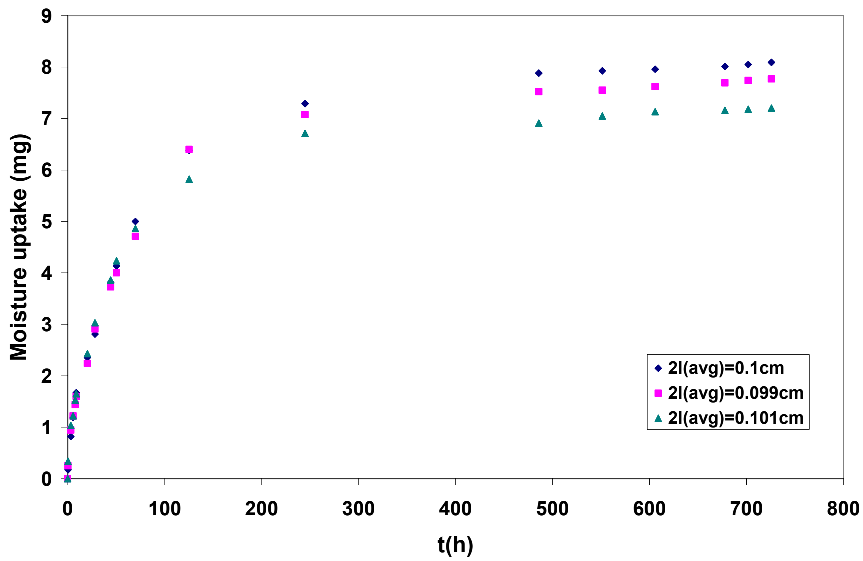


Figure 87 Moisture uptake (mg) versus t (h) for vinyl ester samples containing 5 wt% clay immersed in water and subjected to 17% UTS at 25 °C

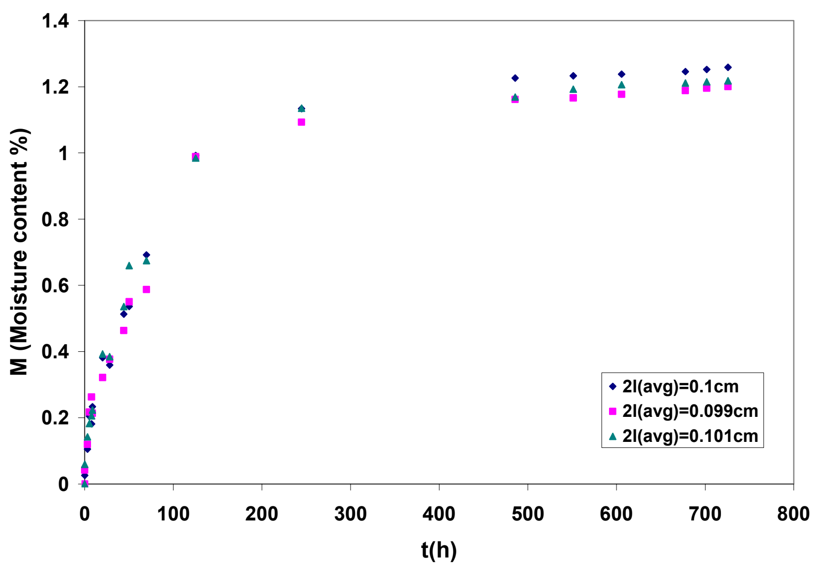


Figure 88 Moisture content versus t for vinyl ester samples containing 5 wt% clay immersed in water and subjected to 17% UTS at 25 °C

A graph of M_t/M_∞ versus $t^{1/2}$ in Figure 89 shows linear initial uptake curve indicating that the diffusion in 5 wt% clay loaded vinyl ester samples under 17% UTS followed Fickian diffusion. The diffusivity was found to be 2.96 x 10^{-9} cm^2/s.

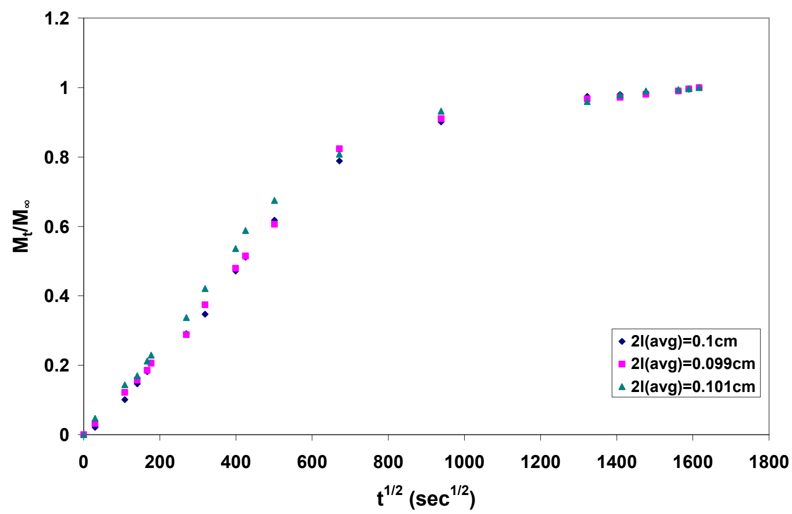


Figure 89 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 5 wt% clay immersed in water and subjected to 17% UTS at 25 °C

Figure 90, Figure 91 and Figure 92 show corresponding plots of moisture uptake versus time, moisture content (%) versus time and M_t/M_∞ versus $t^{1/2}$ for 5 wt% clay loaded vinyl ester samples immersed in water and subjected to 30% UTS. The average equilibrium moisture content of vinyl ester samples containing 5 wt% clay and subjected to 30% UTS was about 1.22%, which is same as that of the samples subjected to 17% UTS. This indicates that the increase in stress level did not affect the equilibrium moisture content of 5 wt% clay loaded vinyl ester samples immersed in water. The raw sorption data of vinyl ester samples containing 5 wt% Cloisite 10A immersed in distilled water subjected to 30% UTS at 25 °C is given in Appendix D in Table 45.

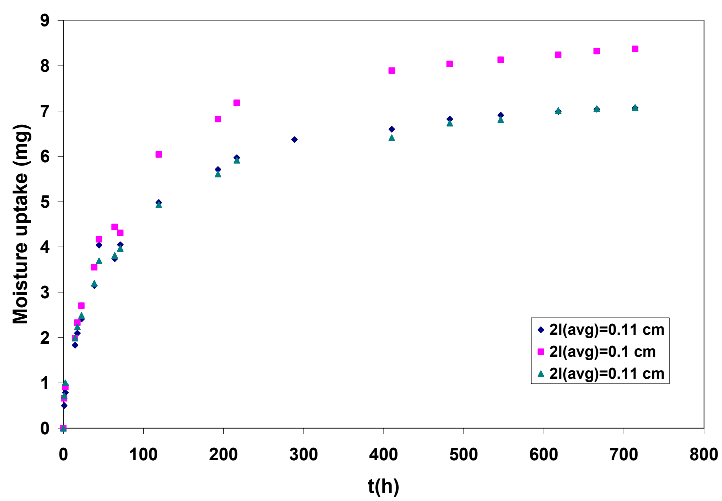


Figure 90 Moisture uptake (mg) versus t (h) for vinyl ester samples containing 5 wt% clay immersed in water and subjected to 30% UTS at 25°C

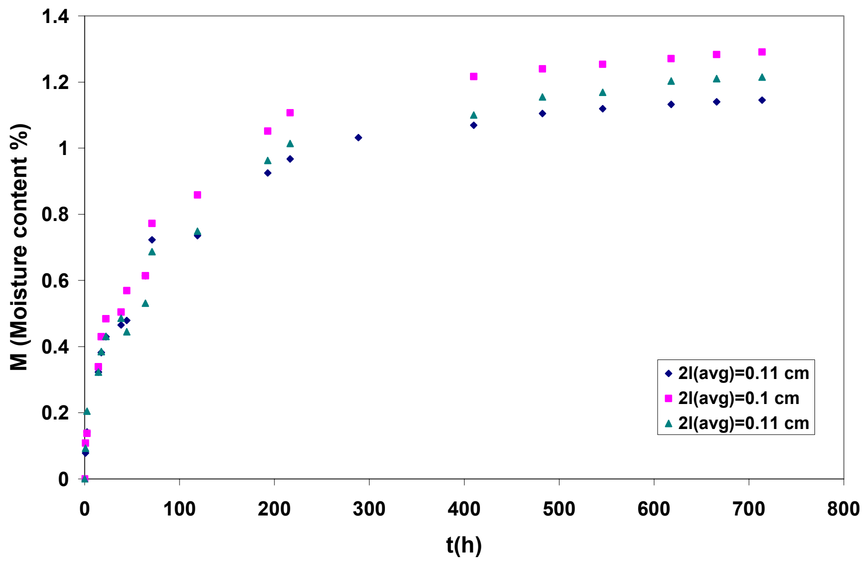


Figure 91 Moisture content versus t for vinyl ester samples containing 5 wt% clay immersed in water and subjected to 30% UTS at 25°C

The linear initial uptake curve of M_t/M_∞ versus $t^{1/2}$ plot in Figure 92 shows that the diffusion under 30% UTS followed Fickian diffusion. The diffusivity was found to be 3.06×10^{-9} cm^2/s.

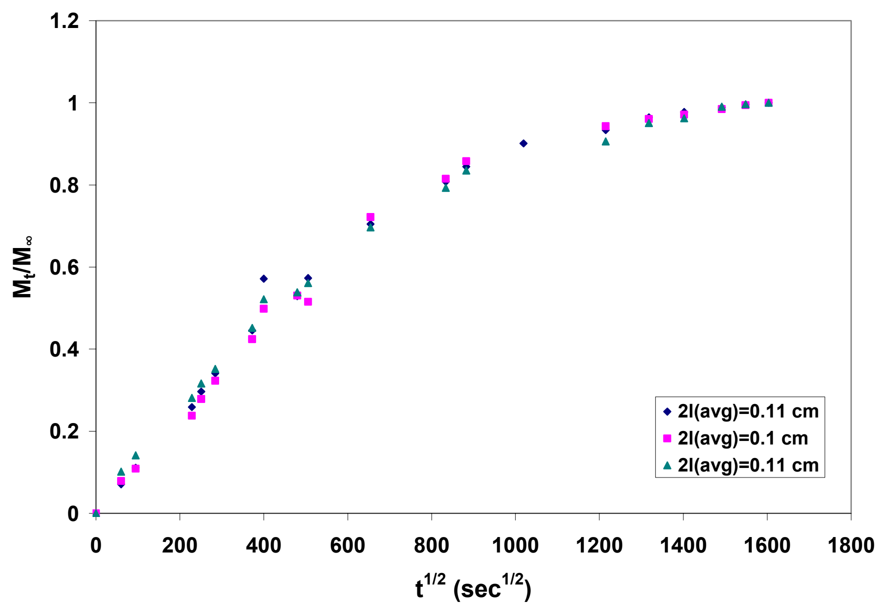


Figure 92 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 5 wt% clay immersed in water and subjected to 30% UTS at 25 °C

For neat vinyl ester samples immersed in water, the diffusivity values and equilibrium moisture content were found to remain constant with stress level. The diffusivity of water in neat vinyl ester samples subjected to 17% UTS was found to be 4 x 10^{-9} cm^2/s and at 30% UTS the value of diffusivity was found to be 4.12 x 10^{-9} cm^2/s. The diffusivity of neat vinyl ester without any stress was found to be 4.15 x 10^{-9} cm^2/s.

5 wt% clay loaded vinyl ester samples exhibited a marked increase in diffusivity values with the application of stress. With the application of stress on 5 wt% clay loaded samples, the diffusivity increased from 2.04 x 10^{-9} cm^2/s (without stress) to 2.96 x 10^{-9} cm^2/s at 17% UTS and 3.06 x 10^{-9} cm^2/s at 30% UTS respectively. The increase in diffusivity was observed in the samples immersed in water and those exposed to 60% RH environment. The equilibrium moisture content of the samples seemed to decrease, though not very significantly, with the application of stress.

4.5.2. Sorption Experiments under Stress at 60% RH

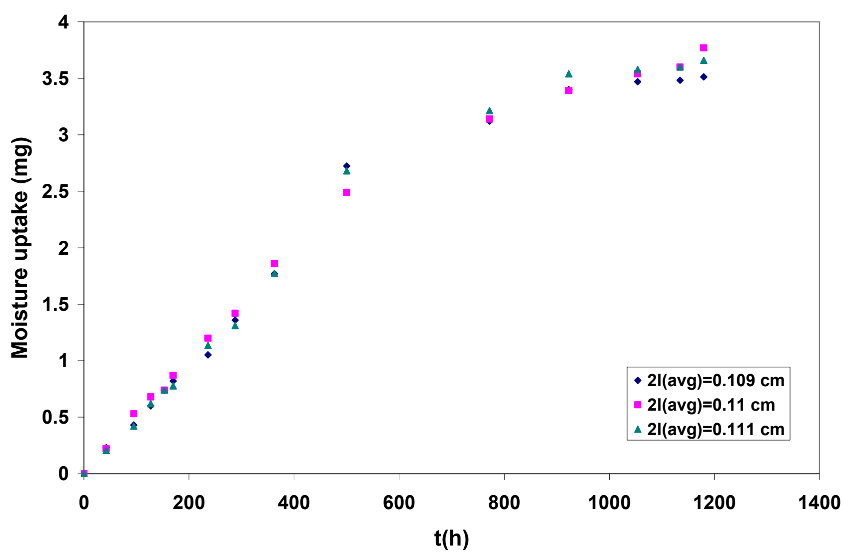


Figure 93 Moisture uptake (mg) versus t (h) for neat vinyl ester samples at 60% RH and subjected to 30% UTS at 25 °C

Figure 93, Figure 94 and Figure 95 show plots of corresponding moisture uptake versus time, moisture content (%) versus time and M_t/M_∞ versus $t^{1/2}$ for neat vinyl ester samples at 60% relative humidity and subjected to 30% UTS at 25 ºC. The raw sorption data of vinyl ester samples containing 0 wt% Cloisite 10A exposed to 60% RH at 25°C subjected to 17% UTS at 25 °C is given in Appendix D in Table 46.

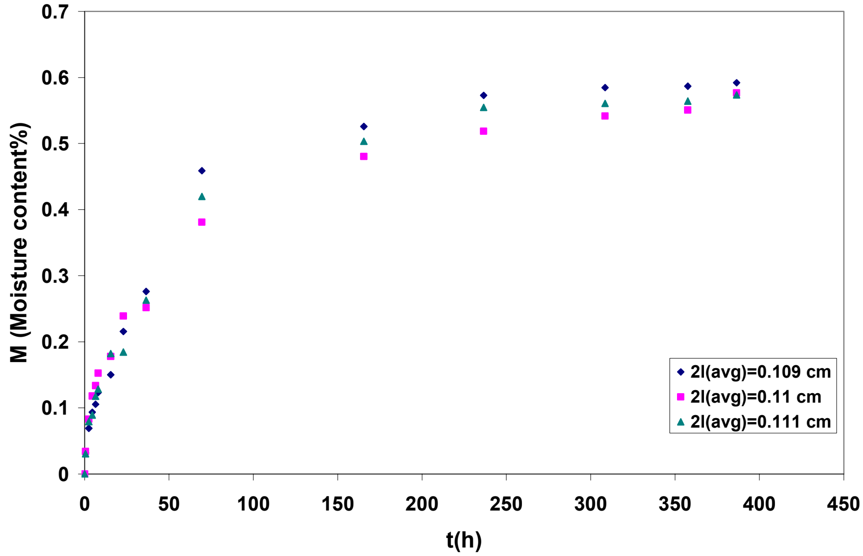


Figure 94 Moisture content versus t for neat vinyl ester samples at 60% RH and subjected to 30% UTS at 25 °C

The average equilibrium moisture content of the samples is about 0.6%, which is same as that of the samples exposed at 60% RH without any stress. This indicates that the increase in stress level did not affect the equilibrium moisture content of neat vinyl ester samples exposed at 60% RH.

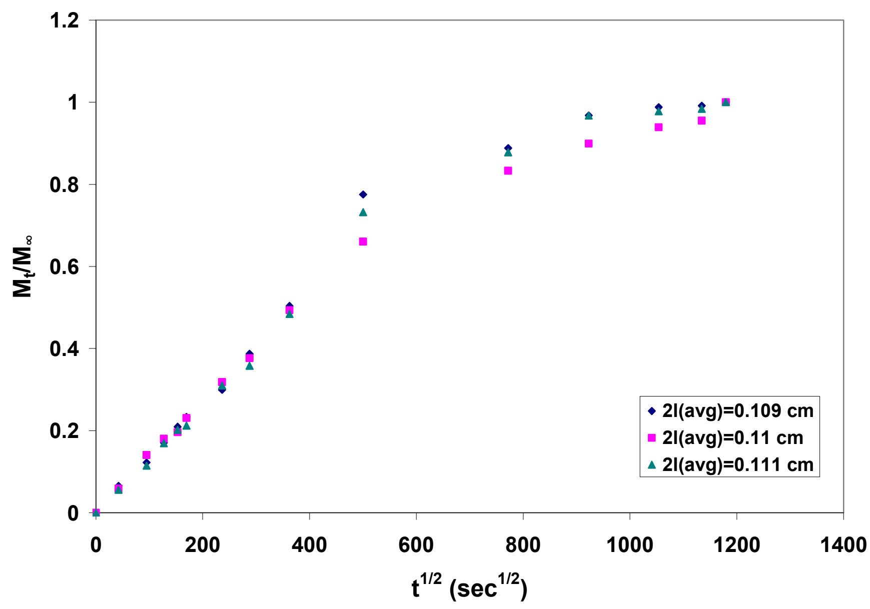


Figure 95 M_t/M_∞ versus $t^{1/2}$ for neat vinyl ester samples at 60% RH and subjected to 30% UTS at 25 °C

The linear initial uptake curve of M_t/M_∞ versus $t^{1/2}$ plot in Figure 95 shows that the diffusion at 60% RH under 30% UTS followed Fickian diffusion. The diffusivity was found to be 4.17 x 10^{-9} cm^2/s, same as that of moisture in neat vinyl ester without any stress (4.15 x 10^{-9} cm^2/s).

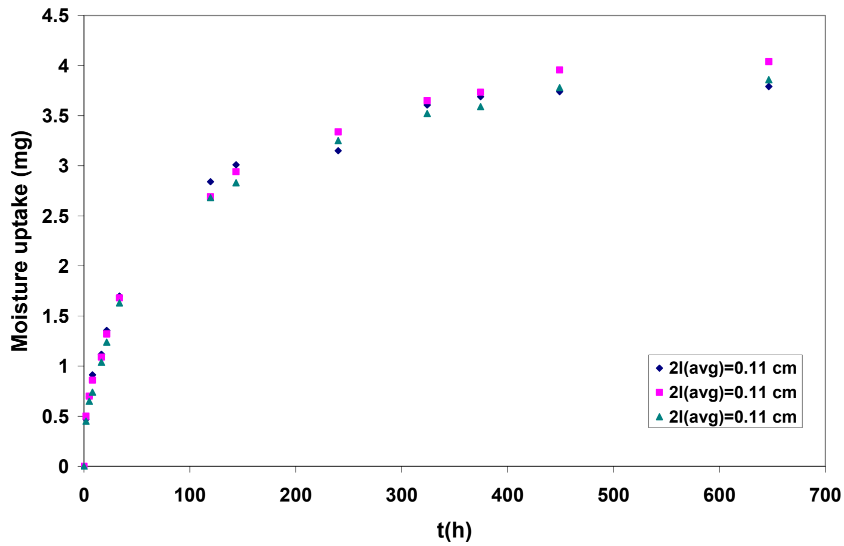


Figure 96 Moisture uptake (mg) versus t (h) for vinyl ester samples containing 5 wt% clay at 60% RH and subjected to 30% UTS at 25 °C

Figure 96, Figure 97 and Figure 98 show corresponding plots of moisture uptake versus time, moisture content (%) versus time and M_t/M_∞ versus $t^{1/2}$ for 5 wt% clay loaded vinyl ester samples exposed at 60% RH and subjected to 30% UTS. Figure 97 shows that the average equilibrium moisture content of vinyl ester samples containing 5 wt% clay and subjected to 30% UTS was about 0.6%, which is same as that of the samples under no stress and exposed at 60% RH. This indicates that the increase in stress level did not affect the equilibrium moisture content of 5 wt% clay loaded vinyl ester samples exposed at 60% RH. The raw sorption data of vinyl ester samples containing 5 wt% Cloisite 10A exposed to 60% RH at 25°C subjected to 17% UTS at 25 °C is given in Appendix D in Table 47.

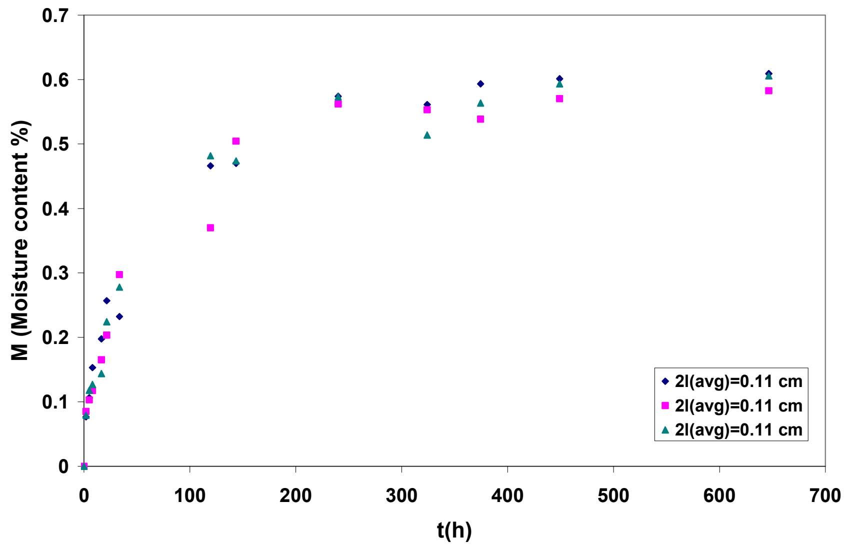


Figure 97 Moisture content versus t (h) for vinyl ester samples containing 5 wt% clay at 60% RH and subjected to 30% UTS at 25 °C

The linear initial uptake curve of M_t/M_∞ versus $t^{1/2}$ plot in Figure 98 shows that the diffusion at 60% RH and at 30% UTS followed Fickian diffusion. The diffusivity was found to be 3.3 x 10^{-9} cm^2/s. Similar to the stress coupled sorption experiments in water, 5 wt% clay loaded vinyl ester samples exposed to 60% RH environment exhibited a marked increase in diffusivity values with the application of stress.

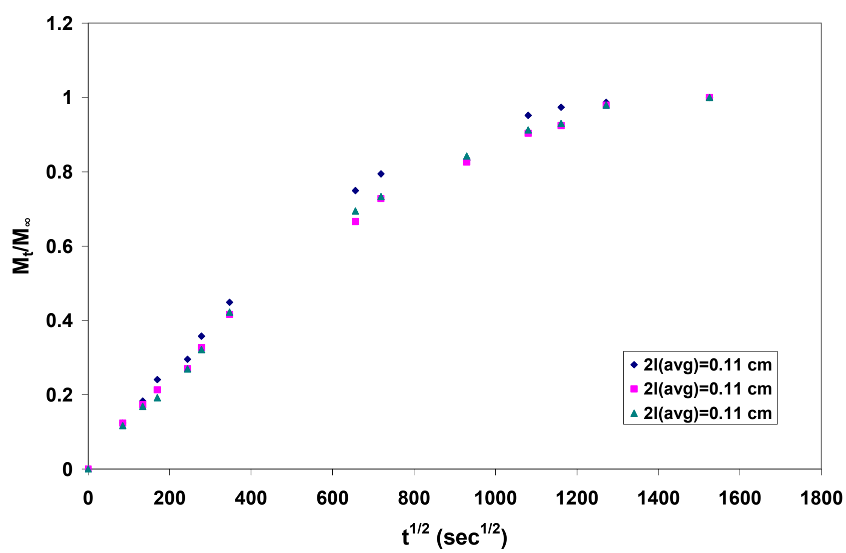


Figure 98 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 5 wt% clay at 60% RH and subjected to 30% UTS at 25 °C

Similar to the results obtained in the stress coupled diffusion in water, for neat vinyl ester samples at 60% RH, the diffusivity seemed to remain constant with stress level. The diffusivity of water in neat vinyl ester samples subjected to 30% UTS was found to be 4.12 x 10^9 cm^2/s. The diffusivity of moisture in neat vinyl ester without any stress at 60% RH was found to be 4.0 x 10^{-9} cm^2/s.

Table 7 and Table 8 show the variation in equilibrium moisture content (EMC) and diffusivity (D) of moisture with various stress levels and percentage clay loadings for samples immersed in water and those exposed at 60% relative humidity (RH) respectively. 5 wt% clay loaded vinyl ester samples exhibited a marked increase in diffusivity values with the application of stress. With the application of stress on 5 wt% clay loaded samples, the diffusivity increased from 2.3 x 10^{-9} cm^2/s (without stress) to 3.3 x 10^{-9} cm^2/s at 30% UTS in samples exposed to 60% RH. No change in equilibrium moisture content was observed in the samples immersed in water and those exposed to 60% RH environment with increase in stress level. The reason for the increase in the diffusivity of moisture in 5 wt% clay loaded samples could be due to the micro-structural damage occurred due to the application of stress. To verify this, SEM analysis on the 5 wt% clay loaded samples subjected to stress was done. The images obtained (Figure 107, Figure 108, Figure 109, Figure 110, Figure 111, Figure 112, Figure 113 and Figure 114) during the analysis showed formation of cracks in the samples.

Table 7. Variation of equilibrium moisture content and diffusivity with various stress levels and percentage clay loadings for samples immersed in water

Clay loading	Stress Level					
	0% UTS		17% UTS		30% UTS	
	EMC (%)	Dx10^9 (cm^2/s)	EMC (%)	Dx10^9 (cm^2/s)	EMC (%)	Dx10^9 (cm^2/s)
0wt%	1.23±0.03	4.15±0.7	1.15±0.04	4.06±0.58	1.15±0.004	4.12±0.45
5wt%	1.49±0.07	2.04±0.14	1.22±0.02	2.96±0.22	1.22±0.07	3.06±0.26

Table 8. Variation of equilibrium moisture content and diffusivity with various stress levels and percentage clay loadings for samples exposed at 60%RH

Clay loading	Stress Level			
	0% UTS		30% UTS	
	EMC (%)	Dx10^9(cm^2/s)	EMC (%)	Dx10^9(cm^2/s)
0 wt%	0.588±0.008	4.0±0.34	0.58±0.001	4.17±0.17
5 wt%	0.615±0.01	2.3±0.12	0.6±0.01	3.3±0.36

4.5.3. Mechanism of Diffusion through Polymer Nanocomposites under Stress

The imposed external stress has important effect on the moisture diffusion through polymers. Liu (2004) studied the diffusion of dichloromethane through PDMS nanocomposites. The results showed that the extension of the membrane will not only decrease the thickness of the membrane, resulting in enhanced diffusion but also packs and reorients the polymer chains (decreasing the free volume), which can decrease the diffusion coefficient. The packing of the polymer chains reduces the free volume and increases the activation energy for diffusion, which leads to a decreased diffusion coefficient. For higher clay concentrations (due to reduced polymer chain mobility Shah, 2002), the packing of the polymer chains became more difficult, resulting in a smaller decrease. It was also reported in literature that application of tensile stress increases the space between the nano-particles which can increase the diffusivity. Also as reported by others, clay proved to be detrimental to the durability of the composites in terms of strength reduction. Ravindran (2005) reported a decrease in the tensile strength of the clay loaded fiber reinforced vinyl ester composites when subjected to a sustained load in alkaline solution. The phenomenon was thought to be due to the formation of microcracks. Wang et al. (2005) and Gam (2003) studied the formation and crack propagation in epoxy nanocomposites and their results indicated that the presence of nanoclay layers forced the crack to propagate along a very tortuous path. The results implied that the clay layers acted as stress concentrators and promoted the formation of a large number of microcracks when the sample was loaded.

4.6 Scanning Electron Microscopy

Scanning electron micrographs of freshly made neat and clay loaded samples were taken. Those were recognized as “Reference” samples. Figure 99, Figure 100, Figure 101 and Figure 102 show the SEM images of the “Reference” samples, neat vinyl ester, 5 wt% clay loaded vinyl ester, 2 wt% clay loaded epoxy and 5 wt% clay loaded epoxy respectively. There were no cracks seen in the images taken.

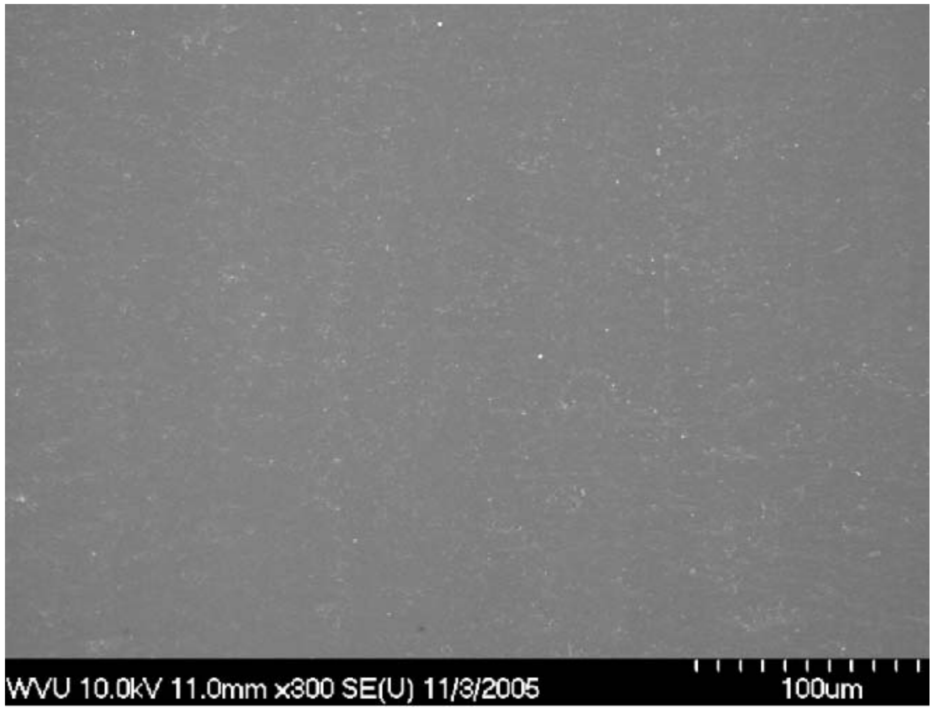


Figure 99 SEM image of freshly prepared neat vinyl ester sample (no cracks)

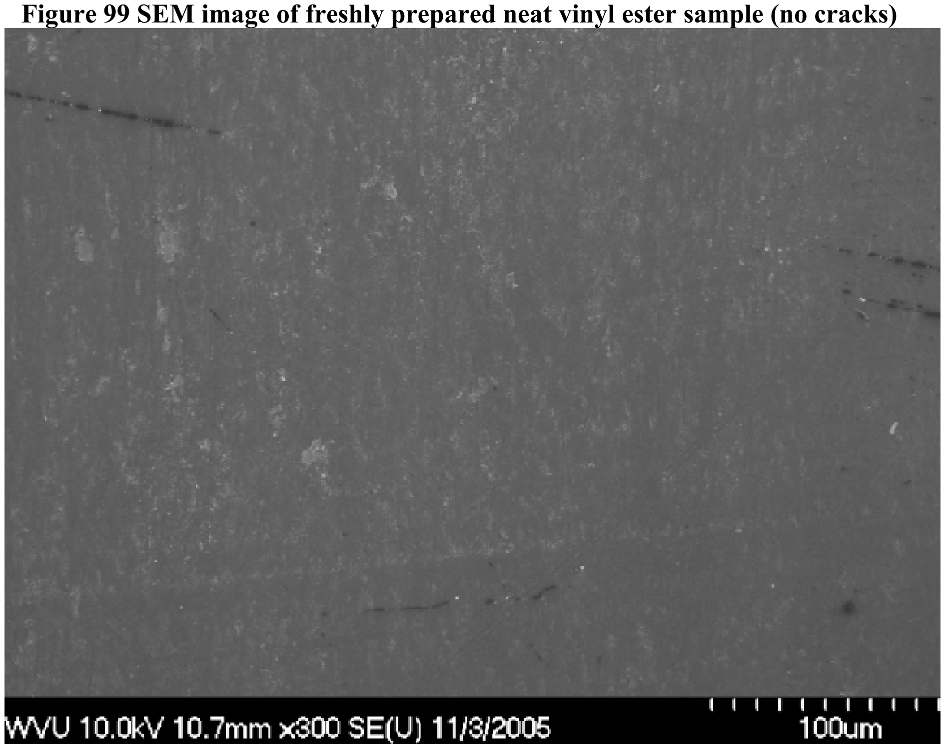


Figure 100 SEM image of freshly prepared 5 wt% clay loaded vinyl ester sample (no cracks)

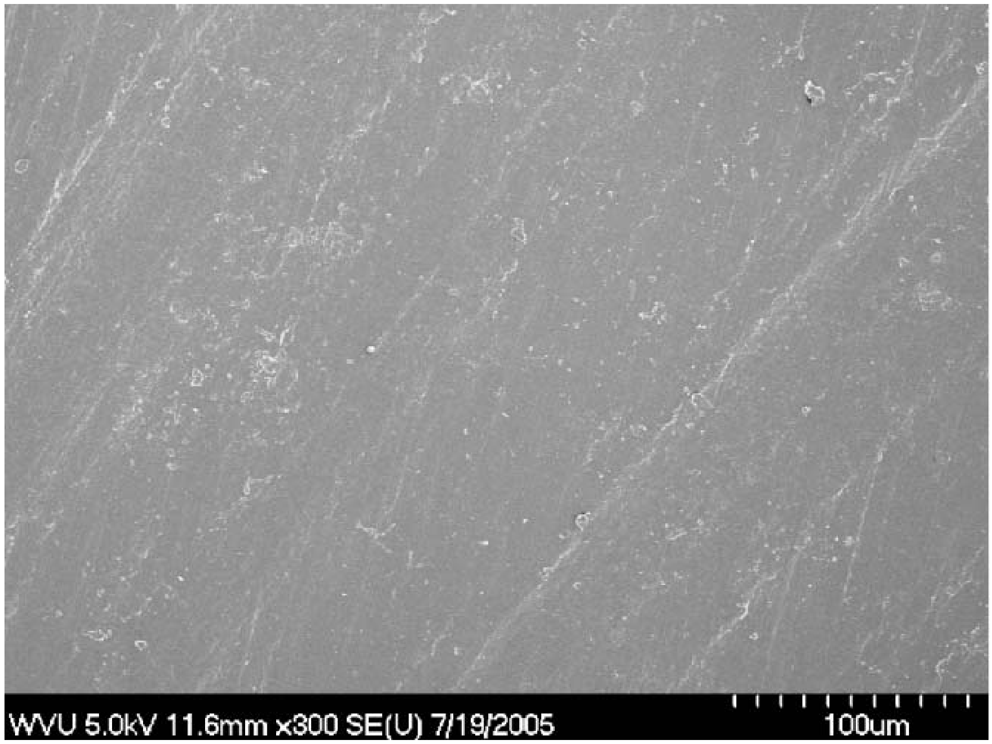


Figure 101 SEM image of freshly prepared 2 wt% clay loaded epoxy sample (no cracks)

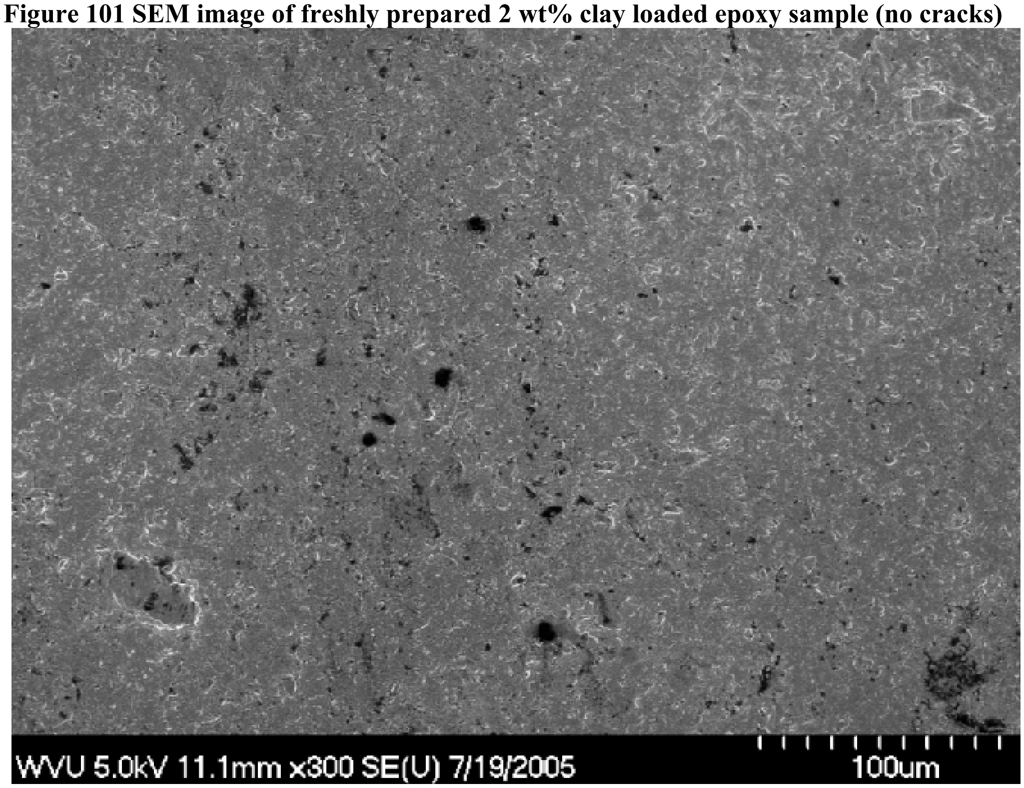


Figure 102 SEM image of freshly prepared 5 wt% clay loaded epoxy sample (no cracks)

The images taken for 2 wt% and 5 wt% clay loaded epoxy samples subjected to cyclic sorption-desorption and 5 wt% clay loaded vinyl ester samples subjected to sorption under stress showed the formation of cracks. Figure 103 and Figure 104 show the images of 2 wt% clay loaded epoxy subjected to cyclic moisture sorption-desorption. Figure 103 shows the presence of microcracks throughout the surface and under higher magnification as shown in Figure 104 the size of the cracks was found to be approximately 0.2μm.

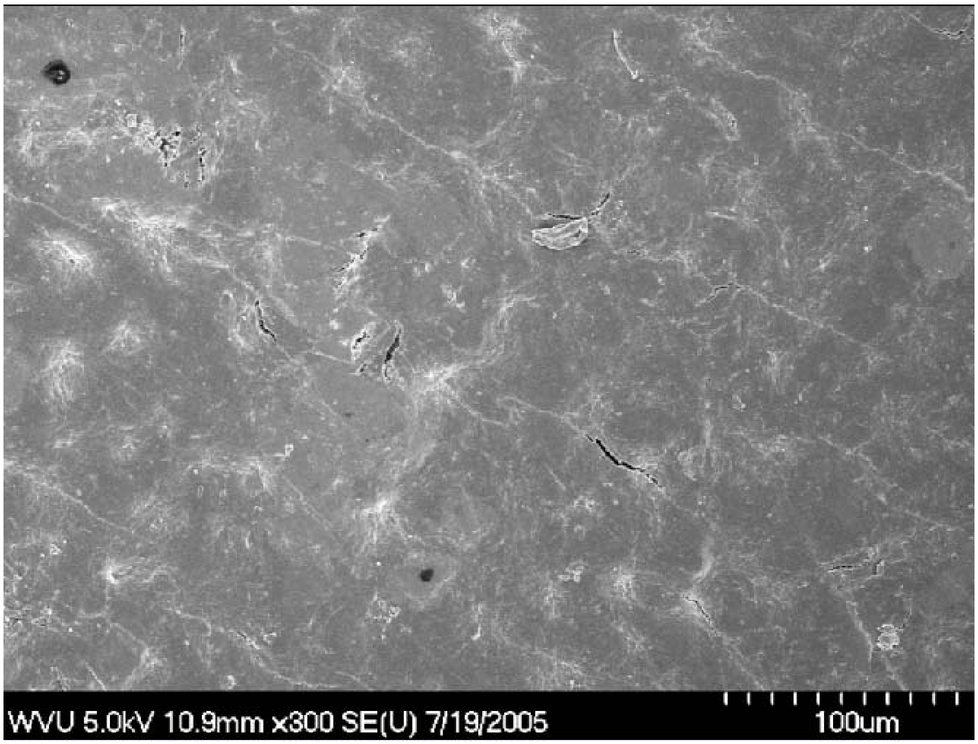


Figure 103 SEM image of 2 wt% clay loaded epoxy subjected to cyclic sorption-desorption

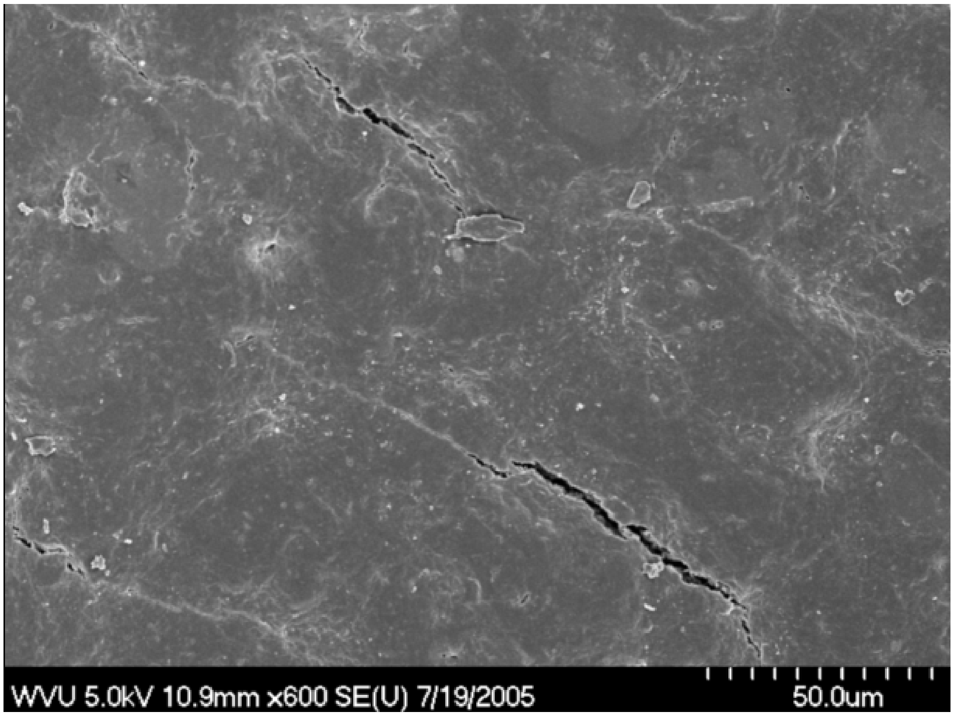


Figure 104 SEM image of 2 wt% clay loaded epoxy subjected to cyclic sorption-desorption (closer view)

Figure 105 and Figure 106 show the images of 5wt% clay loaded epoxy subjected to cyclic moisture sorption-desorption.

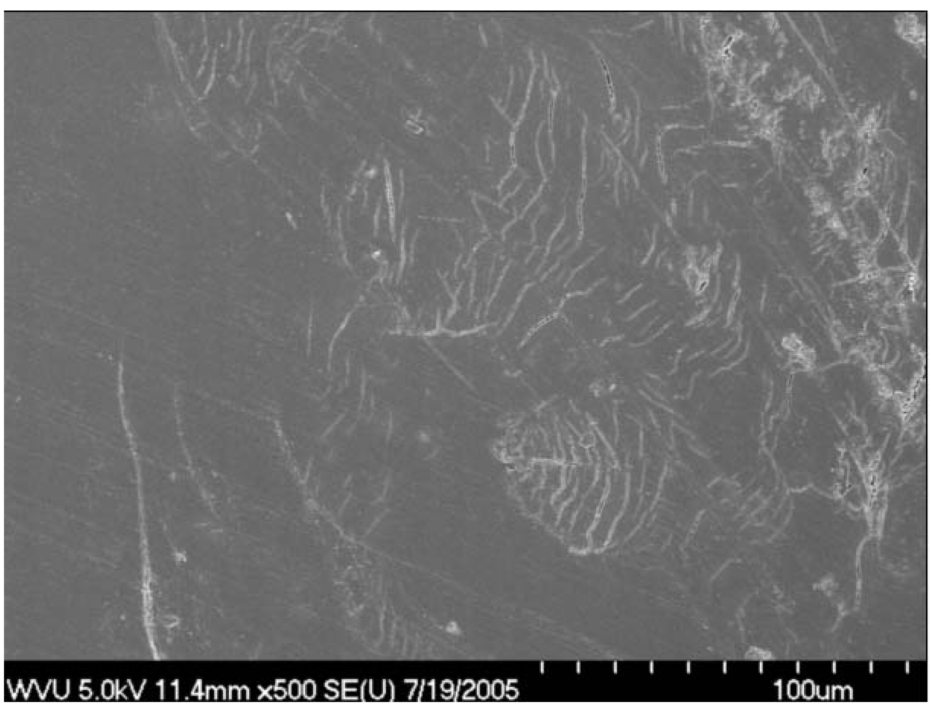


Figure 105 SEM image of 5 wt% clay loaded epoxy subjected to cyclic sorption-desorption

Figure 105 and Figure 106 show the formation of large number of microcracks with increase in clay loading. Some clusters are also observed which indicate the presence of high concentration of clay in the neighboring regions. The path of the cracks was found to be tortuous due to the presence of nanoclay layers which force the crack to propagate along a very tortuous path. Thus it can be concluded that crack density increased with clay loading.

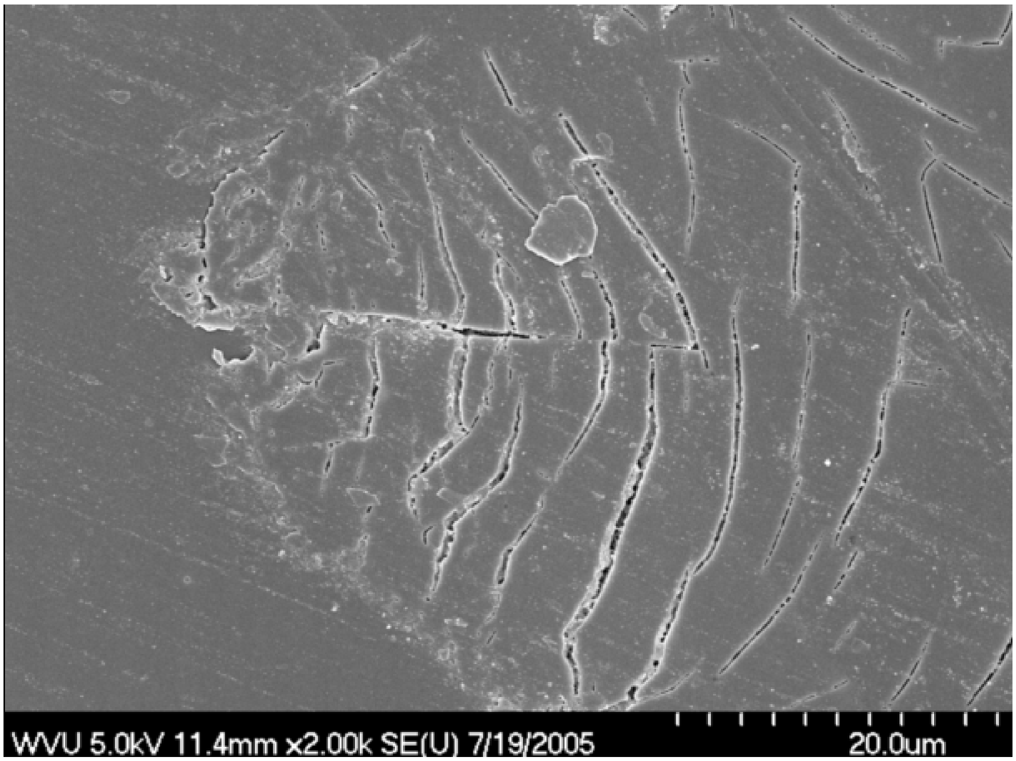


Figure 106 SEM image of 5 wt% clay loaded epoxy subjected to cyclic sorption-desorption (closer view)

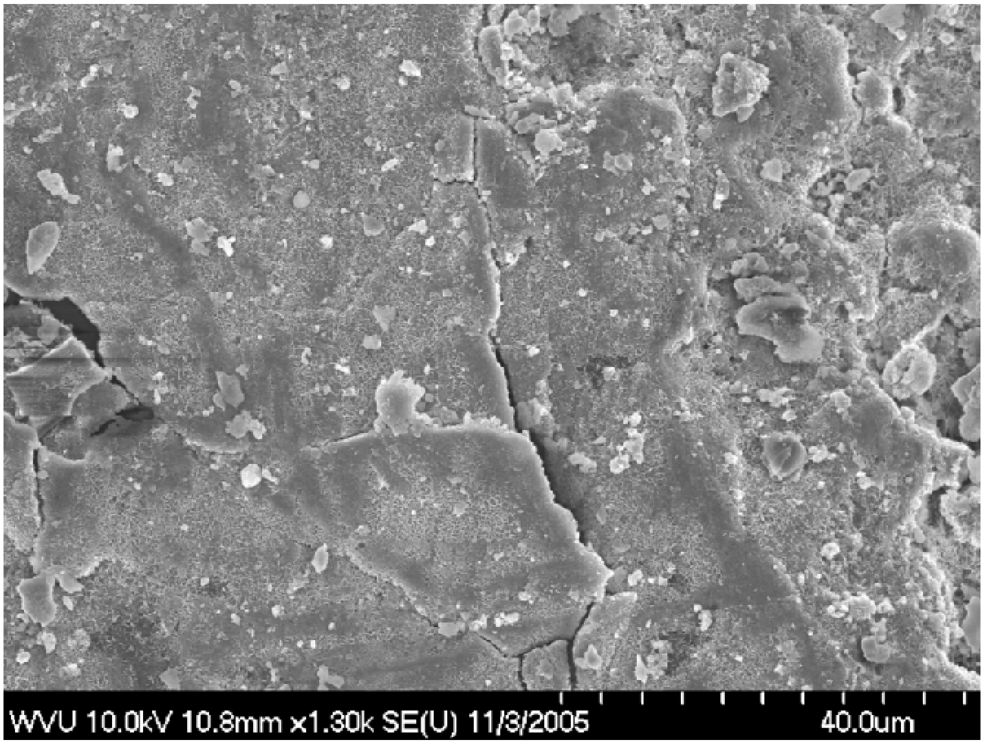


Figure 107 SEM image of 5 wt% clay loaded vinyl ester sample immersed in water and subjected to 17%UTS

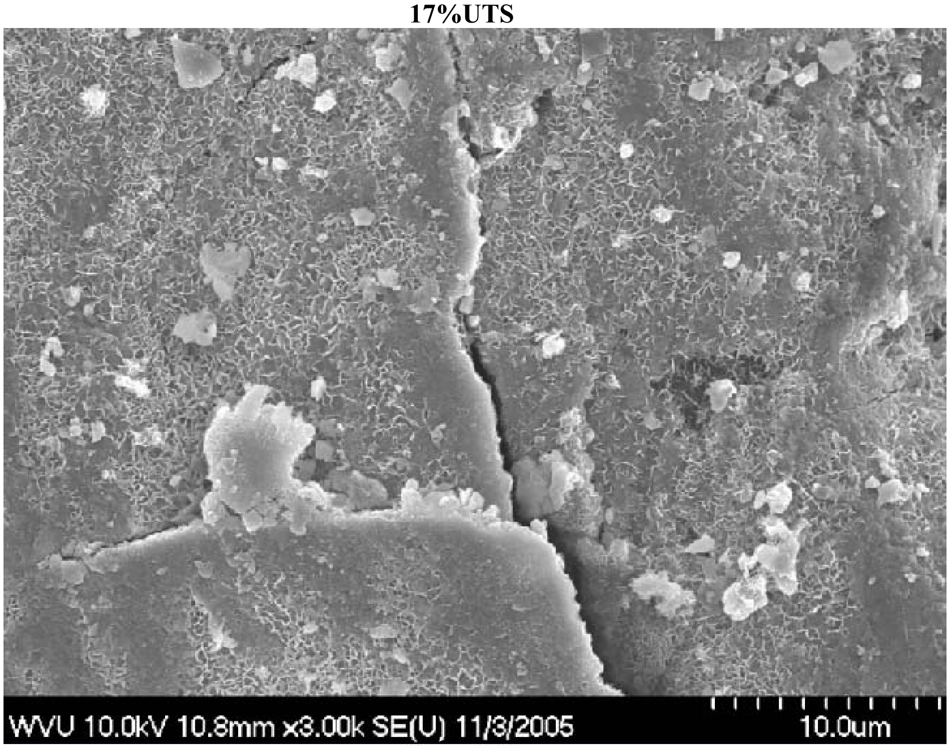


Figure 108 SEM image of 5 wt% clay loaded vinyl ester sample immersed in water and subjected to 17%UTS (closer view)

Figure 107 and Figure 108 show SEM images of 5 wt% clay loaded vinyl ester samples subjected to a load corresponding to 17% UTS. The figures show formation of micrcocracks and also scaling of the surface indicating that the presence of nanoclay layers forced the crack to propagate along a very tortuous path. The clay layers could have acted as stress concentrators and promoted the formation of a large number of microcracks when the sample was loaded. This is clearly seen in Figure 109 and Figure 110, which show the increase in the number of cracks per unit area with the increase in the loading. Figure 109, Figure 110, Figure 111 and Figure 112 show the images of 5 wt% clay loaded samples immersed in water and subjected to 30% UTS. The size of the cracks formed in samples subjected to 30% UTS was found to be 0.2 μm.

Figure 109 SEM image of 5 wt% clay loaded vinyl ester sample immersed in water and subjected to 30%UTS

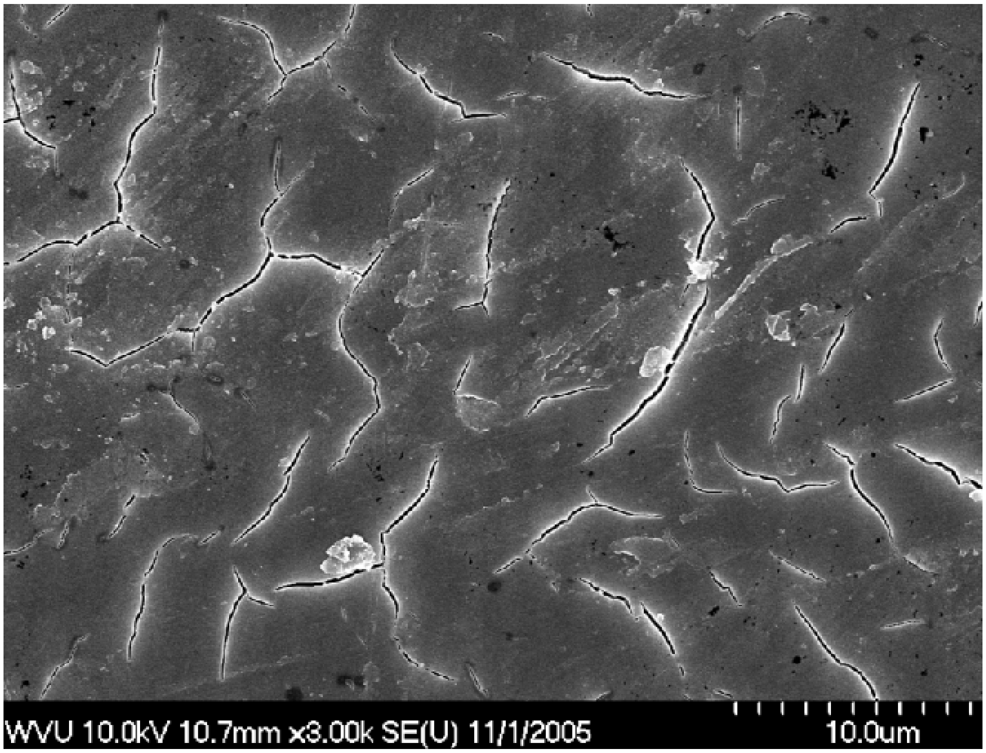


Figure 110 SEM image of 5 wt% clay loaded vinyl ester sample immersed in water and subjected to 30%UTS (closer view)

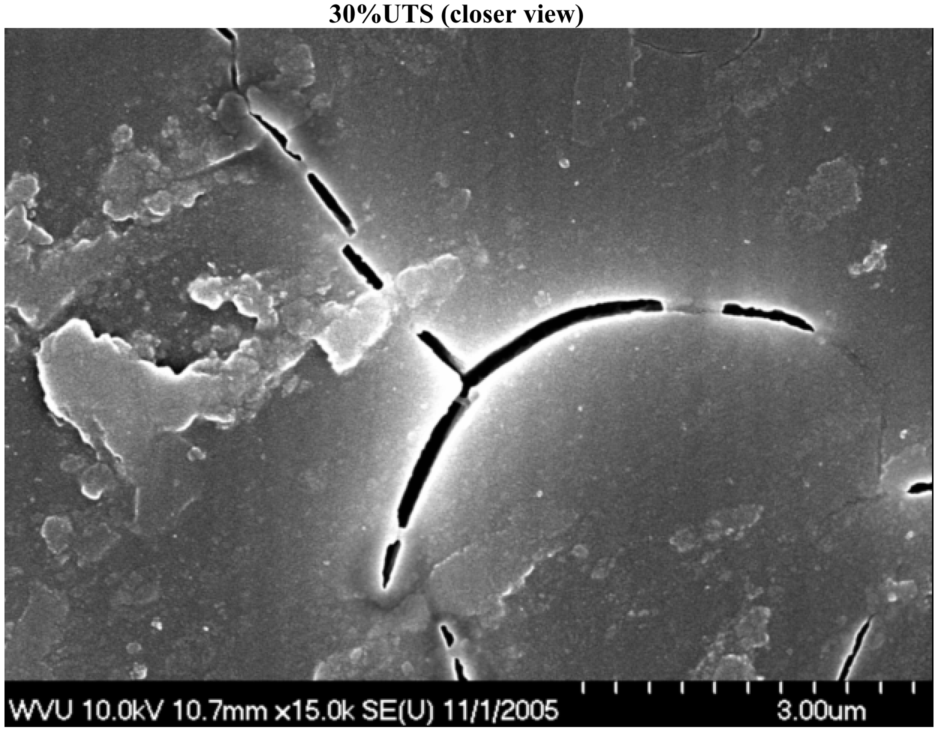


Figure 111 SEM image of 5 wt% clay loaded vinyl ester sample immersed in water and subjected to 30%UTS (closer view)

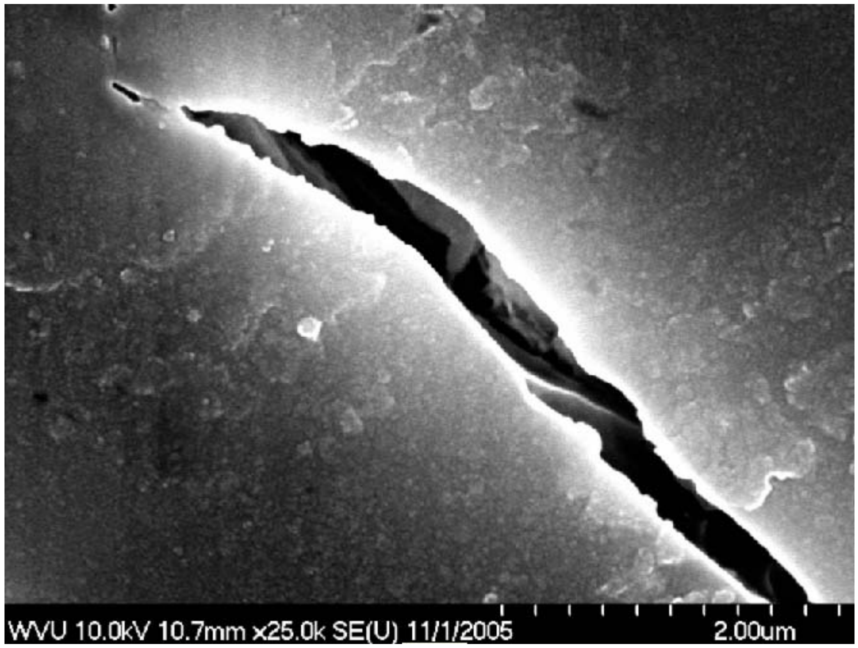


Figure 112 SEM image of 5 wt% clay loaded vinyl ester sample immersed in water and subjected to 30%UTS (closer view, showing the size of crack (0.2 µm)

Figure 111 and Figure 112 clearly show a closer view of crack propagation and the crack dimensions.

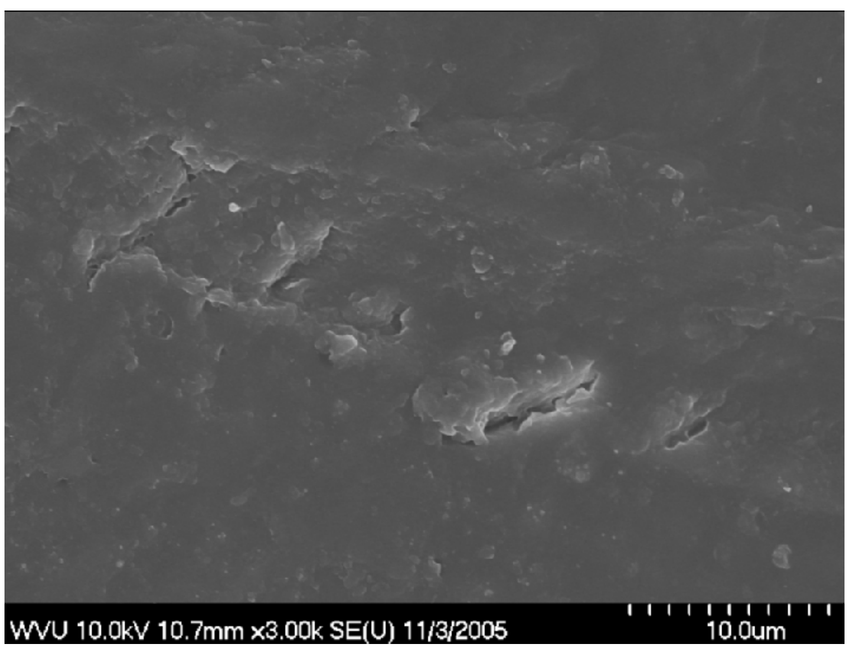


Figure 113 SEM image of 5 wt% clay loaded vinyl ester sample exposed to 60% RH and subjected to 30%UTS

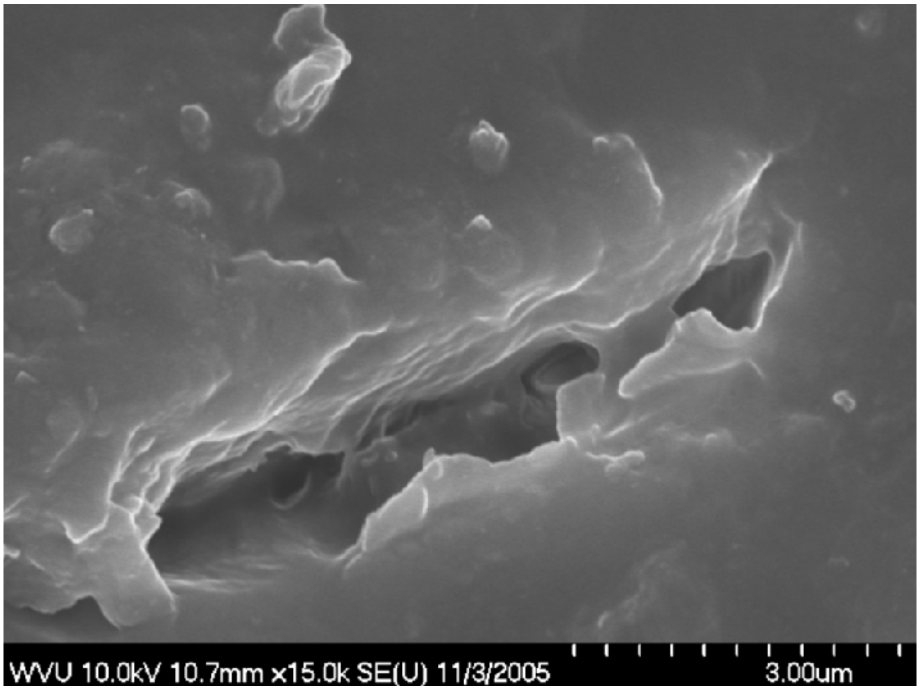


Figure 114 SEM image of 5 wt% clay loaded vinyl ester sample exposed to 60% RH and subjected to 30%UTS (Closer view)

Figure 113 and Figure 114 show SEM images of 5 wt% clay loaded vinyl ester samples exposed to 60% RH and subjected to a load corresponding to 30% UTS. The figures show formation of micrcocracks and also scaling of the surface indicating that the presence of nanoclay layers forced the crack to propagate along a very tortuous path. When moisture is being absorbed into a dry laminate, the outer regions tend to swell isotropically, but, the inner moisture-free core will restrain swelling. This non-uniform swelling through the thickness of the laminate would yield high stresses at the surface of the laminate that can result in crack formation (Shirrell, 1978). Wang et al. (2005) and Liu (2004) studied mechanical properties and fracture mechanisms in epoxy nanocomposites with highly exfoliated and intercalated clay. They observed several discontinuous cavities in the cracks, which are associated with clay platelets. These cavities were also observed in the present study in the vinyl ester nanocomposites subjected to moisture sorption under stress. Most microcracks were assumed to have formed either along the matrix-clay interface or inside the clay platelets via delamination. Similar results on the crack initiation were observed in the work done by Kim et al. (2001). When observed under high magnification with TEM, their work revealed that they were initiated within the intergallery of clay layers rather than at the interface.

4.6.1. Mechanism of Crack Initiation and Propagation

When the sample is subjected to a load, stress concentration around the clay tactoids due to the difference of Young's modulus and Poisson's ratio of clay and matrix occurs (Wang et al., 2005). Due to the weaker interlayer strength of clay than the matrix-clay interfacial bonding strength and epoxy cohesive strength, interlaminar debonding occurs. As a result, microcracks form and on further loading, the neighboring microcracks will extend in length, penetrate into the matrix ligaments between them and finally develop into a macroscopic crack.

CHAPTER 5

CONCLUSIONS

The nanocomposites of various polymers used in the study with montmorillonite clay exhibited a morphology which is a combination of exfoliation and intercalation. XRD scans and TEM pictures reveal the fact that the clay existed as individual platelets and aggregates and total breakdown of such aggregates could be achieved by vigorous mixing techniques.

Cyclic sorption-desorption experiments with vinyl ester and its nanocomposites showed that the montmorillonite clay was effective in reducing the diffusivity of water through the polymer and also retained its effectiveness with subsequent sorption-desorption cycles. The diffusivity of water in neat vinyl ester and its nanocomposites decreased after the first absorption cycle and seemed to level off and remain constant with subsequent cycles. This could be due to the catalytic effect of water in further curing and greater cross linking of the polymer chains with time and further reabsorption.

Cyclic sorption-desorption experiments with polyester and its nanocomposites also showed results similar to that shown by vinyl ester. The diffusivity of water in polyester was reduced with the addition of clay and the clay retained its effect throughout the cycling process. The diffusivity of water in polyester resin and its nanocomposites decreased after the first absorption cycle and remained constant with subsequent cycling. This could be again due to the catalytic effect of water in improving curing and greater crosslinking of polymer chains.

Cyclic sorption-desorption experiments with epoxy and its nanocomposites showed an opposite trend to vinyl ester and polyester resins in that the diffusivity of water increased with subsequent cycling. Although, reduction in diffusivity with the addition of clay was observed, the increased diffusivity with further cycling could be due to the micostructural damage done due to cyclical aging in water. The SEM images proved the presence of cracks in 2 wt% and 5 wt% clay loaded epoxy nanocomposites. Number of cracks per unit area increased with increased clay loading and size of the cracks remained the same in both the clay loaded samples. It was found to be around 0.2

μm.

The cyclical aging in water showed no effect on the equilibrium moisture content of all the polymers and their polymer based nanocomposites used in the study. However, it increased with increased clay loading for a given cycle.

The diffusivities of moisture in vinyl ester and its nanocomposites at various relative humidities, 40%RH, 60% RH, 70% RH, 80% RH (all at 25 ºC) showed that the diffusivity remained constant with varying relative humidities indicating that diffusivity of moisture in vinyl ester is concentration-independent. However, the equilibrium moisture content of the neat vinyl ester and its nanocomposites increased with increasing relative humidity and was found to be a non linear function of relative humidity. Also, the equilibrium moisture content of clay loaded samples was found to be same as neat vinyl ester samples at a given relative humidity.

Stress coupled sorption experiments with vinyl ester and 5 wt% clay loaded vinyl ester samples showed that the diffusivity of water in neat vinyl ester resin remained constant with the increasing tensile stress level, while increased with increasing tensile stress level in case of 5 wt% clay loaded nanocomposites. This shows detrimental effects of clay in moisture absorption under stress. Similar results were found when the stress coupled moisture experiments were carried out at a relative humidity of 60% RH.

SEM analysis on vinyl ester nanocomposites subjected to various stress levels revealed the presence of microcracks of about 0.2μm in size, which were responsible for the increase in diffusivity with increasing level of stress in vinyl ester nanocomposites. The number of cracks seemed to increase with the increasing stress levels while the size of the cracks remained the same.

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Appendix A

A.1.Chemistry of Resins used in the Study

A.1.1.Vinyl ester

Vinyl ester resins are produced by addition of various epoxide resins and unsaturated monocarboxylic acids, most commonly methacrylic acid, resulting in a molecule with unsaturated polymeric reaction end groups (double bonds) and ester groups. Figure 115 shows idealized chemical structure of a typical epoxy based vinyl ester. In many industrial products, vinyl ester resins are comprised of 40-50 wt % styrene.

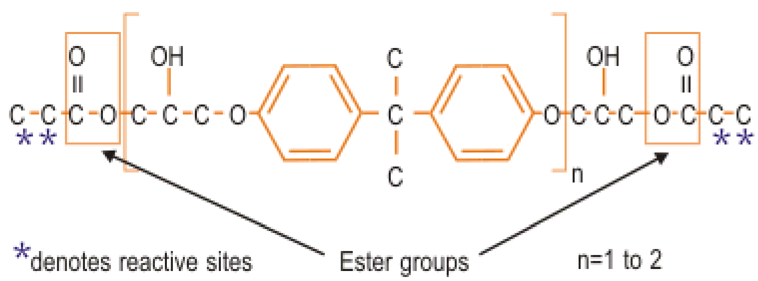

Figure 115 Idealized chemical structure of a typical epoxy based vinyl ester

Vinyl ester resins cure by chemical cross-linking reactions between the vinyl ester oligomers and styrene with initiator/promoter systems. Figure 116 shows schematic of a cross linked vinyl ester resin. The most common sources of free radicals, which are needed to initiate the curing reaction, are peroxides such as methyl ethyl ketone peroxide (MEKP) and benzoyl peroxide; these are called initiators. The function of the promoter, usually cobalt naphthenate, is to decompose the initiator rapidly at room temperature. The promoter is mixed in thoroughly before adding the initiator. The initiator then reacts with the promoter to cause the resin to gel.

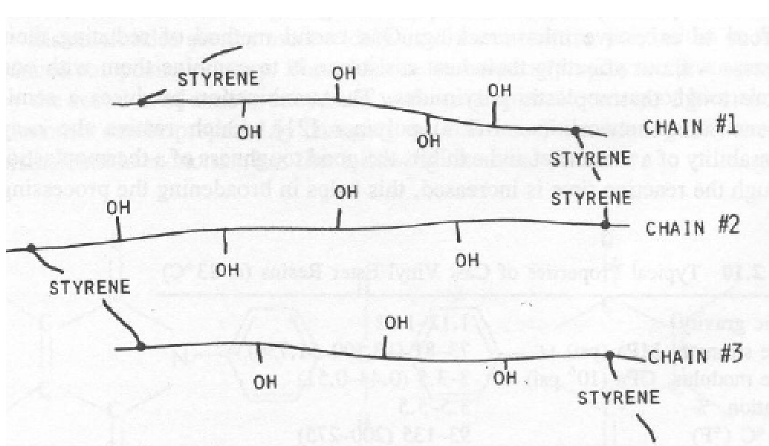

Figure 116 Schematic of a cross linked vinyl ester resin (Mallick, 1993)

A.1.2.Polyester

Polyester is formed when special alcohols such as glycol react with di-basic acids. This reaction, together with the addition of compounds such as saturated di-basic acids and cross-linking monomers, forms the basic process of polyester manufacture. Figure 117 shows idealized chemical structure of a typical epoxy based polyester.

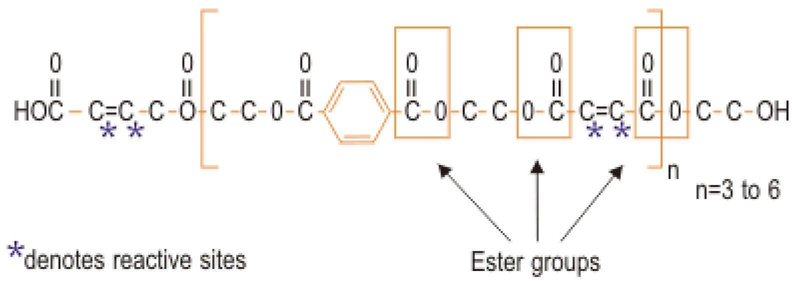

Figure 117 Idealized chemical structure of a typical epoxy based polyester

The reaction of styrene and unsaturated polyester resin is a free radical chain growth crosslinking copolymerization. It includes three major reactions: styrene-polyester vinyl, styrene-styrene and polyester vinyl-polyester vinyl. The styrene in which resin is dissolved performs the vital function of enabling the resin to cure from a liquid to a solid by 'cross-linking' the molecular chains of the polyester in the presence of an initiator and catalyst. Small quantities of inhibitor are added to the resin as polyester resins have limited storage life and will set or gel on their own over a long period of time.

A.1.3.Epoxy

Epoxy resins are formed from a long chain molecular structure similar to vinyl ester with reactive sites at either end. In the epoxy resin, however, epoxy groups instead of ester groups form these reactive sites. The absence of ester groups means that the epoxy resin has particularly good water resistance. The epoxy molecule also contains two ring groups at its centre which are able to absorb both mechanical and thermal stresses better than linear groups and therefore give the epoxy resin very good stiffness, toughness and heat resistant properties. Figure 118 shows the idealized chemical structure of a typical epoxy

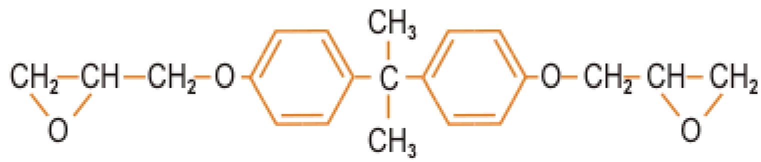

Figure 118 Idealized chemical structure of a typical epoxy (diglycidyl ether of bisphenol-A)

Epoxies differ from polyester resins in that a ‘hardener’ rather than a catalyst cures them. The hardener, often an amine, is used to cure the epoxy by an addition reaction where both materials take part in the chemical reaction. The chemistry of this reaction means that there are usually two epoxy sites binding to each amine site. This forms a complex three-dimensional molecular structure, which is illustrated in the following Figure 119

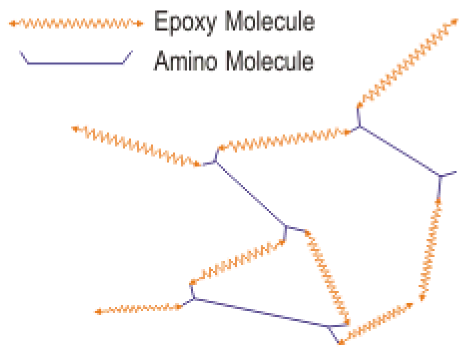

Figure 119 Schematic representation of epoxy resin

Appendix B

B.1.Sample Calculations

B.1.1.Sample Calculation for Absorption Diffusion Coefficient (D_a)

Sample thickness $2l$=0.0488 cm

Initial dry weight of the sample W_0=342.01 mg

Weight of the sample at time t =W_t mg

Table 9. Sorption Data of Vinyl ester Samples containing 0 wt% Cloisite 10A at 25ºC During First Cycle of Absorption

Time,h	√t, sec$^{1/2}$	W_t,mg	M_t,mg	Moisture uptake,%	M_t/M_∞
0	0	W_0=342.01	0	0	0.0000
0.5	42.4264	342.14	0.13	0.0380	0.0313
1.5	73.4847	342.36	0.35	0.1023	0.0844
4	120	342.967	0.957	0.2798	0.2307
5.5	140.712	343.387	1.377	0.4026	0.3319
7	158.745	343.55	1.54	0.4503	0.3712
8	169.706	343.711	1.701	0.4974	0.4100
10.75	196.723	344.011	2.001	0.5851	0.4823
11.75	205.67	344.11	2.1	0.6140	0.5061
25.75	304.467	344.57	2.56	0.7485	0.6170
32.75	343.366	344.768	2.758	0.8064	0.6647
49.75	423.202	345.184	3.174	0.9280	0.7650
75.25	520.481	345.354	3.344	0.9777	0.8060
95.25	585.577	345.456	3.446	1.0076	0.8306
122.75	664.756	345.587	3.577	1.0459	0.8621
149.25	733.008	345.738	3.728	1.0900	0.8985
166.25	773.628	345.8	3.79	1.1082	0.9135
192	831.384	345.87	3.86	1.1286	0.9303
218.25	886.397	345.923	3.913	1.1441	0.9431
244.75	938.669	346.002	3.992	1.1672	0.9622
271.25	988.18	346.054	4.044	1.1824	0.9747
291.25	1023.96	346.098	4.088	1.1953	0.9853
313.5	1062.36	346.112	4.102	1.1994	0.9887
337	1101.45	346.132	4.122	1.2052	0.9935
365	1146.3	346.144	4.134	1.2087	0.9964
387	1180.34	346.151	4.141	1.2108	0.9981
409	1213.42	346.159	M_∞=4.149	1.2131	1.0000

$$\text{Moisture uptake} = \frac{W_t - W_0}{W_0} \times 100$$

$$= \frac{342.14 - 342.01}{342.01} \times 100 \;=0.03801$$

$$M_t/M_\infty = \frac{W_t - W_0}{W_\infty - W_0} = \frac{342.14 - 342.01}{346.159 - 342.01} = 0.0313$$

The absorption diffusion coefficient was then calculated using equation

$$\frac{M_t}{M_\infty} = 4\left(\frac{Dt}{\pi(2l)^2}\right)^{1/2}$$

$$D = \frac{\pi \times (2l)^2}{16}\left(\frac{M_t/M_\infty}{\sqrt{t}}\right)^2$$

Where $\frac{M_t/M_\infty}{\sqrt{t}}$ is the slope of the straight line from the plot of M_t/M_∞ versus $\sqrt{t}$ drawn up to $M_t/M_\infty<0.5$ and the units of D are cm^2/sec

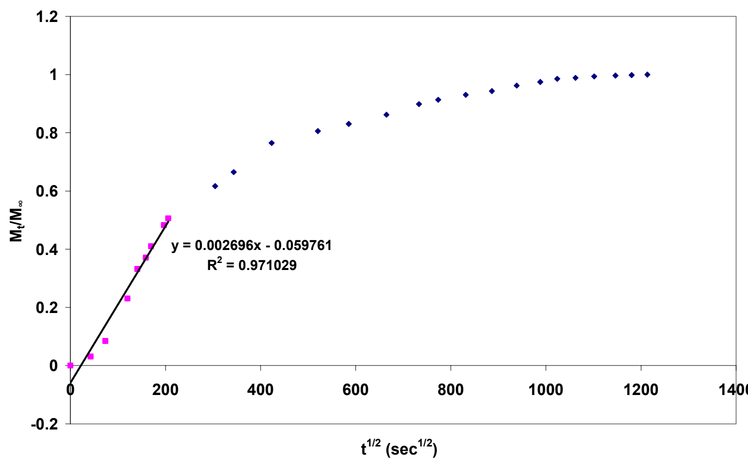

Figure 120 M_t/M_∞ versus $t^{1/2}$ for vinyl ester sample containing 0 wt% Cloisite 10A® at 25 °C during first cycle of absorption

$$\therefore D_a = \frac{\pi \times (0.0488)^2}{16}(0.002696)^2 = 3.4\times10^{-9} cm^2/s$$

B.1.2.Sample Calculation for Desortpion Diffusion Coefficient (D_d)

Initial weight of the sample=346.167 mg

M_t=346.167-342.14=4.157 mg

The desorption diffusion coefficient was then calculated using equation

$$\frac{d}{dt}\{\ln[M_t - M_\infty]\} = -\frac{\pi^2 D}{(2l)^2}$$

$$D = \left(\frac{\ln[M_t - M_\infty]}{t} \right) \frac{(2l)^2}{\pi^2}$$

Where $\left(\frac{\ln[M_t - M_\infty]}{t} \right)$ is the negative slope of the straight line from the plot of $\ln[M_t - M_\infty]$ versus t drawn during the last stages of desorption and the units of D are cm^2/sec

Table 10. Desorption Data of Vinyl ester Samples containing 0 wt% Cloisite 10A at 25 °C During First Cycle of Absorption

Time,sec	W_t,mg	M_t,mg	$\ln(M_t-M_\infty)$
0	346.167	4.157	1.3928
3600	345.989	3.979	1.3476
5400	345.698	3.688	1.2689
7200.005	345.356	3.346	1.1678
9000.01	345.054	3.044	1.0692
12600	344.8	2.79	0.9780
16199.99	344.587	2.577	0.8945
19799.98	344.329	2.319	0.7830
23399.97	344.147	2.137	0.6961
30599.95	343.775	1.765	0.4910
41399.92	343.48	1.47	0.2919
92700	342.692	0.682	-0.5960
182700	342.522	0.512	-0.9650
261900	342.309	0.299	-1.7838
353100	342.223	0.213	-2.5010
452700	342.196	0.186	-2.9004
504300	342.178	0.168	-3.2968
521400	342.165	0.155	-3.7297
609600	342.156	0.146	-4.1997
695100	342.148	0.138	-4.9618

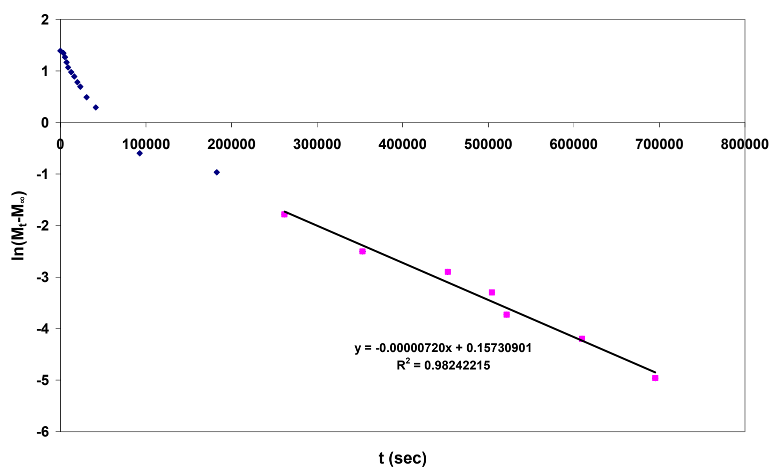

Figure 121 ln (M_t-M_∞) versus t for vinyl ester sample containing 0 wt% Cloisite 10A® at 25 °C during first cycle of desorption

$$\therefore D_d = (0.0000072)\frac{(0.0488)^2}{\pi^2} = 1.736\times10^{-9} cm^2/s$$

B.1.3.Sample Calculation for Sorption Experiments under Stress

Sample average thickness 2*l*=0.111 cm

Table 11. Sorption data of vinyl ester samples containing 0 wt% Cloisite 10A immersed in distilled water subjected to 17% UTS at 25 °C

Time,h	√t, sec$^{1/2}$	W_t,mg	M_t,mg	Moisture uptake,%	M_t/M_∞
0	0	804.631	0	0.0000	0.0000
0.5	42.42641	805	0.369	0.0459	0.0498
	sample-2	688.14			
1.5	73.48469	688.94	0.8	0.1163	0.1080
	sample-3	629.167			
6.25	150	630.632	1.465	0.2328	0.1978
	sample-4	530.92			
9	180	532.654	1.734	0.3266	0.2341
	sample-5	698.485			
12.25	210	700.51	2.025	0.2899	0.2734
	sample-6	668.596			
17.25	249.1987	670.89	2.294	0.3431	0.3097
	sample-7	624.16			
20.25	270	626.854	2.694	0.4316	0.3637
	sample-8	638.521			
23.25	289.3095	641.287	2.766	0.4313	0.3734
	sample-9	630.21			
27.5	314.6427	633.213	3.003	0.4742	0.4054
	sample-10	704.7			
31.75	338.0828	707.889	3.189	0.4505	0.4305
	sample-11	589.414			
36.75	363.7307	593.07	3.656	0.6165	0.4935
	sample-12	650.412			
60.25	465.7252	655.08	4.668	0.7177	0.6301
188.75	824.3179	657.1	6.688	1.0283	0.9028
318.75	1071.214	657.543	7.131	1.0964	0.9626
449.75	1272.439	657.6	7.188	1.1051	0.9703
499.75	1341.305	657.67	7.258	1.1159	0.9798
571.75	1434.678	657.74	7.328	1.1267	0.9892
619.75	1493.687	657.79	7.378	1.1344	0.9960

$$\text{Moisture uptake} = \frac{W_t - W_0}{W_0} \times 100$$

$$= \frac{657.6 - 650.412}{650.412} \times 100 = 1.1051$$

$$M_t/M_\infty = \frac{W_t - W_0}{W_\infty - W_0} = \frac{657.6 - 650.412}{657.82 - 650.412} = 0.9703$$

The absorption diffusion coefficient was then calculated using equation

$$\frac{M_t}{M_\infty} = 4\left(\frac{Dt}{\pi(2l)^2}\right)^{1/2}$$

$$D = \frac{\pi \times (2l)^2}{16}\left(\frac{M_t / M_\infty}{\sqrt{t}}\right)^2$$

Where $\frac{M_t / M_\infty}{\sqrt{t}}$ is the slope of the straight line from the plot of M_t / M_∞ versus √t drawn up to $M_t / M_\infty < 0.5$ and the units of D are cm^2/sec

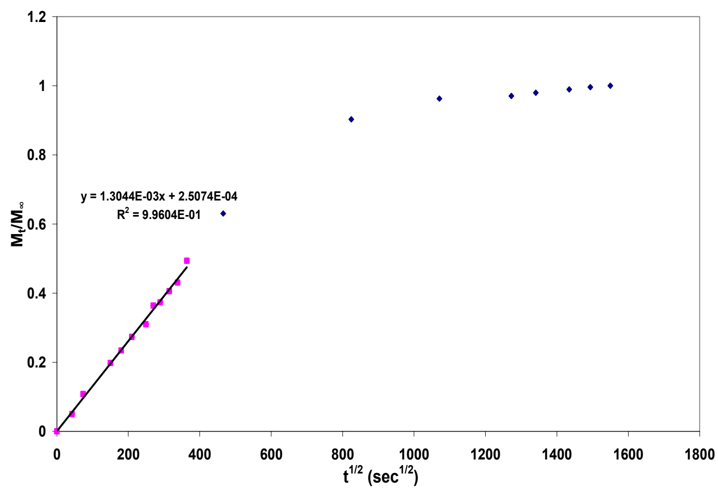

Figure 122 M_t/M_∞ versus t1/2 for vinyl ester sample containing 0 wt% Cloisite 10A® immersed in distilled water and subjected to 17% UTS at 25 °C

$$\therefore D = \frac{\pi \times (0.111)^2}{16}(0.001304)^2 = 4.12 \times 10^{-9} cm^2/s$$

Appendix C

C.1.Results of Cyclic Sorption-Desorption Experiments with Distilled Water at Room Temperature

C.1.1.Experiments with Vinyl ester

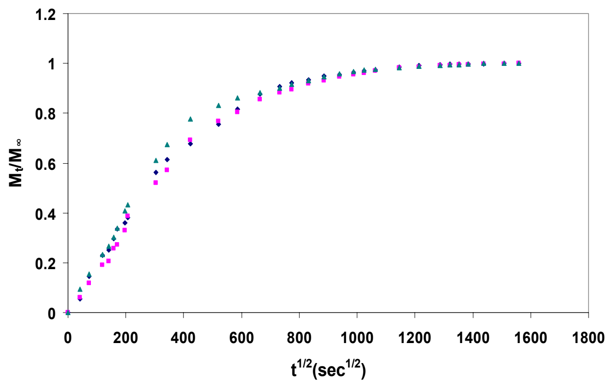

Figure 123 M_t/M_∞ **versus** $t^{1/2}$ **for vinyl ester samples containing 5 wt% Cloisite 10A® at 25 °C during first cycle of absorption**

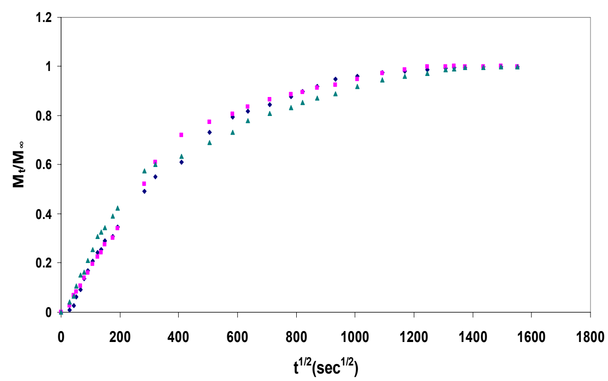

Figure 124 M_t/M_∞ **versus** $t^{1/2}$ **for vinyl ester samples containing 5 wt% Cloisite 10A® at 25 °C during second cycle of absorption**

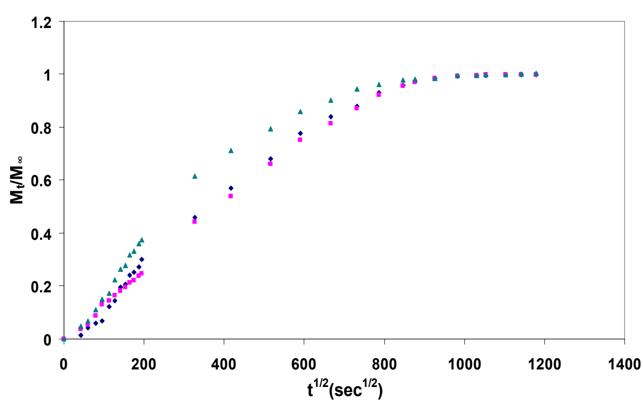

Figure 125 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 5 wt% Cloisite 10A® at 25 °C during third cycle of absorption

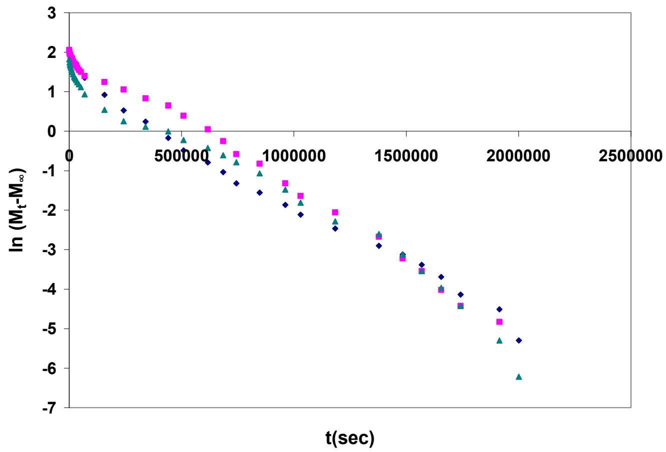

Figure 126 ln (M_t-M_∞) versus t for vinyl ester samples containing 5 wt% Cloisite 10A® at 25 °C during first cycle of desorption

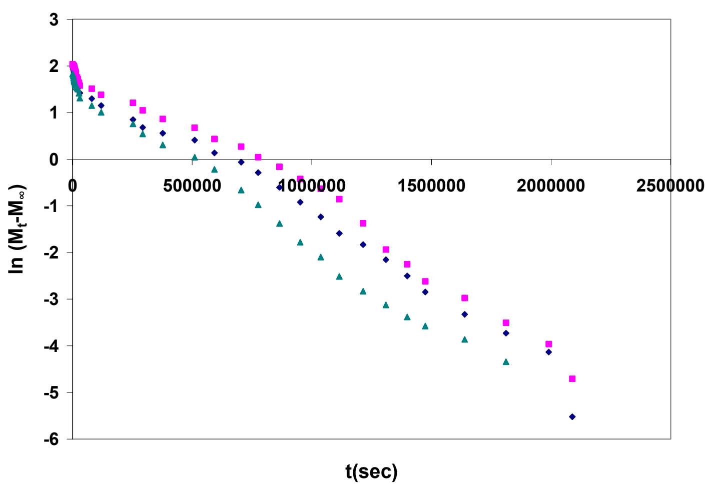

Figure 127 ln (M_t-M_∞) versus t for vinyl ester samples containing 5 wt% Cloisite 10A® at 25 °C during second cycle of desorption

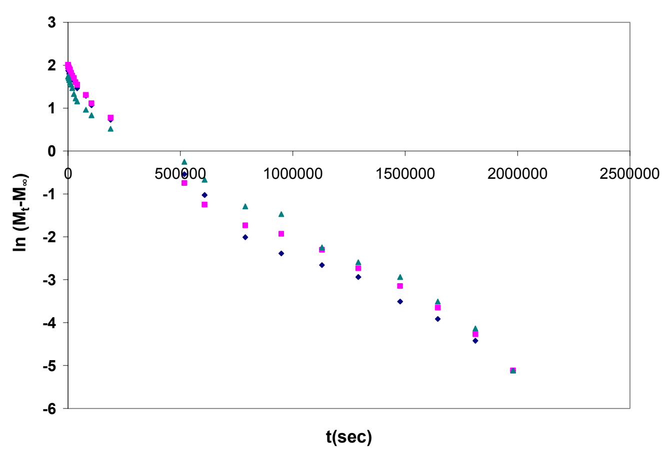

Figure 128 ln (M_t-M_∞) versus t for vinyl ester samples containing 5 wt% Cloisite 10A® at 25 °C during third cycle of desorption

C.1.2.Experiments with Polyester

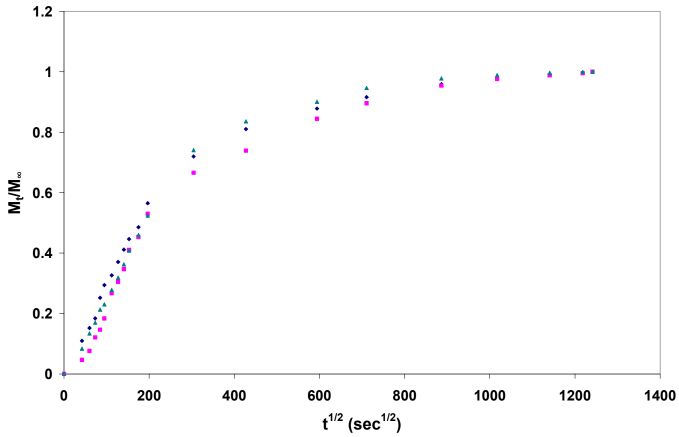

Figure 129 M_t/M_∞ versus $t^{1/2}$ for polyester samples containing 0 wt% Cloisite 10A® at 25 °C during first cycle of absorption

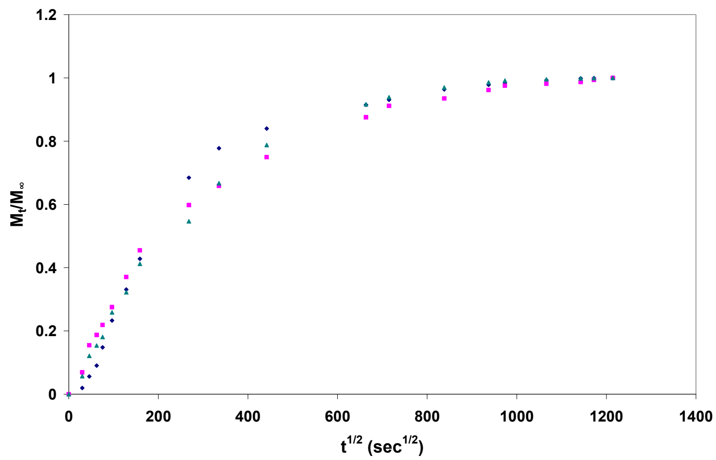

Figure 130 M_t/M_∞ versus $t^{1/2}$ for polyester samples containing 0 wt% Cloisite 10A® at 25 °C during second cycle of absorption

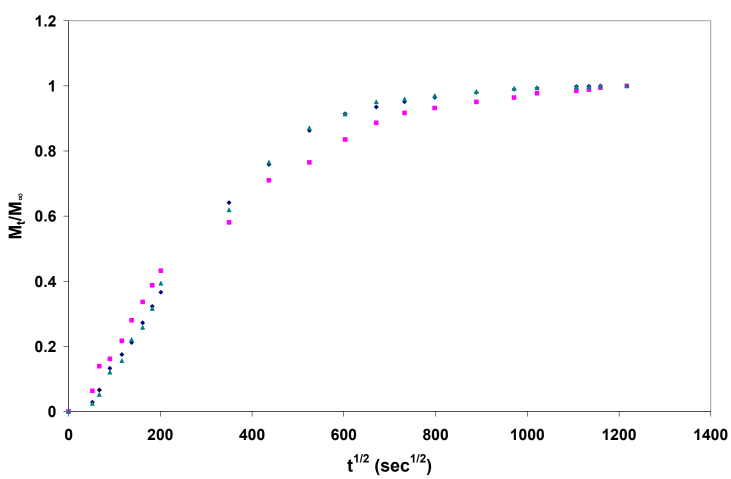

Figure 131 M_t/M_∞ versus $t^{1/2}$ for polyester samples containing 0 wt% Cloisite 10A® at 25 °C during third cycle of absorption

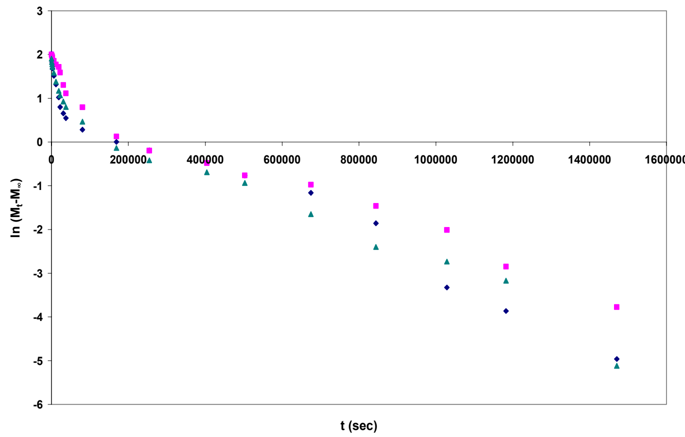

Figure 132 ln (M_t-M_∞) versus t for polyester samples containing 0 wt% Cloisite 10A® at 25 °C during first cycle of desorption

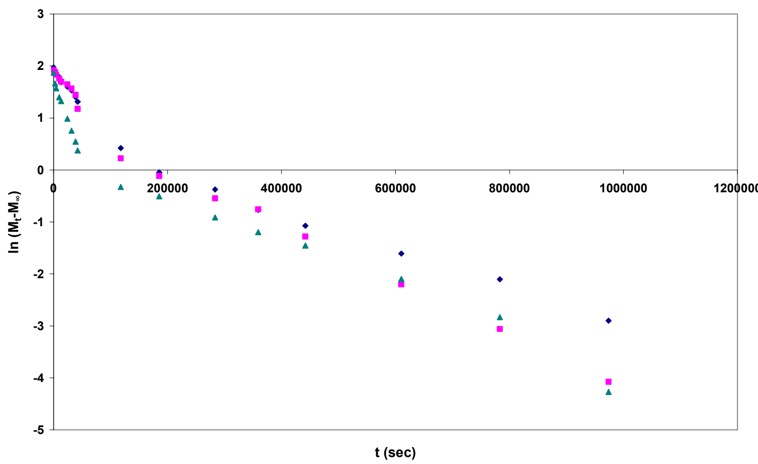

Figure 133 ln (M_t-M_∞) versus t for polyester samples containing 0 wt% Cloisite 10A® at 25 °C during second cycle of desorption

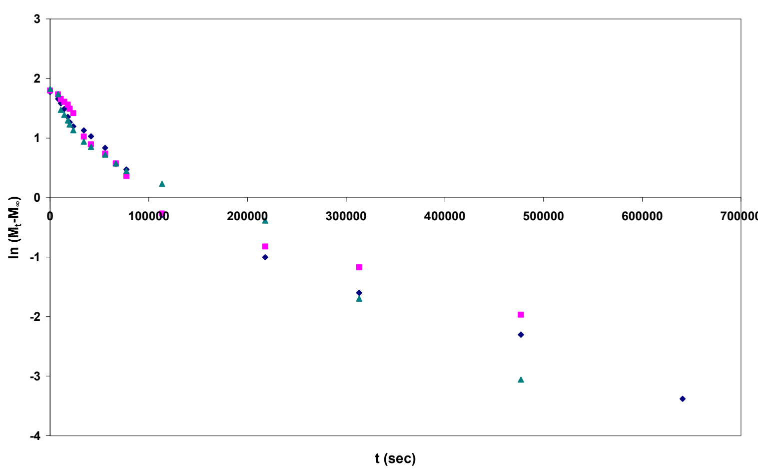

Figure 134 ln (Mt-M∞) versus t for samples containing 0 wt% Cloisite 10A® at 25 °C during third cycle of desorption

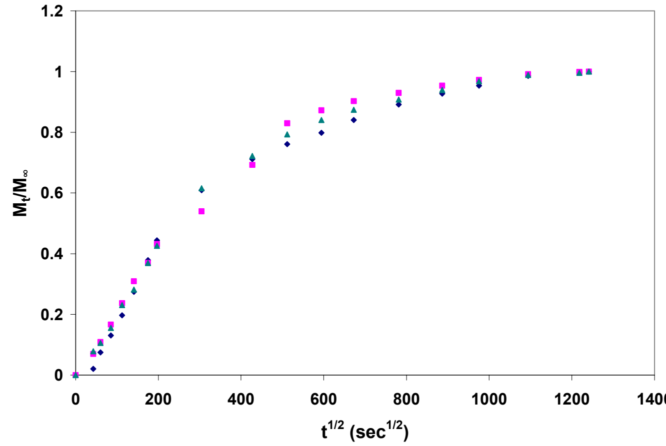

Figure 135 M_t/M_∞ versus $t^{1/2}$ for polyester samples containing 2 wt% Cloisite 10A® at 25 °C during first cycle of absorption

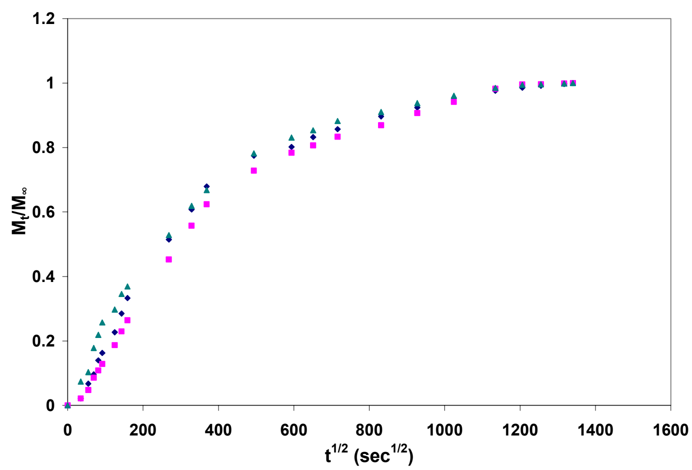

Figure 136 M_t/M_∞ versus $t^{1/2}$ for polyester samples containing 2 wt% Cloisite 10A® at 25 °C during second cycle of absorption

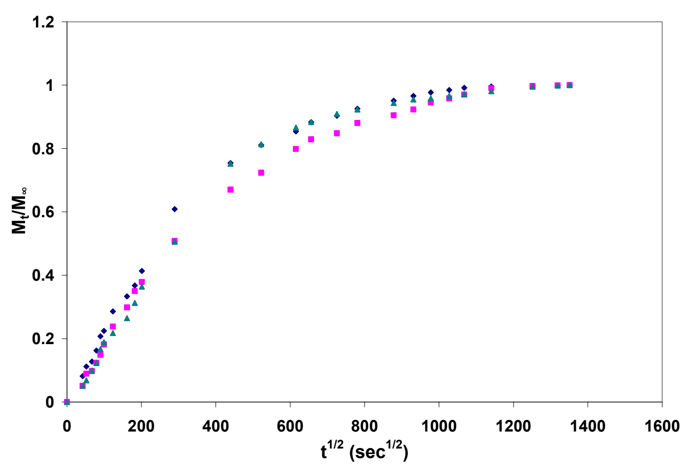

Figure 137 M_t/M_∞ versus $t^{1/2}$ for polyester samples containing 2 wt% Cloisite 10A® at 25 °C during third cycle of absorption

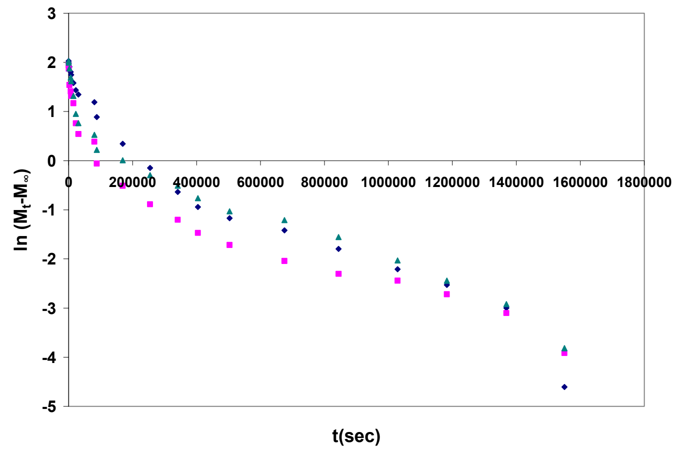

Figure 138 ln (M_t-M_∞) versus t for polyester samples containing 2 wt% Cloisite 10A® at 25 °C during first cycle of desorption

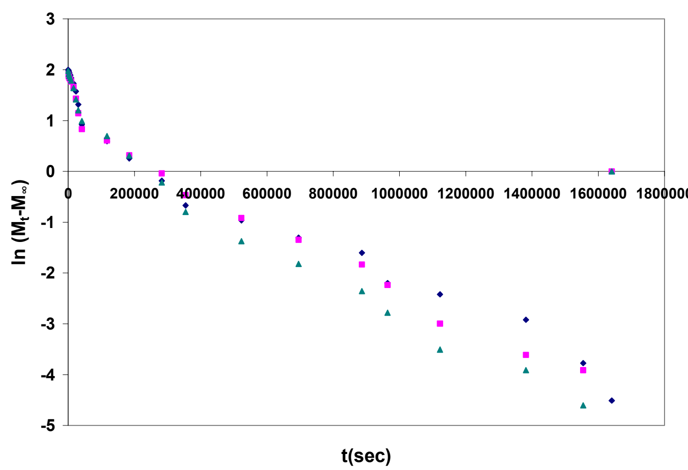

Figure 139 ln (M_t-M_∞) versus t for polyester samples containing 2 wt% Cloisite 10A® at 25 °C during second cycle of desorption

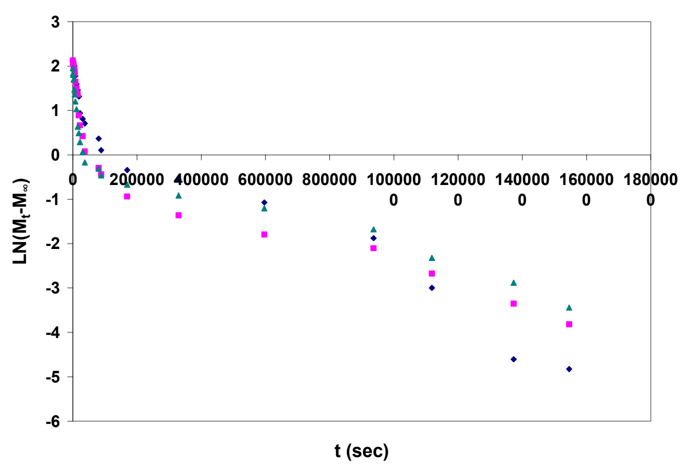

Figure 140 ln (M_t-M_∞) versus t for polyester samples containing 2 wt% Cloisite 10A® at 25 °C during third cycle of desorption

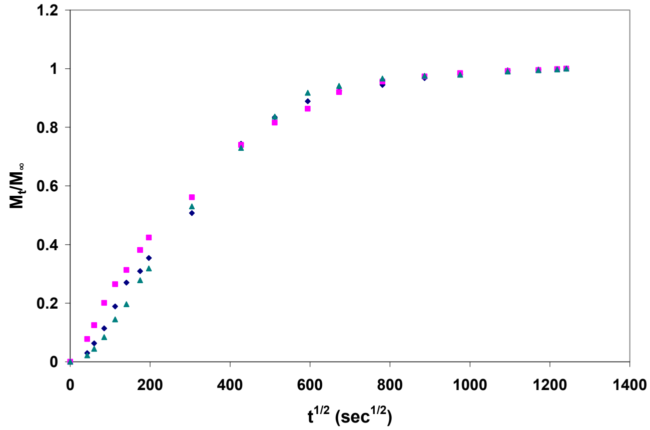

Figure 141 M_t/M_∞ versus $t^{1/2}$ for polyester samples containing 5 wt% Cloisite 10A® at 25 °C during first cycle of absorption

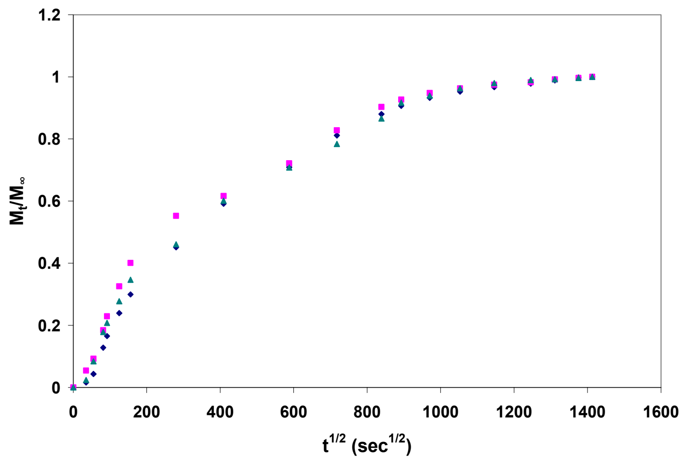

Figure 142 M_t/M_∞ versus $t^{1/2}$ for polyester samples containing 5 wt% Cloisite 10A® at 25 °C during second cycle of absorption

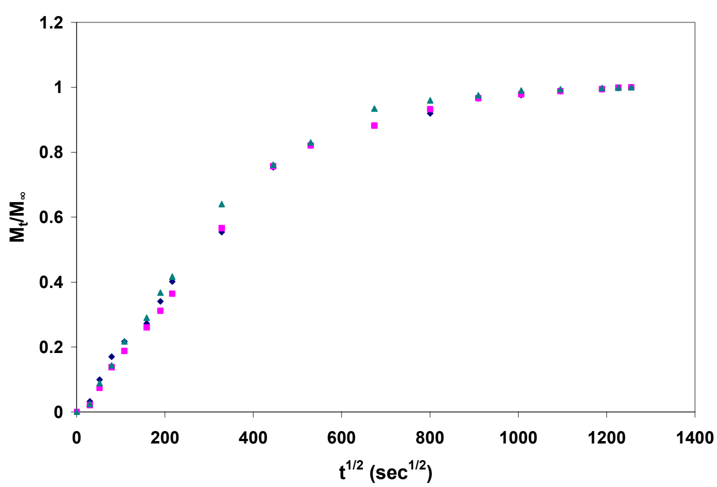

Figure 143 M_t/M_∞ versus $t^{1/2}$ for polyester samples containing 5 wt% Cloisite 10A® at 25 °C during third cycle of absorption

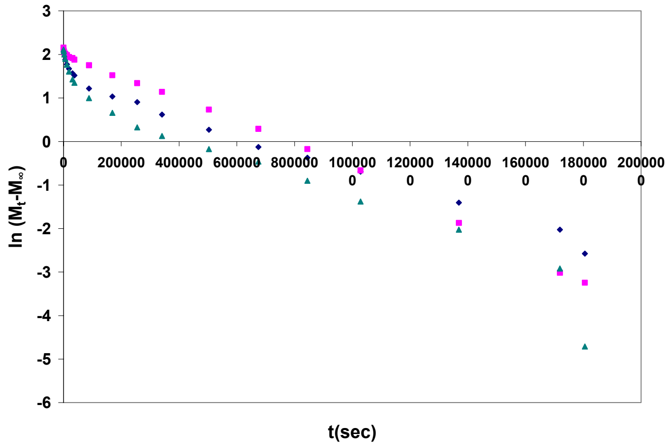

Figure 144 ln (M_t-M_∞) versus t for polyester samples containing 5 wt% Cloisite 10A® at 25 °C during first cycle of desorption

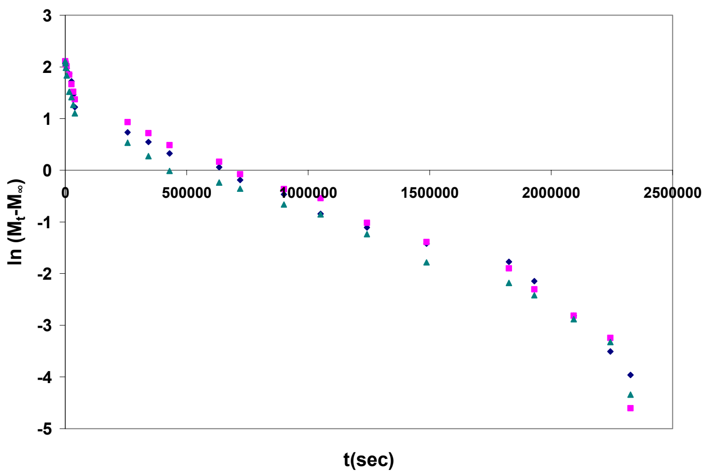

Figure 145 ln (M_t-M_∞) versus t for polyester samples containing 5wt % Cloisite 10A® at 25 °C during second cycle of desorption

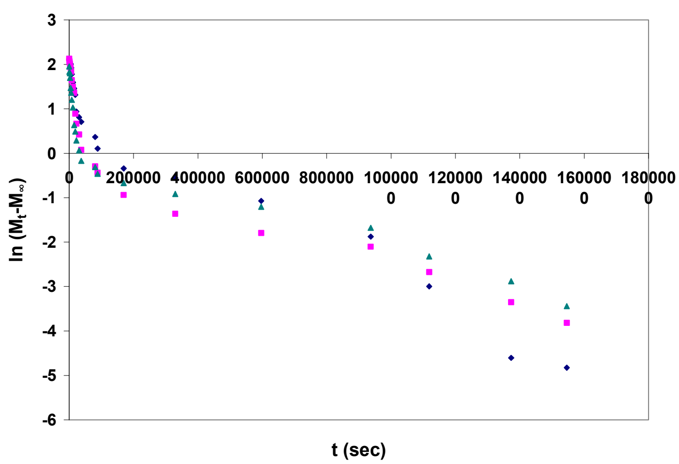

Figure 146 ln (M_t-M_∞) versus t for polyester samples containing 5wt % Cloisite 10A® at 25 °C during third cycle of desorption

C.1.3.Experiments with Epoxy

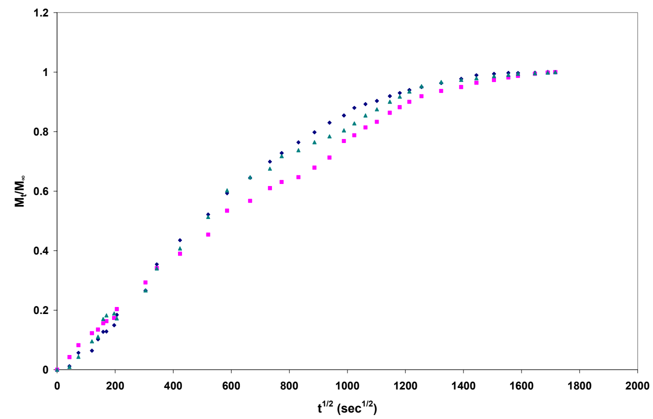

Figure 147 M_t/M_∞ versus $t^{1/2}$ for epoxy samples containing 0 wt% Cloisite 10A® at 25 °C during first cycle of absorption

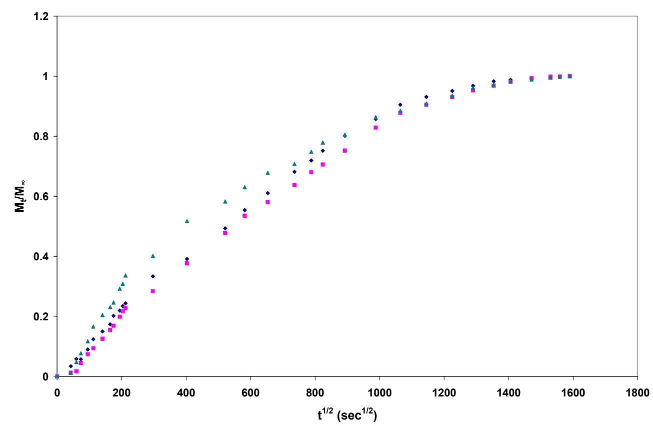

Figure 148 M_t/M_∞ versus $t^{1/2}$ for epoxy samples containing 0 wt% Cloisite 10A® at 25 °C during second cycle of absorption

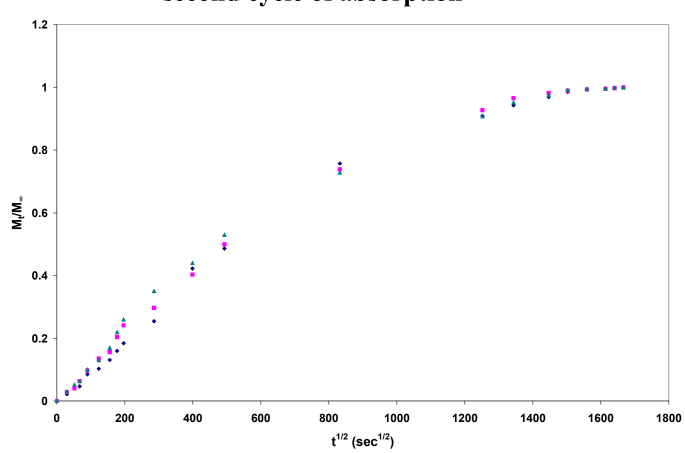

Figure 149 M_t/M_∞ versus $t^{1/2}$ for epoxy samples containing 0 wt% Cloisite 10A® at 25 °C during third cycle of absorption

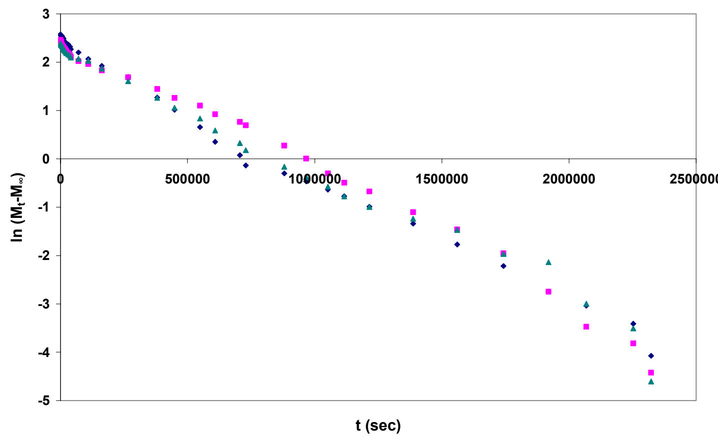

Figure 150 ln (M_t-M_∞) versus t for epoxy samples containing 0 wt% Cloisite 10A® at 25 °C during first cycle of desorption

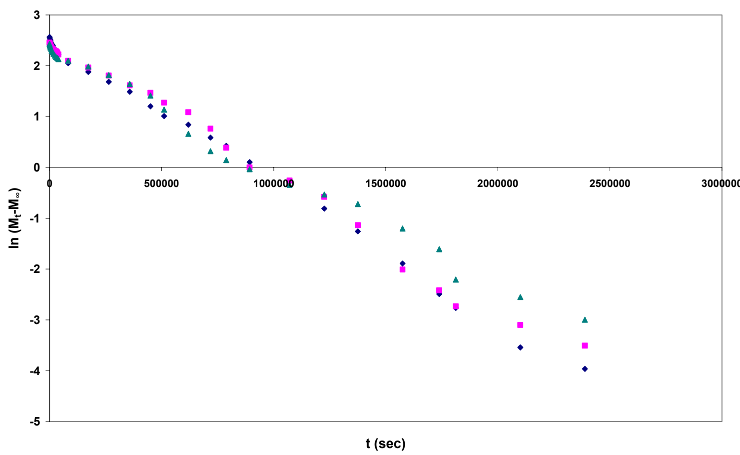

Figure 151 ln (M_t-M_∞) versus t for epoxy samples containing 0 wt% Cloisite 10A® at 25 °C during second cycle of desorption

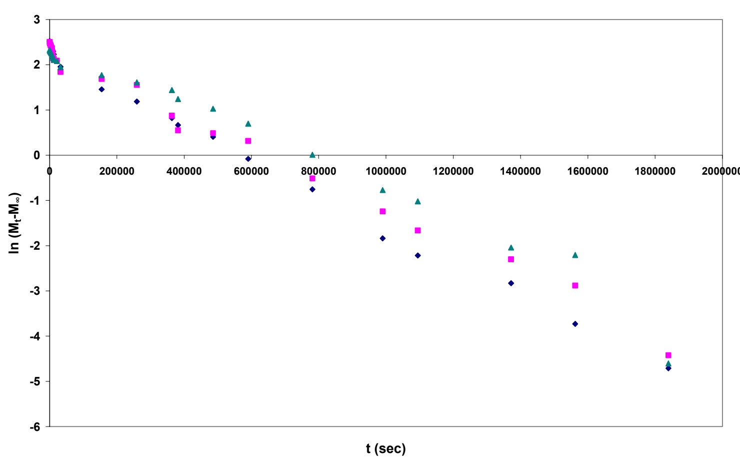

Figure 152 ln (M_t-M_∞) versus t for epoxy samples containing 0 wt% Cloisite 10A® at 25 °C during third cycle of desorption

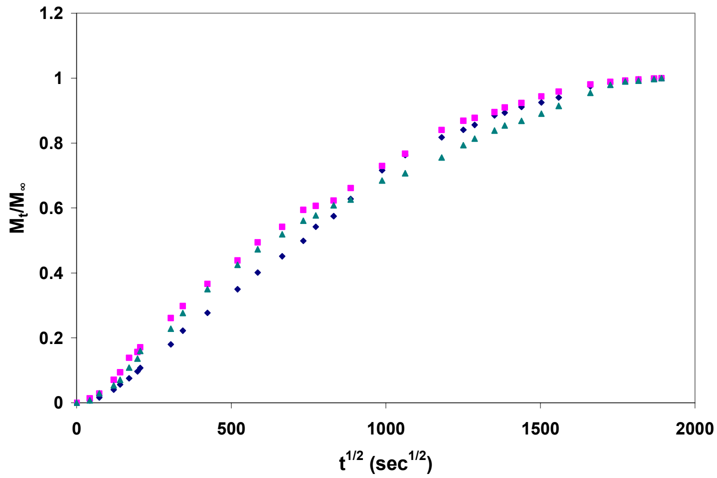

Figure 153 M_t/M_∞ versus $t^{1/2}$ for epoxy samples containing 2 wt% Cloisite 10A® at 25 °C during first cycle of absorption

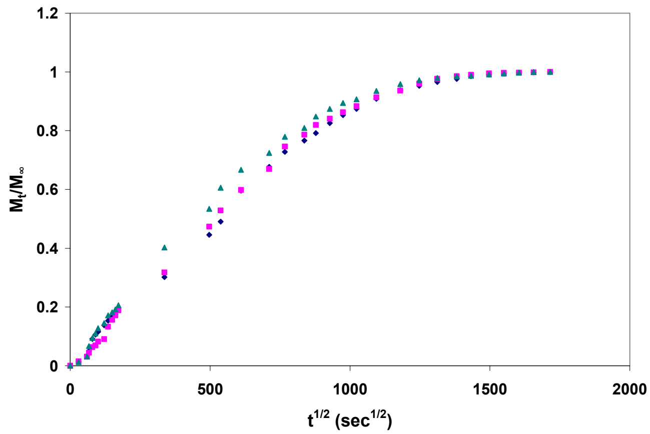

Figure 154 M_t/M_∞ versus $t^{1/2}$ for epoxy samples containing 2 wt% Cloisite 10A® at 25 °C during second cycle of absorption

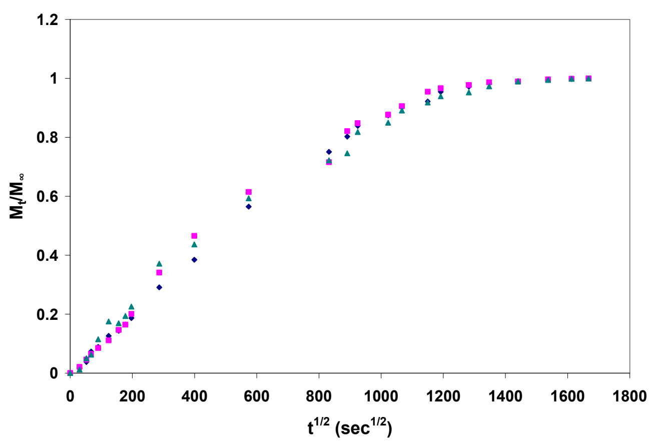

Figure 155 M_t/M_∞ versus $t^{1/2}$ for epoxy samples containing 2 wt% Cloisite 10A® at 25 °C during third cycle of absorption

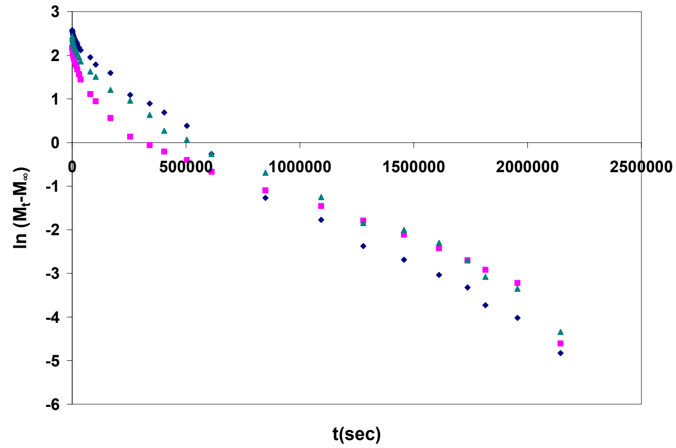

Figure 156 ln (M_t-M_∞) versus t for epoxy samples containing 2 wt% Cloisite 10A® at 25 °C during first cycle of desorption

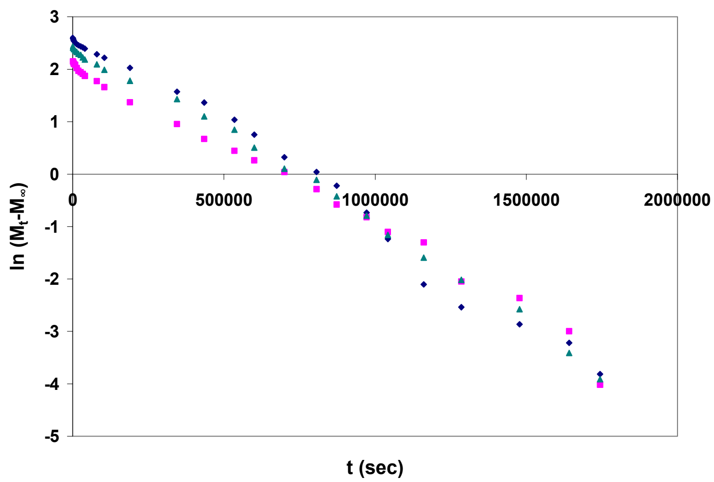

Figure 157 ln (M_t-M_∞) versus t for epoxy samples containing 2 wt% Cloisite 10A® at 25 °C during second cycle of desorption

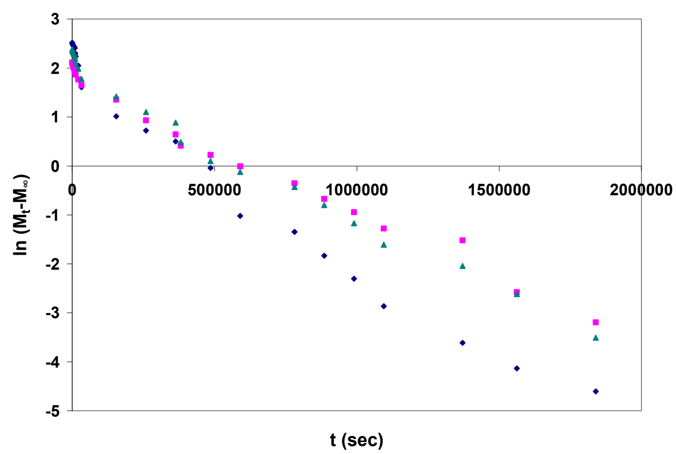

Figure 158 ln (M_t-M_∞) versus t for epoxy samples containing 2 wt% Cloisite 10A® at 25 °C during third cycle of desorption

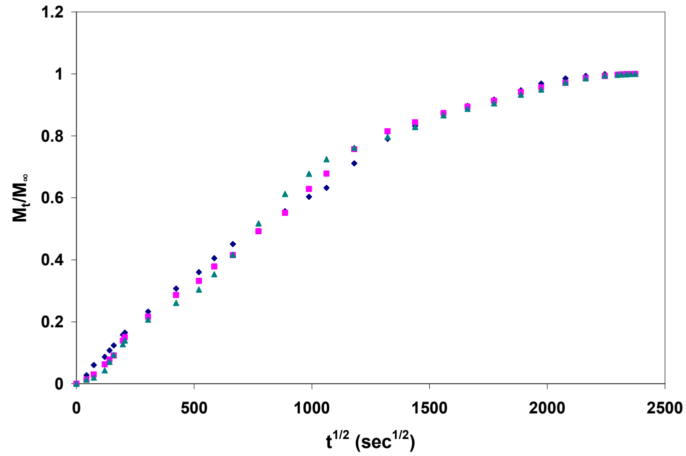

Figure 159 M_t/M_∞ versus $t^{1/2}$ for epoxy samples containing 5 wt% Cloisite 10A® at 25 °C during first cycle of absorption

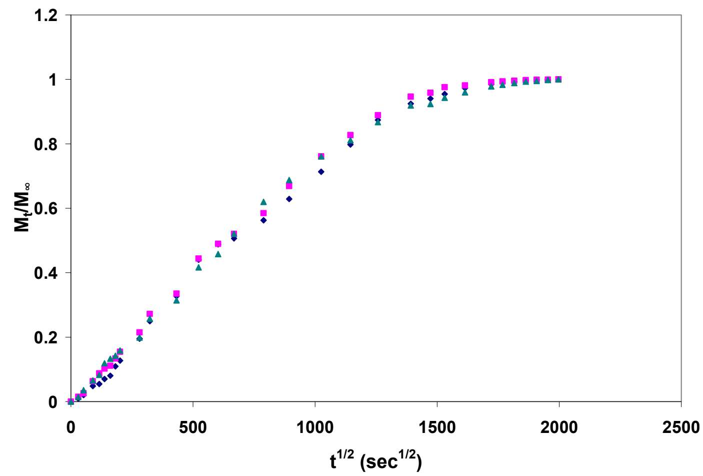

Figure 160 M_t/M_∞ versus $t^{1/2}$ for epoxy samples containing 5 wt% Cloisite 10A® at 25 °C during second cycle of absorption

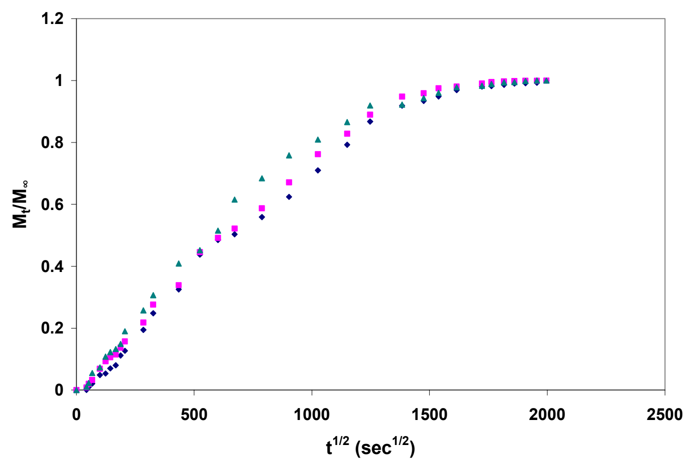

Figure 161 M_t/M_∞ versus $t^{1/2}$ for epoxy samples containing 5 wt% Cloisite 10A® at 25 °C during third cycle of absorption

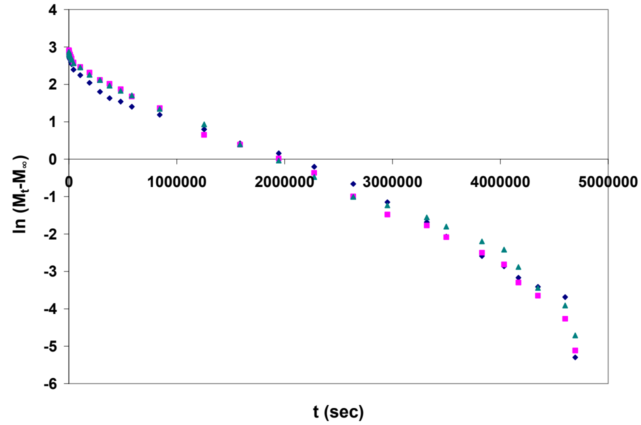

Figure 162 ln (M_t-M_∞) versus t for epoxy samples containing 5 wt% Cloisite 10A® at 25 °C during first cycle of desorption

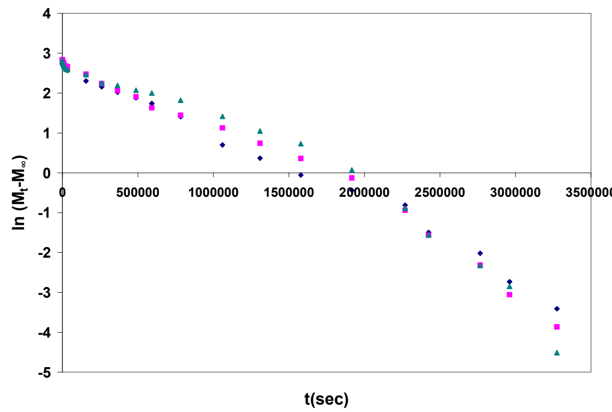

Figure 163 ln (M_t-M_∞) versus t for epoxy samples containing 5 wt% Cloisite 10A® at 25 °C during second cycle of desorption

C.2.Results of Sorption Experiments with Neat and Clay loaded Vinyl ester Samples at Different Relative Humidities (%RH)

C.2.1.Experiments at 60%RH

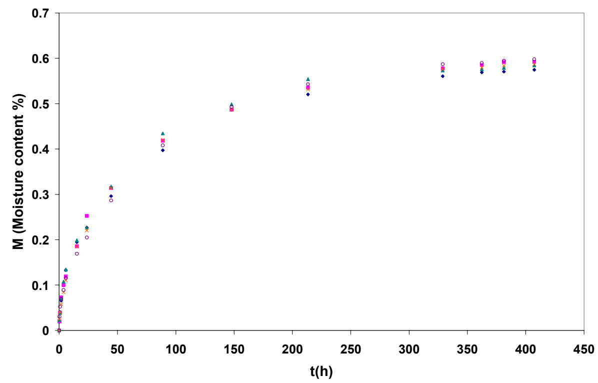

Figure 164 Moisture content versus t for neat vinyl ester samples exposed to 60%RH at 25 °C

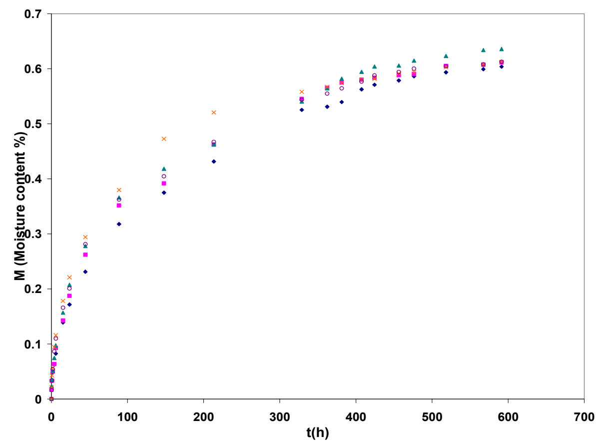

Figure 165 Moisture content versus t for 2 wt% clay loaded vinyl ester samples exposed to 60%RH at 25 °C

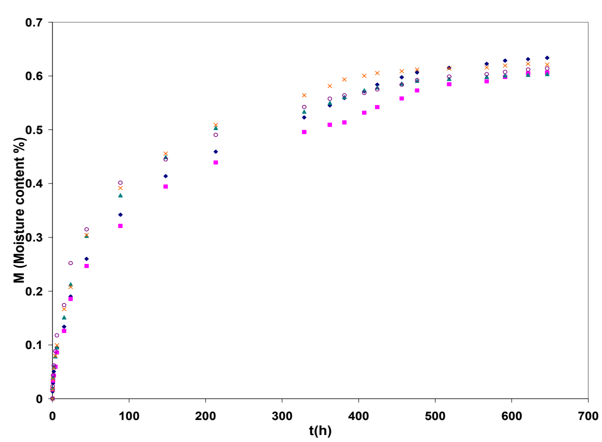

Figure 166 Moisture content versus t for 5 wt% clay loaded vinyl ester samples exposed to 60%RH at 25 °C

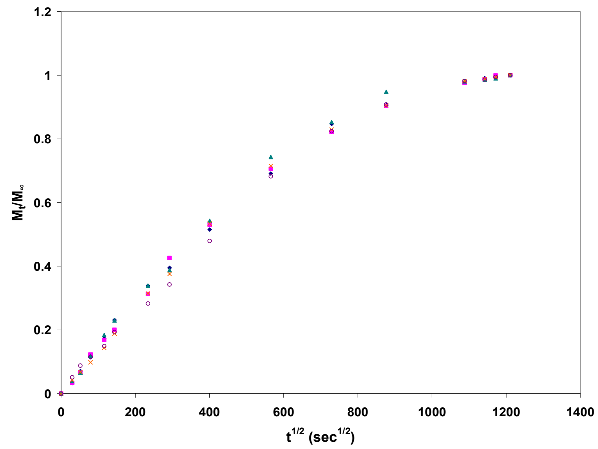

Figure 167 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 0 wt% Cloisite 10A® exposed to 60% RH

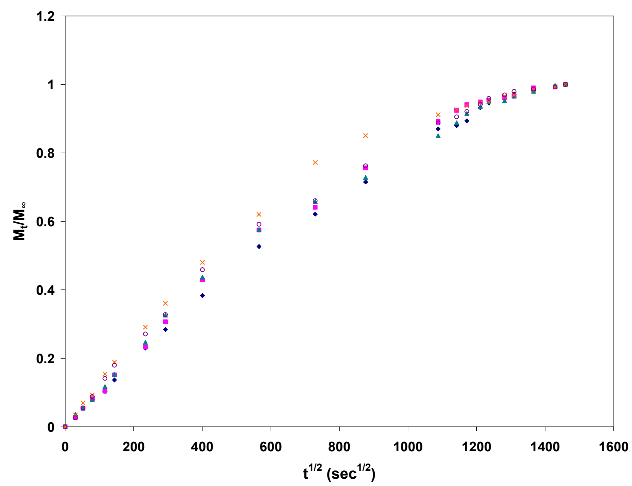

Figure 168 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 2 wt% Cloisite 10A® exposed to 60% RH

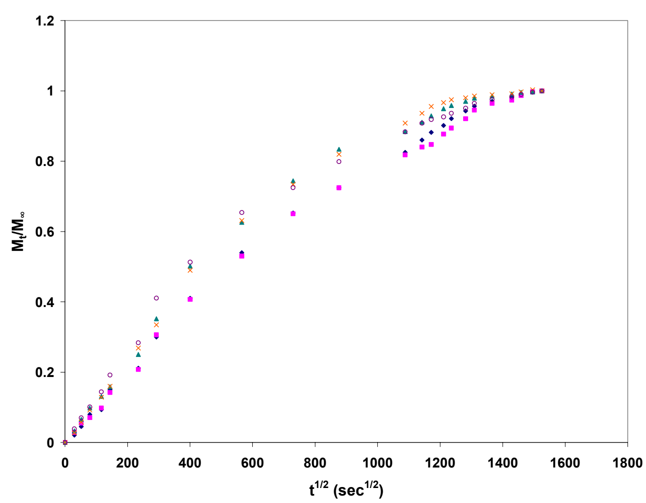

Figure 169 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 5 wt% Cloisite 10A® exposed to 60% RH

C.2.2.Experiments at 70%RH

Figure 170 Moisture content versus t for neat vinyl ester samples exposed to 70%RH at 25 °C

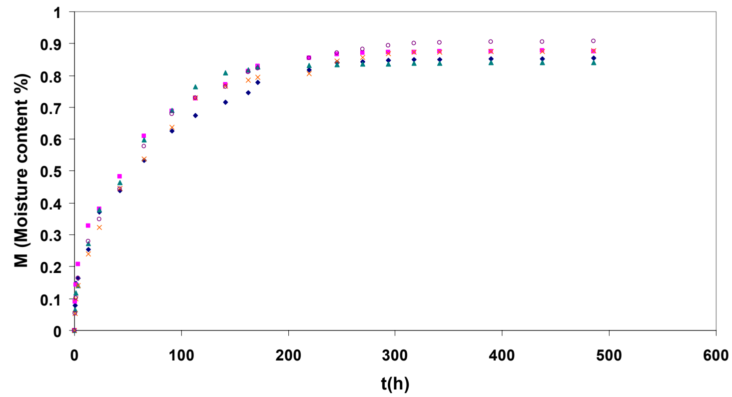

Figure 171 Moisture content versus t for 2 wt% clay loaded vinyl ester samples exposed to 70%RH at 25 °C

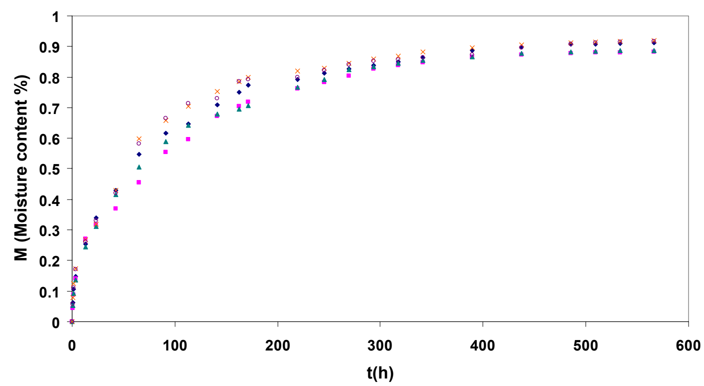

Figure 172 Moisture content versus t for 5 wt% clay loaded vinyl ester samples exposed to 70%RH at 25 °C

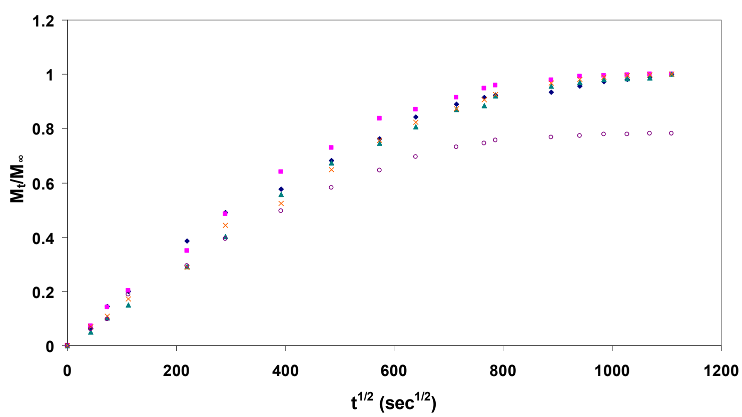

Figure 173 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 0 wt% Cloisite 10A® exposed to 70% RH

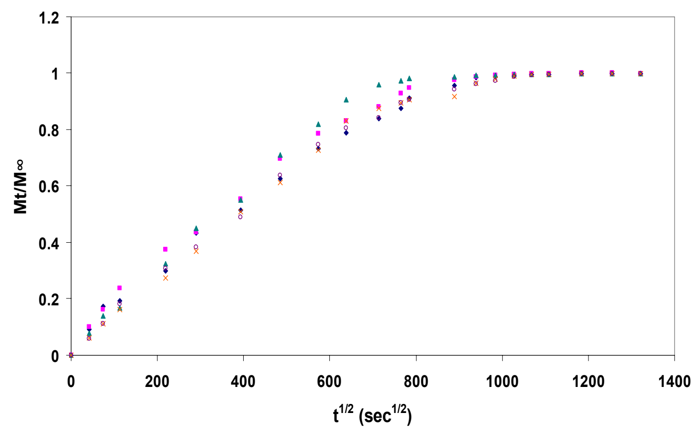

Figure 174 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 2 wt% Cloisite 10A® exposed to 70% RH

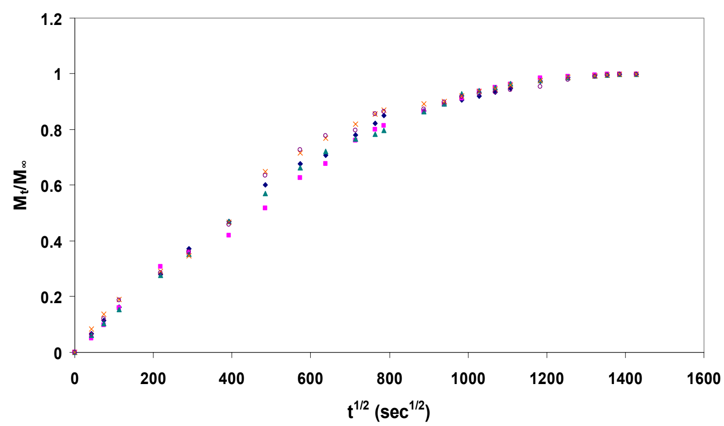

Figure 175 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 5 wt% Cloisite 10A® exposed to 70% RH

C.2.3.Experiments at 80%RH

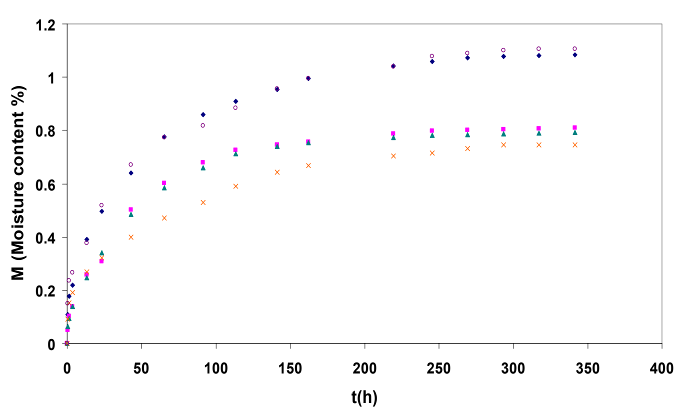

Figure 176 Moisture content versus t for neat vinyl ester samples exposed to 80%RH at 25 °C

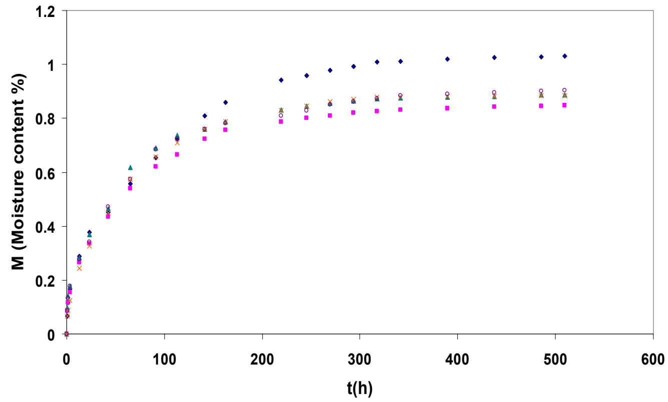

Figure 177 Moisture content versus t for 2 wt% clay loaded vinyl ester samples exposed to 80%RH at 25 °C

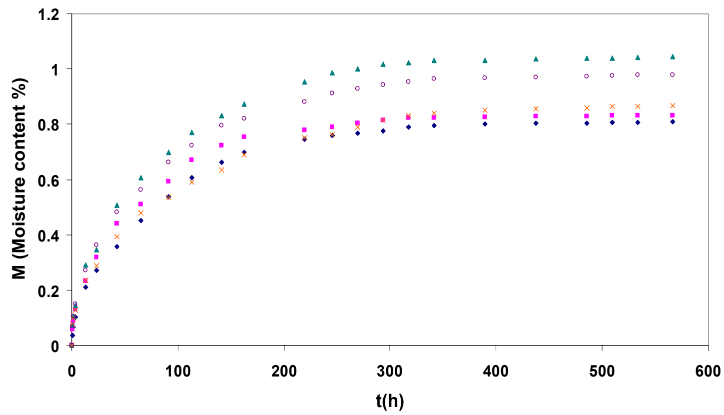

Figure 178 Moisture content versus t for 5 wt% clay loaded vinyl ester samples exposed to 80%RH at 25 °C

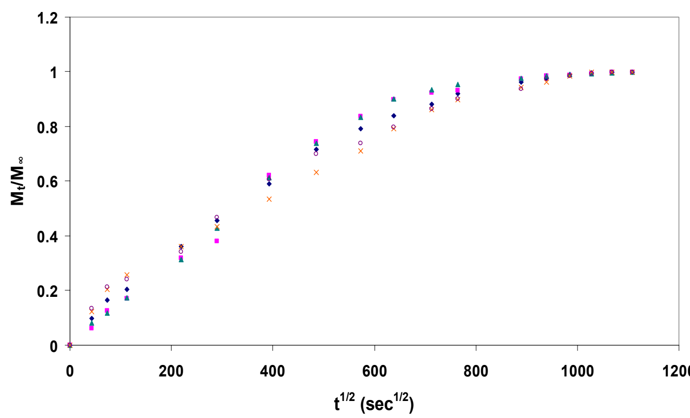

Figure 179 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 0 wt% Cloisite 10A® exposed to 80% RH

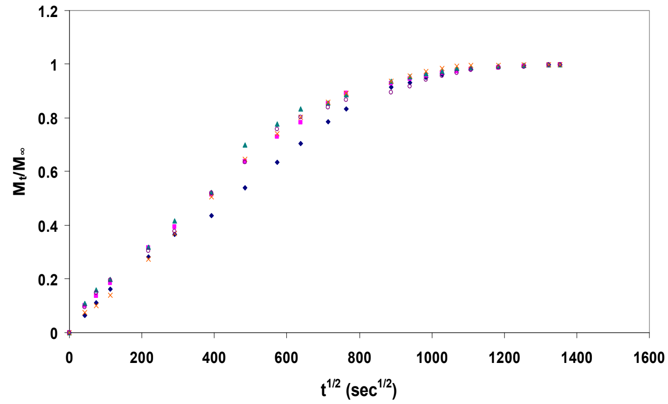

Figure 180 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 2 wt% Cloisite 10A® exposed to 80% RH

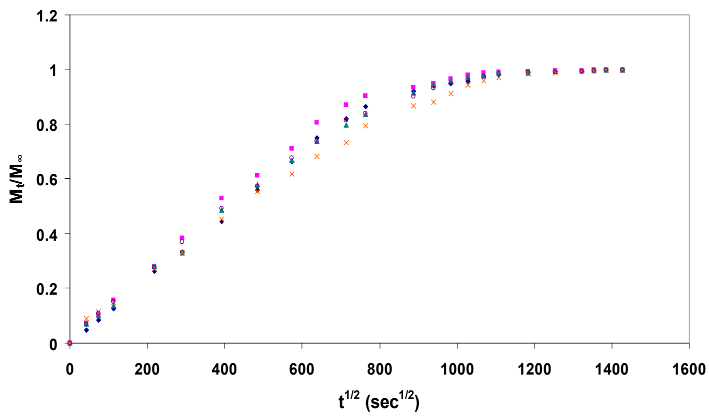

Figure 181 M_t/M_∞ versus $t^{1/2}$ for vinyl ester samples containing 5 wt% Cloisite 10A® exposed to 80% RH

Appendix D

Raw Data

Table 12. Sorption Data of Vinyl ester Samples containing 0 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

					sample-1		2*l* =0.0488 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0	342.01	0.0000	0.0000		0	342.138	0.037425806	0		0	342.24	0.067249496	0
0.5	342.14	0.0380	0.0313		0.5	342.298	0.084208064	0.04		0.25	342.352	0.099997076	0.0287
1.5	342.36	0.1023	0.0844		1	342.411	0.117248034	0.068		0.5	342.461	0.131867489	0.0567
4	342.967	0.2798	0.2307		1.5	342.551	0.158182509	0.103		1.25	342.765	0.220753779	0.1347
5.5	343.387	0.4026	0.3319		2	342.685	0.19736265	0.137		1.5	342.911	0.263442589	0.1721
7	343.55	0.4503	0.3712		2.5	342.756	0.218122277	0.155		2	343.065	0.308470513	0.2116
8	343.711	0.4974	0.4100		3	342.843	0.24356013	0.176		2.5	343.248	0.36197772	0.2586
10.75	344.011	0.5851	0.4823		4	343.012	0.29297389	0.219		3	343.349	0.39150902	0.2845
11.75	344.11	0.6140	0.5061		5	343.138	0.329814918	0.25		4.333	343.581	0.459343294	0.344
25.75	344.57	0.7485	0.6170		7	343.342	0.389462296	0.301		5.333	343.764	0.512850501	0.391
32.75	344.768	0.8064	0.6647		27	344.234	0.650273384	0.525		6.5	343.892	0.550276308	0.4238
49.75	345.184	0.9280	0.7650		43	344.632	0.76664425	0.624		7.5	343.951	0.567527265	0.4389
75.25	345.354	0.9777	0.8060		54.8333	344.843	0.828338353	0.677		25.25	344.511	0.731265168	0.5826
95.25	345.456	1.0076	0.8306		57.8333	345.037	0.88506184	0.726		42.75	344.943	0.857577264	0.6934
122.75	345.587	1.0459	0.8621		66.0833	345.123	0.910207304	0.747		70	345.332	0.971316628	0.7932
149.25	345.738	1.0900	0.8985		76.8333	345.218	0.937984269	0.771		91.75	345.552	1.035642233	0.8497
166.25	345.8	1.1082	0.9135		91.5833	345.417	0.996169703	0.821		119.7	345.774	1.100552615	0.9066
192	345.87	1.1286	0.9303		120.333	345.698	1.078331043	0.891		143	345.921	1.143533815	0.9443
218.25	345.923	1.1441	0.9431		152.083	345.921	1.143533815	0.947		162.5	346.039	1.17803573	0.9746
244.75	346.002	1.1672	0.9622		171.083	346.021	1.172772726	0.972		197.3	346.098	1.195286688	0.9897
271.25	346.054	1.1824	0.9747		198.833	346.068	1.186515014	0.984		219.2	346.111	1.199087746	0.9931
291.25	346.098	1.1953	0.9853		217.833	346.112	1.199380135	0.995		237.2	346.132	1.205227917	0.9985
313.5	346.112	1.1994	0.9887		238.833	346.121	1.202011637	0.997		264.2	346.138	1.206982252	1
337	346.132	1.2052	0.9935		267.833	346.127	1.203765972	0.998					
365	346.144	1.2087	0.9964		287.333	346.133	1.205520306	1					
387	346.151	1.2108	0.9981										

					sample-2		2l =0.0588 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0	394.85	0.0000	0.0000		0	395.154	0.07699263	0		0	395.324	0.120045587	0
0.5	395.17	0.0810	0.0666		0.5	395.215	0.092440167	0.013		0.25	395.483	0.160314043	0.0362
1.5	395.789	0.2378	0.1954		1	395.279	0.108648854	0.028		0.5	395.673	0.208433582	0.0795
4	396.33	0.3748	0.3079		1.5	395.386	0.135747752	0.051		1.25	395.888	0.26288464	0.1284
5.5	396.532	0.4260	0.3500		2	395.468	0.156515132	0.069		1.5	396.112	0.319615044	0.1795
7	396.723	0.4744	0.3897		2.5	395.564	0.180828163	0.091		2	396.342	0.377865012	0.2318
8	396.886	0.5156	0.4236		3	395.638	0.199569457	0.107		2.5	396.564	0.434088895	0.2824
10.75	397.15	0.5825	0.4786		4	395.802	0.241104217	0.143		3	396.687	0.465239965	0.3104
11.75	397.243	0.6061	0.4979		5	395.961	0.281372673	0.178		4.333	396.765	0.484994302	0.3282
25.75	398.126	0.8297	0.6816		7	396.131	0.324426998	0.216		5.333	396.856	0.508041028	0.3489
32.75	398.334	0.8824	0.7249		27	397.265	0.611624668	0.466		6.5	396.956	0.533367101	0.3717
49.75	398.611	0.9525	0.7826		43	397.689	0.719007218	0.56		7.5	397.033	0.552868178	0.3892
75.25	398.812	1.0034	0.8244		54.8333	397.9	0.772445232	0.607		25.25	397.711	0.724578954	0.5436
95.25	398.967	1.0427	0.8566		57.8333	398	0.797771306	0.629		42.75	398.209	0.850702799	0.657
122.75	399.213	1.1050	0.9078		66.0833	398.331	0.881600608	0.702		70	398.684	0.971001646	0.7652
149.25	399.268	1.1189	0.9193		76.8333	398.615	0.953526656	0.765		91.75	398.995	1.049765734	0.836
166.25	399.301	1.1273	0.9261		91.5833	398.829	1.007724452	0.812		119.7	399.269	1.119159174	0.8984
192	399.358	1.1417	0.9380		120.333	399.349	1.139420033	0.927		143	399.44	1.16246676	0.9374
218.25	399.467	1.1693	0.9607		152.083	399.499	1.177409143	0.96		162.5	399.571	1.195643915	0.9672
244.75	399.513	1.1810	0.9702		171.083	399.618	1.20754717	0.986		197.3	399.679	1.222996074	0.9918
271.25	399.567	1.1946	0.9815		198.833	399.645	1.21438521	0.992		219.2	399.687	1.22502216	0.9936
291.25	399.589	1.2002	0.9861		217.833	399.656	1.217171078	0.994		237.2	399.699	1.228061289	0.9964
313.5	399.598	1.2025	0.9879		238.833	399.673	1.22147651	0.998		264.2	399.715	1.232113461	1
337	399.615	1.2068	0.9915		267.833	399.666	1.219703685	0.997					
365	399.634	1.2116	0.9954		287.333	399.681	1.223502596	1					
387	399.639	1.2129	0.9965										
409	399.656	1.2172	1.0000										

					sample-3		2*l* =0.0588 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞
0	397.85	0.0000	0.0000		0	398.164	0.078924218	0		0	398.327	0.119894433	0
0.5	398.37	0.1307	0.1032		0.5	398.223	0.093753927	0.012		0.25	398.387	0.134975493	0.0132
1.5	398.656	0.2026	0.1600		1	398.345	0.124418751	0.038		0.5	398.498	0.162875456	0.0377
4	399.175	0.3330	0.2629		1.5	398.564	0.179464622	0.084		1.25	398.564	0.179464622	0.0522
5.5	399.466	0.4062	0.3207		2	398.734	0.222194294	0.12		1.5	398.712	0.216664572	0.0849
7	399.824	0.4962	0.3917		2.5	398.856	0.252859118	0.146		2	398.803	0.239537514	0.1049
8	400.104	0.5665	0.4473		3	398.978	0.283523941	0.172		2.5	398.956	0.277994219	0.1386
10.75	400.483	0.6618	0.5225		4	399.164	0.330275229	0.211		3	399.136	0.323237401	0.1783
11.75	400.587	0.6879	0.5432		5	399.345	0.375769762	0.249		4.333	399.277	0.358677894	0.2094
25.75	401.312	0.8702	0.6870		7	399.567	0.431569687	0.296		5.333	399.399	0.389342717	0.2363
32.75	401.543	0.9282	0.7329		27	400.269	0.608018097	0.444		6.5	399.562	0.430312932	0.2722
49.75	401.786	0.9893	0.7811		43	400.884	0.762598969	0.574		7.5	399.638	0.449415609	0.289
75.25	402.113	1.0715	0.8460		54.8333	401.345	0.878471786	0.671		25.25	400.564	0.682166646	0.4931
95.25	402.289	1.1157	0.8809		57.8333	401.546	0.928993339	0.713		42.75	401.243	0.852833983	0.6427
122.75	402.412	1.1467	0.9053		66.0833	401.879	1.012693226	0.784		70	401.646	0.95412844	0.7315
149.25	402.578	1.1884	0.9383		76.8333	402.187	1.090109338	0.849		91.75	402.125	1.074525575	0.8371
166.25	402.665	1.2103	0.9555		91.5833	402.52	1.173809225	0.919		119.7	402.498	1.168279502	0.9193
192	402.723	1.2248	0.9671		120.333	402.775	1.237903733	0.973		143	402.672	1.212014578	0.9577
218.25	402.743	1.2299	0.9710		152.083	402.854	1.257760462	0.989		162.5	402.745	1.230363202	0.9738
244.75	402.759	1.2339	0.9742		171.083	402.861	1.25951992	0.991		197.3	402.829	1.251476687	0.9923
271.25	402.772	1.2371	0.9768		198.833	402.888	1.266306397	0.996		219.2	402.856	1.258263165	0.9982
291.25	402.802	1.2447	0.9827		217.833	402.872	1.262284781	0.993		237.2	402.873	1.262536132	1.002
313.5	402.823	1.2500	0.9869		238.833	402.884	1.265300993	0.996		264.2	402.864	1.260273973	1
337	402.834	1.2527	0.9891		267.833	402.891	1.26706045	0.997					
365	402.856	1.2583	0.9935		287.333	402.905	1.270579364	1					
387	402.876	1.2633	0.9974										
409	402.889	1.2666	1.0000										

Table 13. Desorption Data of Vinyl ester Samples containing 0 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

				sample-1		2*l* =0.0488 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)
0	346.167	1.2155	1.3928	0	346.138	1.2070	1.36046	0	346.144	1.2087	1.3271
1	345.989	1.1634	1.3476	0.25	345.92	1.1432	1.30291	0.25	345.958	1.1544	1.2765
1.5	345.698	1.0783	1.2689	0.5	345.659	1.0669	1.22935	0.75	345.653	1.0652	1.1875
2	345.356	0.9783	1.1678	1	345.264	0.9514	1.10658	1.25	345.375	0.9839	1.0989
2.5	345.054	0.8900	1.0692	1.5	344.869	0.8359	0.9666	2	345.16	0.9210	1.0246
3.5	344.8	0.8158	0.9780	2	344.536	0.7386	0.83117	2.75	344.831	0.8248	0.8989
4.5	344.587	0.7535	0.8945	3	344.212	0.6438	0.67905	4	344.626	0.7649	0.8118
5.5	344.329	0.6781	0.7830	4	344.02	0.5877	0.57661	5	344.492	0.7257	0.7505
6.5	344.147	0.6248	0.6961	5	343.824	0.5304	0.45995	6.5	344.351	0.6845	0.6816
8.5	343.775	0.5161	0.4910	6	343.571	0.4564	0.28593	8	344.209	0.6430	0.607
11.5	343.48	0.4298	0.2919	8.25	343.188	0.3444	-0.0534	9.5	343.905	0.5541	0.4259
25.75	342.692	0.1994	-0.5960	10	343.012	0.2930	-0.2588	11	343.983	0.5769	0.4756
50.75	342.522	0.1497	-0.9650	22	342.765	0.2208	-0.6444	25	343.304	0.3784	-0.0726
72.75	342.309	0.0874	-1.7838	28.5	342.632	0.1819	-0.9365	58	342.834	0.2409	-0.7765
98.083	342.223	0.0623	-2.5010	46.5	342.489	0.1401	-1.3903	72.75	342.657	0.1892	-1.2623
125.75	342.196	0.0544	-2.9004	70.5	342.385	0.1096	-1.931	100.5	342.567	0.1629	-1.6451
140.08	342.178	0.0491	-3.2968	94.25	342.324	0.0918	-2.4769	127.7	342.487	0.1395	-2.1804
144.83	342.165	0.0453	-3.7297	112	342.3	0.0848	-2.8134	148.7	342.454	0.1298	-2.5257
169.33	342.156	0.0427	-4.1997	139.5	342.275	0.0775	-3.3524	171.8	342.421	0.1202	-3.0576
193.08	342.148	0.0403	-4.9618	169.75	342.265	0.0746	-3.6889	194.5	342.4	0.1140	-3.6497
218.08	342.141	0.0383	0.9768	187.25	342.258	0.0725	-4.0174	224	342.387	0.1102	-4.3428
				210.25	342.25	0.0702	-4.6052	248	342.38	0.1082	-5.116
				235.5	342.248	0.0696	-4.8283	272	342.377	0.1073	-5.8091
				254.5	342.24	0.0672		296	342.374	0.1064	

				sample-2		2*l* =0.0588 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)
0	399.661	1.2184	1.5047	0	399.675	1.2220	1.469	0	399.702	1.2288	1.4495
1	399.402	1.1528	1.4455	0.25	399.425	1.1587	1.41	0.25	399.472	1.1706	1.394
1.5	399.406	1.1539	1.4464	0.5	399.155	1.0903	1.342	0.75	399.337	1.1364	1.36
2	399.045	1.0624	1.3576	1	398.912	1.0287	1.276	1.25	399.158	1.0910	1.3129
2.5	399.018	1.0556	1.3507	1.5	398.697	0.9743	1.215	2	398.918	1.0303	1.2462
3.5	398.732	0.9832	1.2737	2	398.466	0.9158	1.144	2.75	398.776	0.9943	1.2045
4.5	398.513	0.9277	1.2105	3	398.133	0.8315	1.031	4	398.552	0.9376	1.1349
5.5	398.407	0.9008	1.1783	4	397.869	0.7646	0.933	5	398.407	0.9008	1.0872
6.5	398.089	0.8203	1.0753	5	397.711	0.7246	0.868	6.5	398.121	0.8284	0.9858
8.5	397.716	0.7258	0.9392	6	397.397	0.6451	0.727	8	397.896	0.7714	0.8981
11.5	397.297	0.6197	0.7603	8.25	397.272	0.6134	0.665	9.5	397.511	0.6739	0.7275
25.75	396.369	0.3847	0.1914	10	396.827	0.5007	0.405	11	397.123	0.5757	0.52
50.75	395.445	0.1507	-1.2483	22	396.131	0.3244	-0.219	25	396.456	0.4067	0.0149
72.75	395.311	0.1168	-1.8773	28.5	395.956	0.2801	-0.465	58	396.032	0.2994	-0.5259
98.083	395.21	0.0912	-2.9565	46.5	395.511	0.1674	-1.698	72.75	395.896	0.2649	-0.7875
125.75	395.192	0.0866	-3.3814	70.5	395.443	0.1502	-2.163	100.5	395.668	0.2072	-1.4828
140.08	395.18	0.0836	-3.8167	94.25	395.412	0.1423	-2.477	127.7	395.6	0.1899	-1.8389
144.83	395.178	0.0831	-3.9120	112	395.386	0.1357	-2.847	148.7	395.556	0.1788	-2.1628
169.33	395.171	0.0813	####	139.5	395.36	0.1292	-3.442	171.8	395.511	0.1674	-2.6593
193.08	395.17	0.0810	####	169.75	395.35	0.1266	-3.817	194.5	395.489	0.1618	-3.0366
218.08	395.158	0.0780		187.25	395.342	0.1246	-4.269	224	395.467	0.1563	-3.6497
				210.25	395.335	0.1228	-4.962	248	395.456	0.1535	-4.1997
				235.5	395.33	0.1216	-6.215	272	395.448	0.1514	-4.9618
				254.5	395.328	0.1211		296	395.441	0.1497	

					sample-3		2*l*=0.0588 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	n(Mt-M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)
0	402.902	1.2698	1.5548		0	402.865	1.2605	1.5116		0	402.882	1.2648	1.51447
1	402.793	1.2424	1.5315		0.25	402.789	1.2414	1.4947		0.25	402.691	1.2168	1.47155
1.5	402.563	1.1846	1.4805		0.5	402.518	1.1733	1.432		0.75	402.633	1.2022	1.45815
2	402.276	1.1125	1.4129		1	402.269	1.1107	1.3707		1.25	402.408	1.1457	1.40438
2.5	402.185	1.0896	1.3905		1.5	402.026	1.0496	1.307		2	402.245	1.1047	1.36354
3.5	402.014	1.0466	1.3470		2	401.766	0.9843	1.234		2.75	402.073	1.0615	1.31855
4.5	401.805	0.9941	1.2912		3	401.986	1.0396	1.2961		4	401.864	1.0089	1.26101
5.49999	401.625	0.9489	1.2404		4	401.21	0.8445	1.0574		5	401.699	0.9675	1.21313
6.49999	401.498	0.9169	1.2030		5	401.037	0.8011	0.9955		6.5	401.515	0.9212	1.15688
8.49999	401.114	0.8204	1.0804		6	400.733	0.7246	0.8763		8	401.342	0.8777	1.10094
11.5	400.611	0.6940	0.8932		8.25	400.345	0.6271	0.7001		9.5	401.249	0.8543	1.06953
25.75	399.612	0.4429	0.3674		10	400.028	0.5474	0.5289		11	401.095	0.8156	1.01523
50.75	398.878	0.2584	######		22	399.287	0.3612	-0.045		25	400.157	0.5799	0.59993
72.75	398.617	0.1928	######		28.5	399.138	0.3237	-0.214		58	398.896	0.2629	-0.578
98.0833	398.376	0.1322	-1.5702		46.5	398.799	0.2385	-0.759		72.75	398.687	0.2104	-1.0441
125.75	398.211	0.0907	-3.1466		70.5	398.512	0.1664	-1.709		100.5	398.523	0.1692	-1.6713
140.083	398.201	0.0882	-3.4112		94.25	398.451	0.1511	-2.12		127.75	398.416	0.1423	-2.5133
144.833	398.189	0.0852	######		112	398.432	0.1463	-2.293		148.75	398.38	0.1332	-3.1011
169.333	398.18	0.0829	######		139.5	398.4	0.1382	-2.674		171.75	398.365	0.1294	-3.5066
193.083	398.175	0.0817	-4.9618		169.75	398.376	0.1322	-3.101		194.5	398.352	0.1262	-4.0745
218.083	398.168	0.0799			187.25	398.359	0.1279	-3.576		224	398.343	0.1239	-4.8283
					210.25	398.349	0.1254	-4.017		248	398.339	0.1229	-5.5215
					235.5	398.34	0.1232	-4.711		272	398.333	0.1214	
					254.5	398.331	0.1209			296	398.335	0.1219	

Table 14. Sorption Data of Vinyl ester Samples containing 2 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

				sample-1		2*l* =0.0611 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞	Time, h	Weight, mg	Water Content, wt%	M_t/M_∞	Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0	450.94	0.0000	0.0000	0	451.145	0.0455	0	0	451.352	0.0914	0.0000
0.5	451.32	0.0843	0.0588	0.25	451.532	0.1313	0.061	0.5	452.187	0.2765	0.1391
1.5	451.71	0.1708	0.1192	0.5	451.8	0.1907	0.103	1.25	452.356	0.3140	0.1672
4	452.19	0.2772	0.1935	1	451.934	0.2204	0.124	2	452.443	0.3333	0.1817
5.5	452.585	0.3648	0.2546	1.5	452.183	0.2756	0.164	3	452.576	0.3628	0.2038
7	452.7	0.3903	0.2724	2	452.479	0.3413	0.21	4	452.712	0.3930	0.2265
8	452.93	0.4413	0.3080	3	453.028	0.4630	0.297	5	452.897	0.4340	0.2573
10.75	453.18	0.4967	0.3467	4	453.195	0.5001	0.323	6	452.998	0.4564	0.2741
11.75	453.32	0.5278	0.3684	5	453.491	0.5657	0.37	7	453.11	0.4812	0.2928
25.75	454.608	0.8134	0.5677	6	453.702	0.6125	0.403	8	453.219	0.5054	0.3109
32.75	455.003	0.9010	0.6289	8.25	453.953	0.6682	0.443	9.25	453.412	0.5482	0.3430
49.75	455.346	0.9771	0.6819	10	454.331	0.7520	0.502	10	453.5	0.5677	0.3577
75.25	455.719	1.0598	0.7397	22	454.843	0.8655	0.583	10.75	453.61	0.5921	0.3760
95.25	455.981	1.1179	0.7802	28.5	455.134	0.9301	0.629	20.75	454.212	0.7256	0.4763
122.75	456.239	1.1751	0.8202	46.5	455.564	1.0254	0.697	43.75	455.058	0.9132	0.6172
149.25	456.487	1.2301	0.8585	70.5	455.856	1.0902	0.743	75.75	455.667	1.0483	0.7186
166.25	456.617	1.2589	0.8787	94.25	456.138	1.1527	0.787	112.3	456.231	1.1733	0.8125
192	456.789	1.2971	0.9053	112	456.353	1.2004	0.821	141.8	456.562	1.2467	0.8676
218.25	456.963	1.3357	0.9322	139.5	456.513	1.2359	0.846	168.8	456.704	1.2782	0.8913
244.75	457.092	1.3643	0.9522	169.75	456.763	1.2913	0.886	188.8	456.845	1.3095	0.9147
271.25	457.161	1.3796	0.9629	187.25	456.913	1.3246	0.909	243.8	456.954	1.3337	0.9329
291.25	457.211	1.3907	0.9706	210.25	457.042	1.3532	0.93	274.8	457.097	1.3654	0.9567
313.5	457.251	1.3995	0.9768	241.75	457.153	1.3778	0.947	322.8	457.145	1.3760	0.9647
337	457.284	1.4068	0.9819	259.25	457.248	1.3989	0.962	389.25	457.212	1.3909	0.9759
365	457.312	1.4130	0.9862	282.25	457.321	1.4150	0.974	430.75	457.261	1.4017	0.9840
387	457.344	1.4201	0.9912	307.50	457.398	1.4321	0.9858	482.75	457.289	1.4079	0.9887
409	457.358	1.4232	0.9933	326.50	457.452	1.4441	0.9943	490.75	457.305	1.4115	0.9913
434.67	457.371	1.4261	0.9954	358.00	457.467	1.4474	0.9967	527.25	457.357	1.4230	1.0000
460.42	457.392	1.4308	0.9986	375.50	457.481	1.4505	0.9989				
485.42	457.384	1.4290	0.9974	402.75	457.491	1.4527	1.0005				
507.42	457.394	1.4312	0.9989	424.50	457.499	1.4545	1.0017				
532.75	457.401	1.4328	1.0000	452.50	457.505	1.4558	1.0027				
				475.75	457.488	1.4521	1.0000				

					sample-2		2*l* =0.0577 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0	338.93	0.0000	0.0000		0	339.155	0.0664	0		0	339.139	0.0617	0.0000
0.5	339.17	0.0708	0.0496		0.25	339.247	0.0935	0.02		0.5	339.256	0.0962	0.0252
1.5	339.56	0.1859	0.1303		0.5	339.434	0.1487	0.06		1.25	339.425	0.1460	0.0615
4	340.021	0.3219	0.2257		1	339.698	0.2266	0.116		2	339.614	0.2018	0.1021
5.5	340.259	0.3921	0.2749		1.5	339.956	0.3027	0.171		3	339.754	0.2431	0.1322
7	340.453	0.4494	0.3151		2	340.234	0.3847	0.23		4	339.987	0.3119	0.1823
8	340.67	0.5134	0.3600		3	340.426	0.4414	0.271		5	340.087	0.3414	0.2038
10.75	340.797	0.5509	0.3862		4	340.613	0.4966	0.311		6	340.296	0.4030	0.2487
11.75	341	0.6107	0.4282		5	340.83	0.5606	0.358		7	340.411	0.4370	0.2734
25.75	341.564	0.7772	0.5449		6	341.045	0.6240	0.404		8	340.524	0.4703	0.2977
32.75	341.886	0.8722	0.6115		8.25	341.338	0.7105	0.466		9.25	340.665	0.5119	0.3280
49.75	342.234	0.9748	0.6835		10	341.432	0.7382	0.486		10	340.733	0.5320	0.3426
75.25	342.476	1.0462	0.7336		22	341.954	0.8922	0.598		10.75	340.812	0.5553	0.3596
95.25	342.696	1.1111	0.7791		28.5	342.344	1.0073	0.681		20.75	341.12	0.6462	0.4258
122.75	342.864	1.1607	0.8138		46.5	342.696	1.1111	0.756		43.75	341.778	0.8403	0.5673
149.25	342.993	1.1988	0.8405		70.5	343.106	1.2321	0.844		75.75	342.443	1.0365	0.7102
166.25	343.087	1.2265	0.8600		94.25	343.286	1.2852	0.882		112.3	342.887	1.1675	0.8057
192	343.187	1.2560	0.8806		112	343.415	1.3233	0.91		141.8	343.118	1.2357	0.8553
218.25	343.287	1.2855	0.9013		139.5	343.488	1.3448	0.925		168.8	343.302	1.2899	0.8949
244.75	343.396	1.3177	0.9239		169.75	343.556	1.3649	0.94		188.8	343.422	1.3253	0.9207
271.25	343.454	1.3348	0.9359		187.25	343.601	1.3782	0.95		243.8	343.511	1.3516	0.9398
291.25	343.497	1.3475	0.9448		210.25	343.645	1.3911	0.959		274.8	343.593	1.3758	0.9574
313.5	343.523	1.3551	0.9501		241.75	343.691	1.4047	0.969		322.8	343.654	1.3938	0.9706
337	343.576	1.3708	0.9611		259.25	343.732	1.4168	0.978		389.25	343.688	1.4038	0.9779
365	343.612	1.3814	0.9686		282.25	343.756	1.4239	0.983		430.75	343.711	1.4106	0.9828
387	343.645	1.3911	0.9754		307.50	343.769	1.4277	0.9855		482.75	343.745	1.4206	0.9901
409	343.671	1.3988	0.9808		326.50	343.777	1.4301	0.9872		490.75	343.765	1.4265	0.9944
434.67	343.697	1.4065	0.9861		358.00	343.792	1.4345	0.9904		527.25	343.791	1.4342	1.0000
460.42	343.715	1.4118	0.9899		375.50	343.802	1.4375	0.9925					
485.42	343.745	1.4206	0.9961		402.75	343.811	1.4401	0.9944					
507.42	343.756	1.4239	0.9983		424.50	343.820	1.4428	0.9964					
532.75	343.764	1.4263	1.0000		452.50	343.829	1.4454	0.9983					
					475.75	343.837	1.4478	1.0000					

					sample-3		2*l* =0.0833 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0	550.18	0.0000	0.0000		0	550.365	0.0336	0		0	550.36	0.0327	0
0.5	550.312	0.0240	0.0180		0.25	550.564	0.0698	0.027		0.5	550.546	0.0665	0.026
1.5	550.566	0.0702	0.0527		0.5	550.846	0.1211	0.065		1.25	550.785	0.1100	0.0593
4	551.231	0.1910	0.1435		1	551.111	0.1692	0.101		2	551.065	0.1609	0.0984
5.5	551.432	0.2276	0.1709		1.5	551.354	0.2134	0.133		3	551.231	0.1910	0.1215
7	551.673	0.2714	0.2038		2	551.633	0.2641	0.171		4	551.364	0.2152	0.1401
8	551.872	0.3075	0.2310		3	551.812	0.2966	0.195		5	551.488	0.2377	0.1574
10.75	551.999	0.3306	0.2483		4	552.187	0.3648	0.246		6	551.623	0.2623	0.1762
11.75	552.345	0.3935	0.2955		5	552.387	0.4011	0.273		7	551.732	0.2821	0.1915
25.75	553.373	0.5804	0.4358		6	552.485	0.4190	0.286		8	551.854	0.3043	0.2085
32.75	553.756	0.6500	0.4881		8.25	552.673	0.4531	0.311		9.25	551.933	0.3186	0.2195
49.75	554.677	0.8174	0.6138		10	552.947	0.5029	0.348		10	552.098	0.3486	0.2425
75.25	555.234	0.9186	0.6899		22	553.978	0.6903	0.487		10.75	552.114	0.3515	0.2448
95.25	555.568	0.9793	0.7355		28.5	554.221	0.7345	0.52		20.75	552.967	0.5066	0.3638
122.75	556.131	1.0816	0.8123		46.5	554.877	0.8537	0.608		43.75	553.989	0.6923	0.5064
149.25	556.362	1.1236	0.8438		70.5	555.555	0.9770	0.7		75.75	555.342	0.9382	0.6952
166.25	556.587	1.1645	0.8746		94.25	555.996	1.0571	0.759		112.3	555.788	1.0193	0.7575
192	556.859	1.2140	0.9117		112	556.312	1.1145	0.802		141.8	556.321	1.1162	0.8318
218.25	557.068	1.2520	0.9402		139.5	556.656	1.1771	0.848		168.8	556.754	1.1949	0.8923
244.75	557.186	1.2734	0.9563		169.75	556.856	1.2134	0.875		188.8	556.998	1.2392	0.9263
271.25	557.248	1.2847	0.9648		187.25	557.1	1.2578	0.908		243.8	557.212	1.2781	0.9562
291.25	557.312	1.2963	0.9735		210.25	557.3	1.2941	0.935		274.8	557.335	1.3005	0.9733
313.5	557.348	1.3028	0.9784		241.75	557.412	1.3145	0.95		322.8	557.412	1.3145	0.9841
337	557.396	1.3116	0.9850		259.25	557.5	1.3305	0.962		389.25	557.489	1.3285	0.9948
365	557.421	1.3161	0.9884		282.25	557.589	1.3467	0.974		430.75	557.500	1.3305	0.9964
387	557.44	1.3196	0.9910		307.50	557.654	1.3585	0.9826		482.75	557.512	1.3327	0.9980
409	557.456	1.3225	0.9932		326.50	557.700	1.3668	0.9888		490.75	557.521	1.3343	0.9993
434.67	557.466	1.3243	0.9945		358.00	557.723	1.3710	0.9919		527.25	557.526	1.3352	1.0000
460.42	557.472	1.3254	0.9954		375.50	557.740	1.3741	0.9942					
485.42	557.490	1.3287	0.9978		402.75	557.760	1.3777	0.9969					
507.42	557.500	1.3305	0.9992		424.50	557.770	1.3795	0.9982					
532.75	557.506	1.3316	1.0000		452.50	557.778	1.3810	0.9993					
					475.75	557.783	1.3819	1.0000					

Table 15. Desorption Data of Vinyl ester Samples containing 2 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

					sample-1		2*l* =0.0611 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	457.408	1.4343	1.8339		0.00	457.501	1.4550	1.8166		0	457.362	1.4241	1.7954
0.33	457.129	1.3725	1.7883		0.25	457.421	1.4372	1.8035		0.5	457.117	1.3698	1.7539
0.83	456.889	1.3192	1.7473		0.75	457.354	1.4224	1.7924		1	456.918	1.3257	1.7188
1.33	456.396	1.2099	1.6575		1.00	457.223	1.3933	1.7704		2	456.676	1.2720	1.6745
1.83	456.209	1.1684	1.6212		1.25	457.132	1.3731	1.7547		3.5	456.545	1.2430	1.6496
2.83	455.936	1.1079	1.5657		1.50	457.023	1.3490	1.7357		5	456.275	1.1831	1.5964
3.83	455.716	1.0591	1.5186		2.00	457.011	1.3463	1.7336		7	456.011	1.1245	1.5414
4.83	455.645	1.0434	1.5030		2.50	456.912	1.3243	1.7160		9	455.735	1.0633	1.4805
5.83	455.523	1.0163	1.4754		3.00	456.832	1.3066	1.7015		11	455.711	1.0580	1.4750
6.83	455.389	0.9866	1.4443		3.50	456.682	1.2733	1.6737		21.75	454.836	0.8640	1.2516
7.83	455.296	0.9660	1.4221		4.83	456.557	1.2456	1.6500		28.75	454.379	0.7626	1.1115
8.83	454.879	0.8735	1.3161		5.83	456.427	1.2168	1.6247		50.75	453.473	0.5617	0.7575
9.83	454.416	0.7708	1.1836		7.00	456.3	1.1886	1.5994		80.75	452.389	0.3213	0.0478
11.83	454.284	0.7416	1.1423		8.00	455.987	1.1192	1.5341		94.75	451.9	0.2129	-0.5798
14.33	454.183	0.7192	1.1096		21.75	455.676	1.0503	1.4646		122.25	451.677	0.1634	-1.0877
19.08	453.821	0.6389	0.9825		32.75	455.123	0.9276	1.3279		148.75	451.523	0.1293	-1.6983
43.58	452.82	0.4169	0.5128		45.75	454.666	0.8263	1.1988		171.25	451.449	0.1129	-2.2164
67.33	452.37	0.3171	0.1989		57.00	454.06	0.6919	0.9969		190.75	451.398	0.1016	-2.8473
94.33	452.121	0.2619	-0.0294		80.25	453.533	0.5750	0.7807		216.75	451.367	0.0947	-3.6119
122.33	451.881	0.2087	-0.3133		117.25	453.132	0.4861	0.5777		245.25	451.352	0.0914	-4.4228
141.33	451.674	0.1628	-0.6463		140.25	452.612	0.3708	0.2327		269.25	451.347	0.0903	-4.9618
171.33	451.562	0.1379	-0.8867		171.25	452.134	0.2648	-0.2433		293.25	451.34	0.0887	#NUM!
190.33	451.443	0.1115	-1.2276		191.00	451.92	0.2173	-0.5621					
206.58	451.343	0.0894	-1.6451		215.75	451.779	0.1861	-0.8463					
235.33	451.277	0.0747	-2.0636		239.75	451.679	0.1639	-1.1117					
267.08	451.231	0.0645	-2.5133		263.75	451.598	0.1459	-1.3943					
286.08	451.2	0.0577	-2.9957		285.25	451.532	0.1313	-1.7037					
313.83	451.176	0.0523	-3.6497		309.25	451.476	0.1189	-2.0715					
328.83	451.166	0.0501	-4.1352		336.75	451.443	0.1115	-2.3752					
355.83	451.157	0.0481	-4.9618		363.25	451.412	0.1047	-2.7806					
382.83	451.15	0.0466	#NUM!		388.00	451.39	0.0998	-3.2189					
					409.00	451.38	0.0976	-3.5066					
					432.00	451.371	0.0956	-3.8632					
					454.75	451.367	0.0947	-4.0745					
					478.75	451.36	0.0931	-4.6052					
					502.75	451.355	0.0920	-5.2983					
					525.5	451.35	0.0909	#NUM!					

					sample-2		2*l*=0.0577 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	343.771	1.4283	1.5297		0.00	343.827	1.4448	1.5442		0	343.784	1.4322	1.5399
0.33	343.386	1.3147	1.4427		0.25	343.711	1.4106	1.5191		0.5	343.47	1.3395	1.4702
0.83	343.056	1.2174	1.3615		0.75	343.516	1.3531	1.4754		1	343.312	1.2929	1.4332
1.33	342.905	1.1728	1.3220		1.00	343.427	1.3268	1.4549		2	343.084	1.2256	1.3773
1.83	342.665	1.1020	1.2559		1.25	343.128	1.2386	1.3825		3.5	342.81	1.1448	1.3056
2.83	342.37	1.0150	1.1681		1.50	343.021	1.2070	1.3553		5	342.633	1.0926	1.2565
3.83	342.148	0.9495	1.0966		2.00	342.849	1.1563	1.3100		7	342.406	1.0256	1.1897
4.83	342.008	0.9082	1.0487		2.50	342.651	1.0979	1.2550		9	342.182	0.9595	1.1191
5.83	341.717	0.8223	0.9412		3.00	342.412	1.0274	1.1845		11	341.967	0.8961	1.0463
6.83	341.623	0.7946	0.9038		3.50	342.298	0.9937	1.1490		21.75	341.311	0.7025	0.7844
7.83	341.521	0.7645	0.8616		4.83	342.056	0.9223	1.0692		28.75	341.15	0.6550	0.7080
8.83	341.402	0.7294	0.8100		5.83	341.986	0.9017	1.0449		50.75	340.586	0.4886	0.3825
9.83	341.326	0.7069	0.7756		7.00	341.712	0.8208	0.9435		80.75	340.012	0.3192	-0.1143
11.83	340.911	0.5845	0.5636		8.00	341.553	0.7739	0.8796		94.75	339.786	0.2526	-0.4065
14.33	340.784	0.5470	0.4886		21.75	341.318	0.7046	0.7770		122.25	339.414	0.1428	-1.2242
19.08	340.478	0.4567	0.2807		32.75	341.036	0.6214	0.6382		148.75	339.204	0.0808	-2.4769
43.58	339.98	0.3098	-0.1912		45.75	340.889	0.5780	0.5573		171.25	339.178	0.0732	-2.8473
67.33	339.778	0.2502	-0.4716		57.00	340.762	0.5405	0.4818		190.75	339.156	0.0667	-3.3242
94.33	339.632	0.2071	-0.7381		80.25	340.563	0.4818	0.3507		216.75	339.143	0.0628	-3.7723
122.33	339.487	0.1643	-1.0996		117.25	340.267	0.3945	0.1169		245.25	339.133	0.0599	-4.3428
141.33	339.399	0.1384	-1.4065		140.25	339.989	0.3125	-0.1672		269.25	339.126	0.0578	-5.1160
171.33	339.321	0.1154	-1.7898		171.25	339.842	0.2691	-0.3581		293.25	339.12	0.0561	#NUM!
190.33	339.27	0.1003	-2.1542		191.00	339.708	0.2295	-0.5709					
206.58	339.24	0.0915	-2.4534		215.75	339.576	0.1906	-0.8370					
235.33	339.2	0.0797	-3.0791		239.75	339.439	0.1502	-1.2174					
267.08	339.19	0.0767	-3.3242		263.75	339.325	0.1165	-1.7037					
286.08	339.181	0.0741	-3.6119		285.25	339.286	0.1050	-1.9449					
313.83	339.173	0.0717	-3.9633		309.25	339.256	0.0962	-2.1804					
328.83	339.168	0.0702	-4.2687		336.75	339.235	0.0900	-2.3860					
355.83	339.16	0.0679	-5.1160		363.25	339.212	0.0832	-2.6736					
382.83	339.154	0.0661	#NUM!		388.00	339.189	0.0764	-3.0791					
					409.00	339.175	0.0723	-3.4420					
					432.00	339.165	0.0693	-3.8167					
					454.75	339.157	0.0670	-4.2687					
					478.75	339.15	0.0649	-4.9618					
					502.75	339.147	0.0640	-5.5215					
					525.5	339.143	0.0628	#NUM!					

					sample-3		2l=0.0833 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)
0.00	557.509	1.3321	1.9654		0.00	557.786	1.3825	2.0042		0	557.53	1.3359	1.9455
0.33	557.308	1.2956	1.9369		0.25	557.299	1.2939	1.9363		0.5	556.95	1.2305	1.8590
0.83	556.944	1.2294	1.8830		0.75	557.012	1.2418	1.8940		1	556.411	1.1325	1.7712
1.33	556.755	1.1951	1.8538		1.00	556.785	1.2005	1.8593		2	556.56	1.1596	1.7962
1.83	556.641	1.1743	1.8358		1.25	556.499	1.1485	1.8137		3.5	556.154	1.0858	1.7265
2.83	556.271	1.1071	1.7750		1.50	556.347	1.1209	1.7886		5	555.869	1.0340	1.6745
3.83	556.017	1.0609	1.7309		2.00	556.084	1.0731	1.7436		7	555.411	0.9508	1.5847
4.83	555.81	1.0233	1.6936		2.50	554.947	0.8664	1.5219		9	554.803	0.8403	1.4516
5.83	555.583	0.9820	1.6510		3.00	554.123	0.7167	1.3236		11	554.556	0.7954	1.3920
6.83	555.422	0.9528	1.6196		3.50	553.864	0.6696	1.2522		21.75	553.769	0.6523	1.1743
7.83	555.376	0.9444	1.6104		4.83	553.555	0.6134	1.1597		28.75	553.264	0.5605	1.0047
8.83	555.214	0.9150	1.5775		5.83	553.213	0.5513	1.0463		50.75	552.043	0.3386	0.4121
9.83	555.123	0.8984	1.5586		7.00	553.089	0.5287	1.0017		80.75	551.045	0.1572	-0.6694
11.83	554.789	0.8377	1.4857		8.00	552.989	0.5106	0.9643		94.75	550.873	0.1260	-1.0788
14.33	554.354	0.7587	1.3820		21.75	552.687	0.4557	0.8420		122.25	550.77	0.1072	-1.4397
19.08	553.987	0.6920	1.2854		32.75	552.333	0.3913	0.6765		148.75	550.7	0.0945	-1.7898
43.58	552.598	0.4395	0.8007		45.75	552.012	0.3330	0.4983		171.25	550.612	0.0785	-2.5383
67.33	551.786	0.2919	0.3471		57.00	551.664	0.2697	0.2608		190.75	550.587	0.0740	-2.9188
94.33	551.387	0.2194	0.0159		80.25	551.423	0.2259	0.0554		216.75	550.564	0.0698	-3.4738
122.33	551.111	0.1692	-0.3011		117.25	551.265	0.1972	-0.1065		245.25	550.55	0.0673	-4.0745
141.33	550.887	0.1285	-0.6616		140.25	551.032	0.1549	-0.4065		269.25	550.54	0.0654	-4.9618
171.33	550.711	0.0965	-1.0788		171.25	550.888	0.1287	-0.6501		293.25	550.533	0.0642	#NUM!
190.33	550.612	0.0785	-1.4230		191.00	550.788	0.1105	-0.8627					
206.58	550.523	0.0623	-1.8839		215.75	550.721	0.0983	-1.0356					
235.33	550.476	0.0538	-2.2538		239.75	550.643	0.0842	-1.2837					
267.08	550.443	0.0478	-2.6311		263.75	550.589	0.0743	-1.5006					
286.08	550.421	0.0438	-2.9957		285.25	550.543	0.0660	-1.7316					
313.83	550.4	0.0400	-3.5405		309.25	550.5	0.0582	-2.0099					
328.83	550.389	0.0380	-4.0174		336.75	550.47	0.0527	-2.2634					
355.83	550.38	0.0364	-4.7105		363.25	550.443	0.0478	-2.5639					
382.83	550.371	0.0347	#NUM!		388.00	550.421	0.0438	-2.9004					
					409.00	550.41	0.0418	-3.1236					
					432.00	550.398	0.0396	-3.4420					
					454.75	550.388	0.0378	-3.8167					
					478.75	550.38	0.0364	-4.2687					
					502.75	550.372	0.0349	-5.1160					
					525.5	550.366	0.0338	#NUM!					

Table 16. Sorption Data of Vinyl ester Samples containing 5 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

				sample-1		$2l$=0.0565 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞	Time, h	Weight, mg	Water Content, wt%	M_t/M_∞	Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0	529.35	0.0000	0.0000	0	529.55	0.0378	0	0	529.49	0.0264	0.0000
0.5	529.75	0.0756	0.0537	0.25	529.622	0.0514	0.0099	0.5	529.6	0.0472	0.0149
1.5	530.42	0.2021	0.1436	0.5	529.739	0.0735	0.026	1	529.813	0.0875	0.0438
4	531.06	0.3230	0.2295	0.75	530.012	0.1251	0.0636	1.75	529.934	0.1103	0.0602
5.5	531.22	0.3533	0.2510	1.25	530.212	0.1628	0.0912	2.5	529.984	0.1198	0.0670
7	531.56	0.4175	0.2966	1.75	530.543	0.2254	0.1368	3.5	530.38	0.1946	0.1208
8	531.84	0.4704	0.3342	2.25	530.776	0.2694	0.1688	4.5	530.548	0.2263	0.1436
10.75	532.02	0.5044	0.3584	3.25	531.064	0.3238	0.2085	5.5	530.934	0.2992	0.1959
11.75	532.19	0.5365	0.3812	4.25	531.304	0.3691	0.2416	6.5	531.012	0.3140	0.2065
25.75	533.53	0.7896	0.5611	5.25	531.41	0.3892	0.2562	7.5	531.263	0.3614	0.2406
32.75	533.92	0.8633	0.6134	6.25	531.666	0.4375	0.2914	8.5	531.354	0.3786	0.2529
49.75	534.389	0.9519	0.6764	8.5	531.782	0.4594	0.3074	9.75	531.498	0.4058	0.2725
75.25	534.969	1.0615	0.7542	10.25	532.074	0.5146	0.3476	10.5	531.704	0.4447	0.3004
95.25	535.441	1.1507	0.8176	22.25	533.112	0.7107	0.4906	29.833	532.869	0.6648	0.4585
122.75	535.873	1.2323	0.8756	28.75	533.545	0.7925	0.5502	48.25	533.699	0.8216	0.5711
149.25	536.107	1.2765	0.9070	46.75	533.987	0.8760	0.6111	74.25	534.518	0.9763	0.6822
166.25	536.222	1.2982	0.9224	70.75	534.868	1.0424	0.7324	96.75	535.219	1.1087	0.7773
192	536.318	1.3163	0.9353	94.5	535.321	1.1280	0.7948	123.25	535.678	1.1954	0.8396
218.25	536.412	1.3341	0.9479	112.25	535.489	1.1597	0.8179	148.75	535.978	1.2521	0.8803
244.75	536.468	1.3447	0.9554	139.75	535.687	1.1971	0.8452	171.75	536.356	1.3235	0.9316
271.25	536.523	1.3551	0.9628	170	535.916	1.2404	0.8767	199.25	536.563	1.3626	0.9597
291.25	536.587	1.3671	0.9714	187.5	536.065	1.2685	0.8973	213.5	536.656	1.3802	0.9723
313.5	536.611	1.3717	0.9746	210.5	536.213	1.2965	0.9176	238.75	536.744	1.3968	0.9843
365	536.687	1.3860	0.9848	242	536.425	1.3365	0.9468	268.75	536.798	1.4070	0.9916
409	536.733	1.3947	0.9910	282.5	536.524	1.3552	0.9605	295.25	536.821	1.4114	0.9947
460.417	536.768	1.4013	0.9957	331.50	536.624	1.3741	0.9742	308.75	536.832	1.4134	0.9962
485.417	536.771	1.4019	0.9961	379.75	536.671	1.3830	0.9807	338.25	536.851	1.4170	0.9988
507.42	536.782	1.4040	0.9976	430.25	536.721	1.3925	0.9876	362.25	536.857	1.4182	0.9996
532.75	536.791	1.4057	0.9988	475.00	536.758	1.3995	0.9927	386.25	536.860	1.4187	1.0000
574.75	536.786	1.4047	0.9981	496.75	536.771	1.4019	0.9945				
631.75	536.794	1.4063	0.9992	524.75	536.788	1.4051	0.9968				
674.25	536.800	1.4074	1.0000	572.75	536.795	1.4064	0.9978				
				620.75	536.801	1.4076	0.9986				
				668.75	536.811	1.4095	1.0000				

					sample-2		2*l* =0.0577 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0	526.35	0.0000	0.0000		0	526.471	0.0230	0		0	526.561	0.0401	0.0000
0.5	526.84	0.0931	0.0618		0.25	526.687	0.0640	0.028		0.5	526.645	0.0560	0.0372
1.5	527.29	0.1786	0.1185		0.5	526.993	0.1222	0.067		1	526.777	0.0811	0.0539
4	527.85	0.2850	0.1891		0.75	527.124	0.1471	0.084		1.75	527.054	0.1338	0.0888
5.5	527.99	0.3116	0.2068		1.25	527.289	0.1784	0.105		2.5	527.374	0.1945	0.1292
7	528.38	0.3857	0.2560		1.75	527.549	0.2278	0.139		3.5	527.498	0.2181	0.1449
8	528.51	0.4104	0.2723		2.25	527.711	0.2586	0.16		4.5	527.656	0.2481	0.1648
10.75	528.97	0.4978	0.3303		3.25	527.998	0.3131	0.197		5.5	527.778	0.2713	0.1802
11.75	529.42	0.5833	0.3871		4.25	528.225	0.3562	0.226		6.5	527.912	0.2968	0.1971
25.75	530.47	0.7827	0.5195		5.25	528.364	0.3826	0.244		7.5	528.032	0.3196	0.2122
32.75	530.89	0.8625	0.5724		6.25	528.599	0.4273	0.274		8.5	528.101	0.3327	0.2209
49.75	531.84	1.0430	0.6922		8.5	528.814	0.4681	0.302		9.75	528.234	0.3579	0.2377
75.25	532.431	1.1553	0.7667		10.25	529.112	0.5247	0.34		10.5	528.314	0.3731	0.2478
95.25	532.715	1.2093	0.8025		22.25	530.522	0.7926	0.522		29.83	529.855	0.6659	0.4423
122.75	533.126	1.2874	0.8544		28.75	531.215	0.9243	0.611		48.25	530.611	0.8095	0.5377
149.25	533.357	1.3312	0.8835		46.75	532.054	1.0837	0.72		74.25	531.579	0.9934	0.6598
166.25	533.456	1.3501	0.8960		70.75	532.478	1.1642	0.774		96.75	532.312	1.1327	0.7523
192	533.64	1.3850	0.9192		94.5	532.716	1.2095	0.805		123.2	532.812	1.2277	0.8154
218.25	533.724	1.4010	0.9298		112.25	532.964	1.2566	0.837		148.7	533.245	1.3100	0.8700
244.75	533.856	1.4260	0.9464		139.75	533.172	1.2961	0.864		171.8	533.656	1.3880	0.9219
271.25	533.927	1.4395	0.9554		170	533.346	1.3292	0.886		199.2	533.923	1.4388	0.9556
291.25	533.984	1.4504	0.9626		187.5	533.418	1.3428	0.895		213.5	534.03	1.4591	0.9691
313.5	534.057	1.4642	0.9718		210.5	533.545	1.3670	0.912		238.7	534.156	1.4830	0.9850
365	534.138	1.4796	0.9820		242	533.632	1.3835	0.923		268.75	534.211	1.4935	0.9919
409	534.175	1.4867	0.9866		282.5	533.823	1.4198	0.948		295.25	534.245	1.5000	0.9962
460.42	534.204	1.4922	0.9903		331.50	534.010	1.4553	0.9718		308.75	534.256	1.5020	0.9976
485.42	534.224	1.4960	0.9928		379.75	534.124	1.4770	0.9865		338.25	534.261	1.5030	0.9982
507.42	534.234	1.4979	0.9941		430.25	534.220	1.4952	0.9988		362.25	534.270	1.5047	0.9994
532.75	534.248	1.5005	0.9958		475.00	534.220	1.4952	0.9988		386.25	534.275	1.5057	1.0000
574.75	534.257	1.5022	0.9970		496.75	534.236	1.4982	1.0009					
631.75	534.268	1.5043	0.9984		524.75	534.221	1.4954	0.9990					
674.25	534.281	1.5068	1.0000		572.75	534.228	1.4967	0.9999					
					620.75	534.236	1.4982	1.0009					
					668.75	534.229	1.4969	1.0000					

					sample-3		2*l* =0.05 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0	400.3	0.0000	0.0000		0	400.364	0.0160	0		0	400.403	0.0257	0.0000
0.5	400.88	0.1449	0.0930		0.25	400.624	0.0809	0.042		0.5	400.6	0.0749	0.0478
1.5	401.27	0.2423	0.1555		0.5	400.768	0.1169	0.065		1	400.722	0.1054	0.0673
4	401.756	0.3637	0.2334		0.75	401.032	0.1829	0.107		1.75	401	0.1749	0.1116
5.5	401.95	0.4122	0.2646		1.25	401.317	0.2541	0.152		2.5	401.236	0.2338	0.1493
7	402.18	0.4696	0.3014		1.75	401.392	0.2728	0.164		3.5	401.38	0.2698	0.1722
8	402.412	0.5276	0.3386		2.25	401.674	0.3432	0.209		4.5	401.698	0.3492	0.2229
10.75	402.842	0.6350	0.4076		3.25	401.956	0.4137	0.254		5.5	401.945	0.4109	0.2623
11.75	402.987	0.6712	0.4308		4.25	402.286	0.4961	0.307		6.5	402.034	0.4332	0.2765
25.75	404.102	0.9498	0.6096		5.25	402.407	0.5264	0.326		7.5	402.283	0.4954	0.3162
32.75	404.512	1.0522	0.6753		6.25	402.519	0.5543	0.344		8.5	402.378	0.5191	0.3314
49.75	405.141	1.2093	0.7762		8.5	402.821	0.6298	0.393		9.75	402.548	0.5616	0.3585
75.25	405.488	1.2960	0.8318		10.25	403.019	0.6792	0.424		10.5	402.645	0.5858	0.3739
95.25	405.671	1.3417	0.8612		22.25	403.968	0.9163	0.576		29.83	404.152	0.9623	0.6143
122.75	405.812	1.3770	0.8838		28.75	404.122	0.9548	0.6		48.25	404.757	1.1134	0.7107
149.25	405.916	1.4029	0.9004		46.75	404.328	1.0062	0.633		74.25	405.256	1.2381	0.7903
166.25	406.011	1.4267	0.9157		70.75	404.687	1.0959	0.691		96.75	405.669	1.3412	0.8562
192	406.098	1.4484	0.9296		94.5	404.952	1.1621	0.733		123.2	405.935	1.4077	0.8986
218.25	406.201	1.4741	0.9461		112.25	405.235	1.2328	0.778		148.7	406.201	1.4741	0.9410
244.75	406.285	1.4951	0.9596		139.75	405.423	1.2798	0.808		171.8	406.312	1.5019	0.9587
271.25	406.337	1.5081	0.9679		170	405.568	1.3160	0.831		199.2	406.421	1.5291	0.9761
291.25	406.374	1.5174	0.9739		187.5	405.711	1.3517	0.854		213.5	406.434	1.5324	0.9782
313.5	406.385	1.5201	0.9756		210.5	405.823	1.3797	0.872		238.7	406.459	1.5386	0.9821
365	406.422	1.5294	0.9816		242	405.928	1.4059	0.889		268.75	406.520	1.5538	0.9919
409	406.462	1.5393	0.9880		282.5	406.111	1.4517	0.918		295.25	406.531	1.5566	0.9936
460.42	406.491	1.5466	0.9926		331.50	406.278	1.4934	0.9449		308.75	406.540	1.5588	0.9951
485.42	406.502	1.5493	0.9944		379.75	406.369	1.5161	0.9594		338.25	406.549	1.5611	0.9965
507.42	406.511	1.5516	0.9958		430.25	406.452	1.5368	0.9727		362.25	406.562	1.5643	0.9986
532.75	406.520	1.5538	0.9973		475.00	406.531	1.5566	0.9853		386.25	406.571	1.5666	1.0000
574.75	406.531	1.5566	0.9990		496.75	406.567	1.5656	0.9911					
631.75	406.540	1.5588	1.0005		524.75	406.589	1.5711	0.9946					
674.25	406.537	1.5581	1.0000		572.75	406.596	1.5728	0.9957					
					620.75	406.612	1.5768	0.9982					
					668.75	406.623	1.5796	1.0000					

Table 17. Desorption Data of Vinyl ester Samples containing 5 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

					sample-1		2*l*=0.0565 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	536.802	1.4078	1.9820		0.00	536.798	1.4070	1.9881		0	536.411	1.3339	1.9273
0.33	536.671	1.3830	1.9638		0.50	536.645	1.3781	1.9670		0.25	536.077	1.2708	1.8775
0.83	536.45	1.3413	1.9322		0.75	536.421	1.3358	1.9351		0.75	535.93	1.2430	1.8547
1.33	536.23	1.2997	1.8999		1.25	536.243	1.3022	1.9091		1.25	535.598	1.1803	1.8014
1.83	536.073	1.2700	1.8761		1.50	536.011	1.2583	1.8741		2.25	535.388	1.1406	1.7661
2.83	535.786	1.2158	1.8311		1.75	535.874	1.2325	1.8529		3.75	535.199	1.1049	1.7332
3.83	535.562	1.1735	1.7946		2.00	535.661	1.1922	1.8189		5.25	534.945	1.0570	1.6873
4.83	535.29	1.1221	1.7483		2.50	535.421	1.1469	1.7792		7.25	534.685	1.0078	1.6380
5.83	535.036	1.0741	1.7031		3.00	535.284	1.1210	1.7558		9.25	534.416	0.9570	1.5843
6.83	534.935	1.0551	1.6845		3.50	535.084	1.0832	1.7206		11.25	533.863	0.8526	1.4639
7.83	534.853	1.0396	1.6692		4.00	534.911	1.0505	1.6892		22	533.165	0.7207	1.2879
8.83	534.765	1.0230	1.6525		5.33	534.672	1.0054	1.6440		29	532.443	0.5843	1.0657
9.83	534.631	0.9976	1.6265		6.33	534.546	0.9816	1.6194		52.5	531.61	0.4269	0.7275
11.83	534.311	0.9372	1.5615		7.50	534.212	0.9185	1.5510		143.75	530.123	0.1460	-0.5396
14.33	534.058	0.8894	1.5070		8.50	533.644	0.8112	1.4226		168.75	529.898	0.1035	-1.0272
19.08	533.408	0.7666	1.3514		22.25	533.164	0.7205	1.2996		219	529.674	0.0612	-2.0099
43.58	532.054	0.5108	0.9199		33.25	532.655	0.6244	1.1503		263.5	529.632	0.0533	-2.3860
67.33	531.234	0.3559	0.5241		70.25	531.833	0.4691	0.8489		313.75	529.61	0.0491	-2.6593
94.33	530.819	0.2775	0.2422		81.50	531.474	0.4012	0.6821		358.75	529.593	0.0459	-2.9375
122.33	530.387	0.1959	-0.1720		104.75	531.245	0.3580	0.5590		410.5	529.57	0.0416	-3.5066
141.33	530.158	0.1526	-0.4894		141.75	531.002	0.3121	0.4095		457	529.56	0.0397	-3.9120
171.33	529.998	0.1224	-0.7919		164.75	530.642	0.2441	0.1363		503.5	529.552	0.0382	-4.4228
190.33	529.9	0.1039	-1.0356		195.75	530.435	0.2050	-0.0629		550	529.546	0.0370	-5.1160
206.58	529.812	0.0873	-1.3205		215.50	530.246	0.1693	-0.2877		596.5	529.54	0.0359	
235.33	529.756	0.0767	-1.5559		240.25	530.042	0.1307	-0.6051					
267.08	529.7	0.0661	-1.8643		264.25	529.894	0.1028	-0.9213					
286.08	529.666	0.0597	-2.1120		288.25	529.786	0.0824	-1.2379					
328.83	529.63	0.0529	-2.4651		309.75	529.7	0.0661	-1.5896					
382.83	529.6	0.0472	-2.9004		337.25	529.656	0.0578	-1.8326					
412.33	529.589	0.0451	-3.1236		363.75	529.612	0.0495	-2.1542					
435.83	529.579	0.0433	-3.3814		388.50	529.578	0.0431	-2.5010					
459.83	529.570	0.0416	-3.6889		409.50	529.554	0.0385	-2.8473					
483.83	529.561	0.0399	-4.1352		455.25	529.532	0.0344	-3.3242					
531.83	529.556	0.0389	-4.5099		503.25	529.52	0.0321	-3.7297					
555.83	529.550	0.0378	-5.2983		552.75	529.512	0.0306	-4.1352					
579.83	529.545	0.0368	#NUM!		580.25	529.5	0.0283	-5.5215					
					595	529.496	0.0276	#NUM!					

				sample-2		2l=0.0577 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)
0.00	534.292	1.5089	2.0567	0.00	534.241	1.4992	2.0374	0	534.014	1.4561	2.0136
0.33	533.796	1.4146	1.9912	0.50	534.138	1.4796	2.0239	0.25	533.893	1.4331	1.9973
0.83	533.523	1.3628	1.9532	0.75	534.011	1.4555	2.0070	0.75	533.596	1.3767	1.9561
1.33	533.297	1.3198	1.9206	1.25	533.986	1.4507	2.0036	1.25	533.415	1.3423	1.9302
1.83	533.093	1.2811	1.8902	1.50	533.999	1.4532	2.0054	2.25	533.2	1.3014	1.8985
2.83	532.875	1.2397	1.8568	1.75	533.865	1.4278	1.9872	3.75	532.715	1.2093	1.8231
3.83	532.733	1.2127	1.8343	2.00	533.725	1.4012	1.9678	5.25	532.312	1.1327	1.7558
4.83	532.338	1.1376	1.7692	2.50	533.564	1.3706	1.9451	7.25	532.003	1.0740	1.7009
5.83	532.097	1.0919	1.7272	3.00	533.235	1.3081	1.8969	9.25	531.493	0.9771	1.6032
6.83	531.978	1.0693	1.7058	3.50	533.111	1.2845	1.8781	11.25	531.204	0.9222	1.5433
7.83	531.878	1.0503	1.6875	4.00	532.876	1.2399	1.8415	22	530.212	0.7337	1.3051
8.83	531.763	1.0284	1.6660	5.33	532.356	1.1411	1.7554	29	529.572	0.6121	1.1145
9.83	531.453	0.9695	1.6056	6.33	532.112	1.0947	1.7124	52.5	528.698	0.4461	0.7766
11.83	531.198	0.9211	1.5531	7.50	531.724	1.0210	1.6398	143.75	526.998	0.1231	-0.7465
14.33	530.971	0.8779	1.5039	8.50	531.426	0.9644	1.5802	168.75	526.811	0.0876	-1.2483
19.08	530.519	0.7921	1.3980	22.25	531.103	0.9030	1.5114	219	526.701	0.0667	-1.7316
43.58	529.946	0.6832	1.2453	33.25	530.556	0.7991	1.3828	263.5	526.669	0.0606	-1.9310
67.33	529.338	0.5677	1.0529	70.25	529.916	0.6775	1.2078	313.75	526.624	0.0521	-2.3026
94.33	528.768	0.4594	0.8312	81.50	529.425	0.5842	1.0491	358.75	526.589	0.0454	-2.7334
122.33	528.381	0.3859	0.6466	104.75	528.938	0.4917	0.8620	410.5	526.567	0.0412	-3.1466
141.33	527.949	0.3038	0.3900	141.75	528.533	0.4147	0.6745	457	526.55	0.0380	-3.6497
171.33	527.518	0.2219	0.0450	164.75	528.112	0.3348	0.4331	503.5	526.538	0.0357	-4.2687
190.33	527.251	0.1712	-0.2497	195.75	527.876	0.2899	0.2670	550	526.53	0.0342	-5.1160
206.58	527.032	0.1296	-0.5798	215.50	527.614	0.2401	0.0431	596.5	526.524	0.0331	
235.33	526.912	0.1068	-0.8210	240.25	527.421	0.2035	-0.1613				
267.08	526.739	0.0739	-1.3205	264.25	527.225	0.1662	-0.4231				
286.08	526.666	0.0600	-1.6399	288.25	527.101	0.1427	-0.6330				
328.83	526.6	0.0475	-2.0557	309.75	526.996	0.1227	-0.8533				
382.83	526.541	0.0363	-2.6736	337.25	526.823	0.0899	-1.3744				
412.33	526.512	0.0308	-3.2189	363.75	526.714	0.0692	-1.9379				
435.83	526.501	0.0287	-3.5405	388.50	526.675	0.0617	-2.2538				
459.83	526.490	0.0266	-4.0174	409.50	526.643	0.0557	-2.6173				
483.83	526.484	0.0255	-4.4228	455.25	526.621	0.0515	-2.9759				
531.83	526.480	0.0247	-4.8283	503.25	526.6	0.0475	-3.5066				
555.83	526.476	0.0239	-5.5215	552.75	526.589	0.0454	-3.9633				
579.83	526.472	0.0232	#NUM!	580.25	526.579	0.0435	-4.7105				
				595.00	526.57	0.0418	#NUM!				

				sample-3		2*l* =0.05 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	406.542	1.5593	1.8203	0.00	406.629	1.5811	1.8278	0	406.164	1.4649	1.7417
0.33	406.06	1.4389	1.7391	0.50	406.542	1.5593	1.8137	0.25	406.091	1.4467	1.7288
0.83	405.761	1.3642	1.6851	0.75	406.356	1.5129	1.7829	0.75	405.885	1.3952	1.6916
1.33	405.619	1.3288	1.6584	1.25	406.123	1.4547	1.7429	1.25	405.673	1.3422	1.6517
1.83	405.388	1.2710	1.6134	1.50	405.945	1.4102	1.7113	2.25	405.414	1.2775	1.6008
2.83	405.124	1.2051	1.5594	1.75	405.823	1.3797	1.6890	3.75	405.161	1.2143	1.5484
3.83	404.851	1.1369	1.5003	2.00	405.711	1.3517	1.6681	5.25	404.789	1.1214	1.4660
4.83	404.604	1.0752	1.4436	2.50	405.588	1.3210	1.6446	7.25	404.235	0.9830	1.3292
5.83	404.357	1.0135	1.3835	3.00	405.423	1.2798	1.6122	9.25	403.876	0.8933	1.2293
6.83	404.211	0.9770	1.3463	3.50	405.332	1.2571	1.5939	11.25	403.644	0.8354	1.1591
7.83	404.123	0.9550	1.3231	4.00	405.112	1.2021	1.5482	22	403.074	0.6930	0.9620
8.83	404.011	0.9271	1.2928	5.33	405.001	1.1744	1.5243	29	402.759	0.6143	0.8338
9.83	403.825	0.8806	1.2404	6.33	404.912	1.1521	1.5047	52.5	402.135	0.4584	0.5176
11.83	403.656	0.8384	1.1903	7.50	404.534	1.0577	1.4171	143.75	401.235	0.2336	-0.2510
14.33	403.415	0.7782	1.1142	8.50	404.112	0.9523	1.3091	168.75	400.968	0.1669	-0.6714
19.08	402.911	0.6523	0.9333	22.25	403.571	0.8171	1.1512	219	400.732	0.1079	-1.2910
43.58	402.082	0.4452	0.5388	33.25	403.142	0.7100	1.0054	263.5	400.687	0.0967	-1.4697
67.33	401.657	0.3390	0.2539	70.25	402.542	0.5601	0.7575	313.75	400.563	0.0657	-2.2443
94.33	401.486	0.2963	0.1115	81.50	402.134	0.4582	0.5452	358.75	400.532	0.0580	-2.5903
122.33	401.365	0.2661	-0.0030	104.75	401.768	0.3667	0.3067	410.5	400.51	0.0525	-2.9375
141.33	401.165	0.2161	-0.2269	141.75	401.453	0.2880	0.0431	457	400.487	0.0467	-3.5066
171.33	401.021	0.1801	-0.4262	164.75	401.213	0.2281	-0.2182	503.5	400.473	0.0432	-4.1352
190.33	400.912	0.1529	-0.6088	195.75	400.925	0.1561	-0.6616	550	400.463	0.0407	-5.1160
206.58	400.823	0.1307	-0.7875	215.50	400.785	0.1212	-0.9782	596.5	400.457	0.0392	#NUM!
235.33	400.712	0.1029	-1.0671	240.25	400.661	0.0902	-1.3783				
267.08	400.596	0.0739	-1.4784	264.25	400.578	0.0694	-1.7779				
286.08	400.532	0.0580	-1.8079	288.25	400.532	0.0580	-2.0956				
328.83	400.47	0.0425	-2.2828	309.75	400.49	0.0475	-2.5133				
382.83	400.442	0.0355	-2.6037	337.25	400.468	0.0420	-2.8302				
412.33	400.412	0.0280	-3.1236	363.75	400.453	0.0382	-3.1236				
435.83	400.397	0.0242	-3.5405	388.50	400.443	0.0357	-3.3814				
459.83	400.387	0.0217	-3.9633	409.50	400.437	0.0342	-3.5756				
483.83	400.380	0.0200	-4.4228	455.25	400.43	0.0325	-3.8632				
531.83	400.373	0.0182	-5.2983	503.25	400.422	0.0305	-4.3428				
555.83	400.370	0.0175	-6.2146	552.75	400.416	0.0290	-4.9618				
579.83	400.368	0.0170	#NUM!	580.25	400.411	0.0277	-6.2146				
				595	400.409	0.0272	#NUM!				

Table 18. Sorption Data of Polyester Samples containing 0 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

				sample-1		2*l* =0.05 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞	Time, h	Weight, mg	Water Content, wt%	M_t/M_∞	Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0.00	294.775	0.0000	0.0000	0.00	294.768	-0.0024	0	0	294.73	-0.0153	0.0000
0.50	295.6	0.2799	0.1095	0.25	295.035	0.0882	0.038	0.75	295	0.0763	0.0459
1.00	295.92	0.3884	0.1520	0.58	295.41	0.2154	0.09	1.25	295.312	0.1822	0.0990
1.50	296.161	0.4702	0.1839	1.08	295.645	0.2951	0.124	2.25	295.675	0.3053	0.1607
2.00	296.673	0.6439	0.2519	1.58	296.1	0.4495	0.188	3.75	296	0.4156	0.2160
2.50	296.989	0.7511	0.2938	2.58	296.679	0.6459	0.269	5.25	296.41	0.5547	0.2857
3.50	297.234	0.8342	0.3263	4.58	297.342	0.8708	0.362	7.25	296.732	0.6639	0.3405
4.50	297.568	0.9475	0.3707	7.00	297.997	1.0930	0.455	9.25	297	0.7548	0.3861
5.50	297.874	1.0513	0.4113	20.00	299.732	1.6816	0.699	11.25	297.23	0.8328	0.4252
6.50	298.136	1.1402	0.4461	31.25	300.363	1.8957	0.788	34	298.697	1.3305	0.6747
8.50	298.435	1.2416	0.4857	54.25	300.785	2.0388	0.847	53	299.324	1.5432	0.7813
10.75	299.032	1.4442	0.5650	122.25	301.296	2.2122	0.919	76.5	299.879	1.7315	0.8757
25.75	300.198	1.8397	0.7197	142.00	301.401	2.2478	0.934	101	300.154	1.8248	0.9224
50.75	300.879	2.0707	0.8101	195.25	301.621	2.3224	0.965	125	300.264	1.8621	0.9412
98.08	301.392	2.2448	0.8782	243.92	301.723	2.3571	0.979	149	300.351	1.8916	0.9560
140.33	301.676	2.3411	0.9159	263.25	301.765	2.3713	0.985	177	300.423	1.9160	0.9682
218.25	302	2.4510	0.9589	315.75	301.823	2.3910	0.994	219.5	300.502	1.9428	0.9816
287.42	302.132	2.4958	0.9764	362.75	301.86	2.4035	0.999	262	300.555	1.9608	0.9906
361.50	302.232	2.5297	0.9896	381.75	301.865	2.4052	0.999	289.8	300.575	1.9676	0.9940
412.25	302.298	2.5521	0.9984	409.75	301.869	2.4066	1	340.5	300.6	1.9761	0.9983
428.00	302.31	2.5562	1.0000					357.5	300.604	1.9774	0.9990
								373.5	300.608	1.9788	0.9997
								411.5	300.61	1.9795	1.0000

				sample-2		$2l$ =0.055 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞	Time, h	Weight, mg	Water Content, wt%	M_t/M_∞	Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0.00	348.436	0.0000	0.0000	0.00	348.43	-0.0017	0.0000	0	348.44	0.0011	0.0000
0.50	348.778	0.0980	0.0465	0.25	348.612	0.0504	0.0267	0.75	348.87	0.1244	0.0700
1.00	348.996	0.1605	0.0762	0.58	349	0.1616	0.0835	1.25	349.34	0.2590	0.1464
1.50	349.324	0.2544	0.1208	1.08	349.51	0.3077	0.1583	2.25	349.576	0.3267	0.1848
2.00	349.513	0.3086	0.1465	1.58	350.1	0.4768	0.2448	3.75	350	0.4481	0.2538
2.50	349.785	0.3865	0.1835	2.58	350.47	0.5828	0.2990	5.25	350.37	0.5542	0.3140
3.50	350.4	0.5628	0.2671	4.58	351.1	0.7633	0.3913	7.25	350.7	0.6487	0.3677
4.50	350.678	0.6424	0.3049	7.00	351.657	0.9229	0.4730	9.25	351	0.7347	0.4165
5.50	350.986	0.7307	0.3468	20.00	352.6	1.1931	0.6112	11.25	351.26	0.8092	0.4588
6.50	351.453	0.8645	0.4103	31.25	353	1.3078	0.6698	34	352.13	1.0585	0.6003
8.50	351.768	0.9547	0.4531	54.25	353.6	1.4797	0.7577	53	352.89	1.2762	0.7239
10.75	352.332	1.1163	0.5299	122.25	354.432	1.7181	0.8797	76.5	353.21	1.3679	0.7760
25.75	353.331	1.4026	0.6657	142.00	354.672	1.7868	0.9148	101	353.621	1.4857	0.8429
50.75	353.868	1.5565	0.7387	195.25	354.823	1.8301	0.9370	125	353.921	1.5717	0.8917
98.08	354.645	1.7791	0.8444	243.92	355	1.8808	0.9629	149	354.1	1.6229	0.9208
140.33	355.021	1.8868	0.8956	263.25	355.089	1.9063	0.9760	177	354.188	1.6482	0.9351
218.25	355.453	2.0106	0.9543	315.75	355.132	1.9186	0.9823	219.5	354.298	1.6797	0.9530
287.42	355.61	2.0556	0.9757	362.75	355.167	1.9287	0.9874	262	354.376	1.7020	0.9657
361.50	355.7	2.0814	0.9879	381.75	355.211	1.9413	0.9938	289.8	354.453	1.7241	0.9782
412.25	355.754	2.0969	0.9952	409.75	355.253	1.9533	1.0000	340.5	354.498	1.7370	0.9855
428.00	355.789	2.1069	1.0000					357.5	354.522	1.7439	0.9894
								373.5	354.555	1.7533	0.9948
								411.5	354.587	1.7625	1.0000

					sample-3		2*l* =0.045 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0.00	246.429	0.0000	0.0000		0.00	246.502	0.0295	0.0000		0	246.38	-0.0198	0.0000
0.50	246.998	0.2300	0.0835		0.25	246.869	0.1779	0.0574		0.75	246.71	0.1136	0.0527
1.00	247.342	0.3691	0.1339		0.58	247.277	0.3428	0.1213		1.25	246.89	0.1864	0.0814
1.50	247.585	0.4674	0.1696		1.08	247.486	0.4273	0.1540		2.25	247.31	0.3562	0.1484
2.00	247.879	0.5862	0.2127		1.58	247.656	0.4961	0.1806		3.75	247.568	0.4605	0.1896
2.50	248	0.6352	0.2305		2.58	248.154	0.6974	0.2586		5.25	247.96	0.6190	0.2522
3.50	248.323	0.7657	0.2779		4.58	248.563	0.8628	0.3226		7.25	248.184	0.7095	0.2879
4.50	248.6	0.8777	0.3185		7.00	249.137	1.0948	0.4124		9.25	248.531	0.8498	0.3433
5.50	248.9	0.9990	0.3625		20.00	249.995	1.4417	0.5467		11.25	248.998	1.0386	0.4179
6.50	249.21	1.1244	0.4080		31.25	250.764	1.7526	0.6671		34	250.356	1.5877	0.6346
8.50	249.56	1.2659	0.4594		54.25	251.536	2.0648	0.7879		53	251.234	1.9427	0.7748
10.75	250	1.4437	0.5239		122.25	252.359	2.3975	0.9167		76.5	251.868	2.1990	0.8760
25.75	251.479	2.0417	0.7409		142.00	252.498	2.4537	0.9385		101	252.126	2.3033	0.9172
50.75	252.125	2.3029	0.8357		195.25	252.698	2.5345	0.9698		125	252.35	2.3939	0.9529
98.08	252.568	2.4820	0.9007		243.92	252.801	2.5762	0.9859		149	252.4	2.4141	0.9609
140.33	252.879	2.6077	0.9463		263.25	252.835	2.5899	0.9912		177	252.465	2.4403	0.9713
218.25	253.096	2.6955	0.9781		315.75	252.863	2.6013	0.9956		219.5	252.54	2.4707	0.9832
287.42	253.168	2.7246	0.9887		362.75	252.881	2.6085	0.9984		262	252.598	2.4941	0.9925
361.50	253.22	2.7456	0.9963		381.75	252.889	2.6118	0.9997		289.8	252.611	2.4994	0.9946
412.25	253.24	2.7537	0.9993		409.75	252.891	2.6126	1.0000		340.5	252.624	2.5046	0.9966
428.00	253.245	2.7557	1.0000							357.5	252.631	2.5075	0.9978
										373.5	252.639	2.5107	0.9990
										411.5	252.645	2.5131	1.0000

Table 19. Desorption Data of Polyester Samples containing 0 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

				sample-1		2*l* =0.05 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	302.32	2.5596	2.0210	0	301.901	2.4174	1.9726	0	300.699	2.0097	1.7751
0.25	301.78	2.3764	1.9468	0.75	301.453	2.2655	1.9082	2.25	300.043	1.7871	1.6573
0.50	300.944	2.0928	1.8197	1.25	301	2.1118	1.8386	3	299.675	1.6623	1.5845
0.75	300.153	1.8244	1.6825	2.75	300.675	2.0015	1.7856	4	299.231	1.5117	1.4891
1.75	299.317	1.5408	1.5136	3.75	300.123	1.8143	1.6884	5	298.675	1.3230	1.3551
3.25	298.5	1.2637	1.3153	6.75	299.675	1.6623	1.6020	5.5	298.345	1.2111	1.2661
5.25	297.546	0.9400	1.0196	8.75	299.333	1.5463	1.5306	6.5	298.1	1.1280	1.1945
6.25	297	0.7548	0.8002	10.75	298.787	1.3610	1.4049	9.5	297.89	1.0567	1.1288
8.58	296.698	0.6524	0.6544	11.75	298.433	1.2409	1.3140	11.5	297.6	0.9584	1.0303
10.42	296.5	0.5852	0.5458	32.75	296.234	0.4950	0.4200	15.5	297.1	0.7887	0.8338
22.42	296.1	0.4495	0.2822	51.5	295.667	0.3026	-0.0460	18.5	296.564	0.6069	0.5687
47.00	295.778	0.3403	0.0040	78.75	295.399	0.2117	-0.3754	21.5	296.4	0.5513	0.4713
70.75	295.6	0.2799	-0.1912	99.75	295.176	0.1360	-0.7679	31.5	295.546	0.2616	-0.2904
112.25	295.4	0.2120	-0.4684	122.75	295.054	0.0946	-1.0729	60.5	295.165	0.1323	-1.0024
139.75	295.24	0.1577	-0.7636	169.5	294.912	0.0465	-1.6094	87	295	0.0763	-1.5995
187.50	295.087	0.1058	-1.1616	217.5	294.834	0.0200	-2.1037	132.5	294.898	0.0417	-2.3026
234.50	294.93	0.0526	-1.8579	270.5	294.767	-0.0027	-2.9004	178	294.832	0.0193	-3.3814
285.75	294.81	0.0119	-3.3242	292	294.712	-0.0214	#NUM!	223.5	294.798	0.0078	#NUM!
328.50	294.795	0.0068	-3.8632					269	294.745	-0.0102	#NUM!
408.50	294.781	0.0020	-4.9618								
430.75	294.774	-0.0003	#NUM!								

				sample-2		2*l* =0.055 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	355.82	2.1158	1.9997	0	355.26	1.9553	1.9226	0	354.594	1.7645	1.7974
0.25	355.64	2.0642	1.9751	0.75	355.01	1.8837	1.8854	2.25	354.222	1.6579	1.7338
0.50	355.543	2.0364	1.9615	1.25	354.674	1.7874	1.8331	3	353.789	1.5338	1.6542
0.75	355.332	1.9760	1.9314	2.75	354.231	1.6605	1.7596	4	353.564	1.4694	1.6102
1.75	354.84	1.8350	1.8574	3.75	353.897	1.5648	1.7004	5	353.32	1.3994	1.5602
3.25	354.311	1.6834	1.7712	6.75	353.61	1.4825	1.6465	5.5	353	1.3078	1.4907
5.25	354.007	1.5963	1.7181	8.75	353.21	1.3679	1.5663	6.5	352.684	1.2172	1.4168
6.25	353.33	1.4023	1.5886	10.75	352.661	1.2106	1.4446	9.5	351.349	0.8347	1.0257
8.58	352.108	1.0522	1.3016	11.75	351.661	0.9241	1.1756	11.5	351.006	0.7364	0.8945
10.42	351.48	0.8722	1.1142	32.75	349.674	0.3547	0.2255	15.5	350.649	0.6341	0.7367
22.42	350.648	0.6338	0.7953	51.5	349.312	0.2510	-0.1154	18.5	350.333	0.5436	0.5727
47.00	349.568	0.3244	0.1266	78.75	349	0.1616	-0.5465	21.5	350	0.4481	0.3646
70.75	349.256	0.2350	-0.1948	99.75	348.89	0.1301	-0.7572	31.5	349.325	0.2547	-0.2679
112.25	349.05	0.1759	-0.4829	122.75	348.699	0.0754	-1.2801	60.5	349	0.1616	-0.8210
139.75	348.9	0.1330	-0.7614	169.5	348.532	0.0275	-2.1982	87	348.87	0.1244	-1.1712
187.50	348.81	0.1072	-0.9755	217.5	348.468	0.0092	-3.0576	132.5	348.7	0.0756	-1.9661
234.50	348.665	0.0656	-1.4610	270.5	348.438	0.0006	-4.0745	178	348.6	0.0470	-3.2189
285.75	348.567	0.0375	-2.0099	292	348.421	-0.0043	#NUM!	223.5	348.56	0.0355	#NUM!
328.50	348.491	0.0158	-2.8473					269	348.521	0.0244	#NUM!
408.50	348.456	0.0057	-3.7723								
430.75	348.433	-0.0009	#NUM!								

					sample-3		2*l* =0.045 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	253.248	2.7569	1.9078		0	252.894	2.6138	1.8712		0	252.649	2.5147	1.8260
0.25	252.739	2.5511	1.8292		0.75	251.678	2.1222	1.6639		2.25	252.123	2.3021	1.7375
0.50	252.426	2.4246	1.7777		1.25	251.215	1.9350	1.5722		3	250.799	1.7668	1.4722
0.75	252.038	2.2677	1.7098		2.75	250.454	1.6273	1.4002		4	250.453	1.6269	1.3895
1.75	251.379	2.0013	1.5829		3.75	250.164	1.5101	1.3260		5	250.1	1.4842	1.2975
3.25	250.485	1.6398	1.3800		6.75	249.08	1.0718	0.9866		5.5	249.856	1.3855	1.2285
5.25	249.735	1.3366	1.1709		8.75	248.531	0.8498	0.7575		6.5	249.543	1.2590	1.1324
6.25	249.418	1.2084	1.0675		10.75	248.125	0.6857	0.5464		9.5	249	1.0395	0.9400
8.58	249.037	1.0544	0.9270		11.75	247.854	0.5761	0.3757		11.5	248.78	0.9505	0.8502
10.42	248.737	0.9331	0.8007		32.75	247.12	0.2794	-0.3257		15.5	248.5	0.8373	0.7227
22.42	248.103	0.6768	0.4656		51.5	247	0.2309	-0.5075		18.5	248.213	0.7213	0.5727
47.00	247.384	0.3861	-0.1347		78.75	246.8	0.1500	-0.9113		21.5	248	0.6352	0.4447
70.75	247.168	0.2988	-0.4186		99.75	246.7	0.1096	-1.1973		31.5	247.7	0.5139	0.2311
112.25	247.012	0.2357	-0.6892		122.75	246.632	0.0821	-1.4524		60.5	247.12	0.2794	-0.3857
139.75	246.902	0.1912	-0.9365		169.5	246.521	0.0372	-2.0956		87	246.623	0.0784	-1.6983
187.50	246.702	0.1104	-1.6503		217.5	246.457	0.0113	-2.8302		132.5	246.487	0.0234	-3.0576
234.50	246.601	0.0695	-2.3969		270.5	246.412	-0.0069	-4.2687		178	246.46	0.0125	-3.9120
285.75	246.575	0.0590	-2.7334		292	246.398	-0.0125	#NUM!		223.5	246.44	0.0044	#NUM!
328.50	246.552	0.0497	-3.1701							269	246.425	-0.0016	#NUM!
408.50	246.516	0.0352	-5.1160										
430.75	246.51	0.0327	#NUM!										

Table 20. Sorption Data of Polyester Samples containing 2 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

				sample-1		$2l$ =0.0577 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞	Time, h	Weight, mg	Water Content, wt%	M_t/M_∞	Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0.00	453.358	0.0000	0.0000	0.00	453.581	0.0492	0	0	453.43	0.0159	0.0000
0.50	453.519	0.0355	0.0206	0.33	453.738	0.0838	0.022	0.5	454	0.1416	0.0815
1.00	453.941	0.1286	0.0745	0.83	454.071	0.1573	0.067	0.75	454.211	0.1882	0.1117
2.00	454.38	0.2254	0.1307	1.33	454.28	0.2034	0.096	1.25	454.321	0.2124	0.1275
3.50	454.895	0.3390	0.1965	1.83	454.595	0.2729	0.139	1.75	454.566	0.2665	0.1625
5.50	455.506	0.4738	0.2746	2.33	454.762	0.3097	0.162	2.25	454.879	0.3355	0.2073
8.50	456.32	0.6533	0.3787	4.33	455.231	0.4131	0.227	2.75	455	0.3622	0.2246
10.75	456.832	0.7663	0.4442	5.67	455.653	0.5062	0.285	4.25	455.43	0.4570	0.2861
25.75	458.123	1.0510	0.6093	7.00	456	0.5828	0.333	7.25	455.76	0.5298	0.3333
50.75	458.921	1.2271	0.7113	20.00	457.32	0.8739	0.514	9.25	456	0.5828	0.3677
72.75	459.312	1.3133	0.7613	30.00	458	1.0239	0.608	11.25	456.321	0.6536	0.4136
98.08	459.6	1.3768	0.7981	37.75	458.52	1.1386	0.679	23.25	457.687	0.9549	0.6090
125.75	459.932	1.4501	0.8406	67.75	459.213	1.2915	0.775	53.75	458.7	1.1783	0.7539
169.50	460.333	1.5385	0.8918	98.00	459.411	1.3351	0.802	75.75	459.1	1.2665	0.8112
218.25	460.611	1.5998	0.9274	117.75	459.632	1.3839	0.832	105.3	459.4	1.3327	0.8541
264.42	460.82	1.6459	0.9541	142.50	459.81	1.4232	0.857	119.8	459.603	1.3775	0.8831
332.75	461.065	1.7000	0.9854	192.00	460.1	1.4871	0.897	146.3	459.743	1.4084	0.9031
412.25	461.165	1.7220	0.9982	239.00	460.3	1.5312	0.924	169.3	459.9	1.4430	0.9256
428.00	461.179	1.7251	1.0000	291.50	460.51	1.5776	0.953	214.3	460.076	1.4818	0.9508
				357.50	460.676	1.6142	0.976	240.8	460.181	1.5050	0.9658
				404.00	460.748	1.6301	0.986	265.8	460.26	1.5224	0.9771
				438.00	460.788	1.6389	0.991	293.3	460.31	1.5334	0.9843
				482.00	460.83	1.6481	0.997	316.8	460.36	1.5445	0.9914
				499.00	460.85	1.6526	1	361.25	460.389	1.5509	0.9956
								435.25	460.400	1.5533	0.9971
								483.25	460.410	1.5555	0.9986
								507.25	460.420	1.5577	1.0000

					sample-2		2*l* =0.0655 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0.00	350.069	0.0000	0.0000		0.00	350.39	0.0917	0		0	350.15	0.0231	0.0000
0.50	350.575	0.1445	0.0695		0.33	350.53	0.1317	0.022		0.5	350.499	0.1228	0.0506
1.00	350.865	0.2274	0.1093		0.83	350.698	0.1797	0.048		0.75	350.764	0.1985	0.0891
2.00	351.282	0.3465	0.1666		1.33	350.946	0.2505	0.086		1.25	350.823	0.2154	0.0976
3.50	351.794	0.4928	0.2369		1.83	351.093	0.2925	0.109		1.75	351	0.2659	0.1233
5.50	352.321	0.6433	0.3093		2.33	351.221	0.3291	0.128		2.25	351.175	0.3159	0.1487
8.50	352.763	0.7696	0.3700		4.33	351.6	0.4373	0.187		2.75	351.4	0.3802	0.1814
10.75	353.212	0.8978	0.4316		5.67	351.876	0.5162	0.229		4.25	351.789	0.4913	0.2378
25.75	353.998	1.1224	0.5395		7.00	352.1	0.5802	0.264		7.25	352.21	0.6116	0.2989
50.75	355.111	1.4403	0.6924		20.00	353.32	0.9287	0.452		9.25	352.564	0.7127	0.3503
72.75	356.112	1.7262	0.8299		30.00	354	1.1229	0.557		11.25	352.76	0.7687	0.3787
98.08	356.423	1.8151	0.8726		37.75	354.43	1.2458	0.624		23.25	353.654	1.0241	0.5084
125.75	356.644	1.8782	0.9029		67.75	355.106	1.4389	0.728		53.75	354.769	1.3426	0.6702
169.50	356.839	1.9339	0.9297		98.00	355.466	1.5417	0.784		75.75	355.138	1.4480	0.7237
218.25	357.011	1.9830	0.9533		117.75	355.614	1.5840	0.807		105.3	355.655	1.5957	0.7988
264.42	357.153	2.0236	0.9728		142.50	355.788	1.6337	0.834		119.8	355.862	1.6548	0.8288
332.75	357.289	2.0625	0.9915		192.00	356.021	1.7002	0.87		146.3	355.997	1.6934	0.8484
412.25	357.343	2.0779	0.9989		239.00	356.265	1.7699	0.907		169.3	356.219	1.7568	0.8806
428.00	357.351	2.0802	1.0000		291.50	356.488	1.8336	0.942		214.3	356.387	1.8048	0.9050
					357.50	356.753	1.9093	0.983		240.8	356.512	1.8405	0.9231
					404.00	356.838	1.9336	0.996		265.8	356.667	1.8848	0.9456
					438.00	356.843	1.9350	0.996		293.3	356.754	1.9096	0.9582
					482.00	356.86	1.9399	0.999		316.8	356.837	1.9333	0.9703
					499.00	356.866	1.9416	1		361.25	356.978	1.9736	0.9907
										435.25	357.025	1.9870	0.9975
										483.25	357.037	1.9905	0.9993
										507.25	357.042	1.9919	1.0000

					sample-3		2*l* =0.0455 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0.00	367.713	0.0000	0.0000		0.00	367.845	0.0359	0		0	367.86	0.0400	0.0000
0.50	368.316	0.1640	0.0781		0.33	368.381	0.1817	0.074		0.5	368.213	0.1360	0.0516
1.00	368.531	0.2225	0.1060		0.83	368.592	0.2390	0.103		0.75	368.327	0.1670	0.0683
2.00	368.911	0.3258	0.1552		1.33	369.137	0.3873	0.178		1.25	368.538	0.2244	0.0992
3.50	369.491	0.4835	0.2303		1.83	369.432	0.4675	0.219		1.75	368.7	0.2684	0.1229
5.50	369.89	0.5920	0.2820		2.33	369.711	0.5434	0.257		2.25	369	0.3500	0.1668
8.50	370.563	0.7751	0.3692		4.33	370	0.6220	0.297		2.75	369.154	0.3919	0.1893
10.75	371	0.8939	0.4258		5.67	370.35	0.7171	0.346		4.25	369.35	0.4452	0.2180
25.75	372.465	1.2923	0.6156		7.00	370.52	0.7634	0.369		7.25	369.67	0.5322	0.2648
50.75	373.286	1.5156	0.7220		20.00	371.674	1.0772	0.528		9.25	370	0.6220	0.3130
72.75	373.833	1.6643	0.7928		30.00	372.332	1.2561	0.619		11.25	370.348	0.7166	0.3640
98.08	374.201	1.7644	0.8405		37.75	372.686	1.3524	0.668		23.25	371.32	0.9809	0.5061
125.75	374.463	1.8357	0.8745		67.75	373.515	1.5779	0.782		53.75	373	1.4378	0.7519
169.50	374.721	1.9058	0.9079		98.00	373.869	1.6741	0.831		75.75	373.421	1.5523	0.8135
218.25	374.965	1.9722	0.9395		117.75	374.034	1.7190	0.854		105.3	373.784	1.6510	0.8666
264.42	375.189	2.0331	0.9685		142.50	374.243	1.7758	0.882		119.8	373.899	1.6823	0.8834
332.75	375.346	2.0758	0.9889		192.00	374.445	1.8308	0.91		146.3	374.076	1.7304	0.9093
412.25	375.402	2.0910	0.9961		239.00	374.645	1.8852	0.938		169.3	374.169	1.7557	0.9229
428.00	375.432	2.0992	1.0000		291.50	374.812	1.9306	0.961		214.3	374.311	1.7943	0.9437
					357.50	374.986	1.9779	0.985		240.8	374.387	1.8150	0.9548
					404.00	375.056	1.9969	0.995		265.8	374.412	1.8218	0.9585
					438.00	375.068	2.0002	0.996		293.3	374.464	1.8359	0.9661
					482.00	375.088	2.0056	0.999		316.8	374.498	1.8452	0.9710
					499.00	375.095	2.0075	1		361.25	374.564	1.8631	0.9807
										435.25	374.663	1.8901	0.9952
										483.25	374.688	1.8969	0.9988
										507.25	374.696	1.8990	1.0000

Table 21. Desorption Data of Polyester Samples containing 2 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

					sample-1		2*l* =0.0577 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	461.187	1.7269	2.0278		0	460.866	1.6561	1.9984		0	460.43	1.5599	1.8825
0.25	460.89	1.6614	1.9879		0.5	460.677	1.6144	1.9724		0.25	460.21	1.5114	1.8485
0.75	460.321	1.5359	1.9067		1	460.432	1.5604	1.9377		0.75	460	1.4651	1.8148
1.75	459.675	1.3934	1.8058		1.75	460.123	1.4922	1.8922		1.25	459.679	1.3943	1.7611
2.25	459.321	1.3153	1.7459		2.5	459.765	1.4132	1.8367		2.25	459	1.2445	1.6371
4.25	458.444	1.1219	1.5798		4.5	459.122	1.2714	1.7286		3.25	458.237	1.0762	1.4764
6.25	457.78	0.9754	1.4327		6.5	458.32	1.0945	1.5751		7	457.235	0.8552	1.2164
8.58	457.43	0.8982	1.3455		8.5	457.213	0.8503	1.3148		10	456.531	0.6999	0.9825
22.42	456.87	0.7747	1.1878		11.5	456	0.5828	0.9207		29.75	455.432	0.4575	0.4523
24.50	456.021	0.5874	0.8883		32.5	455.3	0.4284	0.5939		54.75	454.897	0.3395	0.0363
47.00	455	0.3622	0.3436		51.25	454.78	0.3137	0.2554		84.75	454.643	0.2834	-0.2446
70.75	454.453	0.2415	-0.1473		78.5	454.321	0.2124	-0.1839		111.25	454.397	0.2292	-0.6218
94.75	454.12	0.1681	-0.6349		98.5	454	0.1416	-0.6714		154.75	454.3	0.2078	-0.8210
112.25	453.98	0.1372	-0.9416		145.25	453.87	0.1129	-0.9650		198.75	454.1	0.1637	-1.4271
139.75	453.9	0.1196	-1.1712		193.25	453.76	0.0887	-1.3056		248.75	453.98	0.1372	-2.1203
187.50	453.832	0.1046	-1.4188		246.25	453.69	0.0732	-1.6045		292.75	453.94	0.1284	-2.5257
234.50	453.756	0.0878	-1.7958		267.75	453.6	0.0534	-2.1982		350.25	453.9	0.1196	-3.2189
285.75	453.7	0.0754	-2.2073		311.75	453.578	0.0485	-2.4191		395.75	453.89	0.1173	-3.5066
328.50	453.67	0.0688	-2.5257		383.75	453.543	0.0408	-2.9188		441.25	453.87	0.1129	-4.6052
380.25	453.64	0.0622	-2.9957		431.75	453.512	0.0340	-3.7723		486.75	453.86	0.1107	#NUM!
430.75	453.6	0.0534	-4.6052		455.75	453.5	0.0313	-4.5099					
453.50	453.590	0.0512	#NUM!		479.5	453.489	0.0289	#NUM!					

					sample-2		2*l*=0.0655 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	357.364	2.0839	1.9408		0	356.864	1.9410	1.9027		0	357.048	1.9936	1.93442
0.25	356.896	1.9502	1.8712		0.5	356.651	1.8802	1.8704		0.25	356.394	1.8068	1.83514
0.75	355.059	1.4254	1.5388		1	356.421	1.8145	1.8343		0.75	355.849	1.6511	1.74414
1.75	354.496	1.2646	1.4100		1.75	356.235	1.7614	1.8042		1.25	355.463	1.5408	1.67429
2.25	354.131	1.1603	1.3167		2.5	356.012	1.6977	1.7668		2.25	354.687	1.3192	1.5171
4.25	353.615	1.0129	1.1678		4.5	355.423	1.5294	1.6607		3.25	353.976	1.1161	1.34755
6.25	352.542	0.7064	0.7617		6.5	354.334	1.2183	1.4289		7	352.687	0.7479	0.93962
8.58	352.12	0.5859	0.5423		8.5	353.295	0.9215	1.1426		10	351.627	0.4451	0.4048
22.42	351.869	0.5142	0.3846		11.5	352.456	0.6819	0.8312		29.75	350.943	0.2497	-0.2046
24.50	351.343	0.3639	-0.0587		32.5	352	0.5516	0.6098		54.75	350.591	0.1491	-0.77
47.00	351	0.2659	-0.5108		51.25	351.532	0.4179	0.3163		84.75	350.542	0.1351	-0.8819
70.75	350.812	0.2122	-0.8867		78.5	351.121	0.3005	-0.0398		111.25	350.421	0.1006	-1.2276
94.75	350.7	0.1803	-1.2040		98.5	350.786	0.2048	-0.4684		154.75	350.312	0.0694	-1.6928
112.25	350.63	0.1603	-1.4697		145.25	350.56	0.1403	-0.9163		198.75	350.287	0.0623	-1.8389
139.75	350.58	0.1460	-1.7148		193.25	350.42	0.1003	-1.3471		248.75	350.234	0.0471	-2.2443
187.50	350.53	0.1317	-2.0402		246.25	350.32	0.0717	-1.8326		292.75	350.189	0.0343	-2.7969
234.50	350.5	0.1231	-2.3026		267.75	350.267	0.0566	-2.2349		350.25	350.167	0.0280	-3.2442
285.75	350.487	0.1194	-2.4418		311.75	350.21	0.0403	-2.9957		395.75	350.145	0.0217	-4.0745
328.50	350.466	0.1134	-2.7181		383.75	350.187	0.0337	-3.6119		441.25	350.132	0.0180	-5.5215
380.25	350.445	0.1074	-3.1011		431.75	350.18	0.0317	-3.9120		486.75	350.128	0.0169	#NUM!
430.75	350.42	0.1003	-3.9120		455.75	350.16	0.0260	#NUM!					
453.50	350.400	0.0946	#NUM!		479.5	350.16	0.0260	#NUM!					

					sample-3		2*l*=0.0455 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	375.451	2.1044	2.0275		0	375.099	2.0086	1.9781		0	374.711	1.9031	1.9330
0.25	375.211	2.0391	1.9954		0.5	374.685	1.8960	1.9191		0.25	374.156	1.7522	1.8492
0.75	374.387	1.8150	1.8766		1	374.421	1.8242	1.8796		0.75	373.289	1.5164	1.7026
1.75	373.279	1.5137	1.6906		1.75	374.156	1.7522	1.8383		1.25	372.905	1.4120	1.6300
2.25	372.886	1.4068	1.6154		2.5	373.843	1.6671	1.7872		2.25	372.126	1.2001	1.4644
4.25	371.579	1.0514	1.3145		4.5	373.021	1.4435	1.6392		3.25	371.421	1.0084	1.2865
6.25	370.448	0.7438	0.9524		6.5	372	1.1659	1.4183		7	370.784	0.8352	1.0929
8.58	370.002	0.6225	0.7636		8.5	371.198	0.9478	1.2024		10	369.913	0.5983	0.7476
22.42	369.546	0.4985	0.5247		11.5	370.564	0.7753	0.9910		29.75	369.337	0.4416	0.4292
24.50	369.1	0.3772	0.2183		32.5	369.876	0.5882	0.6961		54.75	368.777	0.2894	-0.0243
47.00	368.864	0.3130	0.0080		51.25	369.234	0.4136	0.3104		84.75	368.564	0.2314	-0.2705
70.75	368.6	0.2412	-0.2957		78.5	368.675	0.2616	-0.2169		111.25	368.453	0.2012	-0.4277
94.75	368.457	0.2023	-0.5092		98.5	368.321	0.1653	-0.7963		154.75	368.323	0.1659	-0.6501
112.25	368.323	0.1659	-0.7614		145.25	368.123	0.1115	-1.3744		198.75	368.121	0.1110	-1.1394
139.75	368.213	0.1360	-1.0300		193.25	368.032	0.0868	-1.8202		248.75	368.002	0.0786	-1.6045
187.50	368.154	0.1199	-1.2107		246.25	367.965	0.0685	-2.3539		292.75	367.898	0.0503	-2.3330
234.50	368.067	0.0963	-1.5559		267.75	367.932	0.0596	-2.7806		350.25	367.856	0.0389	-2.9004
285.75	367.987	0.0745	-2.0326		311.75	367.9	0.0509	-3.5066		395.75	367.832	0.0324	-3.4738
328.50	367.943	0.0625	-2.4418		383.75	367.89	0.0481	-3.9120		441.25	367.811	0.0267	-4.6052
380.25	367.91	0.0536	-2.9188		431.75	367.88	0.0454	-4.6052		486.75	367.801	0.0239	#NUM!
430.75	367.878	0.0449	-3.8167		455.75	367.87	0.0427	#NUM!					
453.50	367.856	0.0389	#NUM!		479.5	367.87	0.0427	#NUM!					

Table 22. Sorption Data of Polyester Samples containing 5 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

					sample-1		2*l* =0.06 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0.00	419.701	0.0000	0.0000		0.00	419.98	0.0665	0.0000		0	420.16	0.1094	0.0000
0.50	419.951	0.0596	0.0295		0.33	420.115	0.0986	0.0159		0.25	420.43	0.1737	0.0324
1.00	420.235	0.1272	0.0631		0.83	420.349	0.1544	0.0435		0.75	420.991	0.3074	0.0996
2.00	420.667	0.2302	0.1141		1.83	421.068	0.3257	0.1282		1.75	421.578	0.4472	0.1700
3.50	421.301	0.3812	0.1889		2.33	421.384	0.4010	0.1654		3.25	421.967	0.5399	0.2167
5.50	421.989	0.5451	0.2702		4.33	422.013	0.5509	0.2395		7	422.435	0.6514	0.2728
8.50	422.32	0.6240	0.3092		6.75	422.523	0.6724	0.2995		10	423	0.7860	0.3405
10.75	422.7	0.7146	0.3541		21.75	423.811	0.9793	0.4512		13	423.512	0.9080	0.4019
25.75	424	1.0243	0.5076		46.50	425	1.2626	0.5913		30	424.78	1.2101	0.5540
50.75	426	1.5008	0.7438		96.00	426	1.5008	0.7091		55	426.444	1.6066	0.7535
72.75	426.765	1.6831	0.8341		143.00	426.87	1.7081	0.8115		78	427	1.7391	0.8201
98.08	427.23	1.7939	0.8890		195.50	427.45	1.8463	0.8799		126.2	427.521	1.8632	0.8826
125.75	427.533	1.8661	0.9248		221.50	427.678	1.9006	0.9067		178	427.832	1.9373	0.9199
169.50	427.7	1.9059	0.9445		261.50	427.898	1.9531	0.9326		229.7	428.211	2.0276	0.9653
218.25	427.9	1.9535	0.9681		308.00	428.065	1.9928	0.9523		281.5	428.3	2.0488	0.9760
264.42	428	1.9774	0.9799		364.75	428.187	2.0219	0.9667		333.2	428.4	2.0727	0.9880
332.75	428.121	2.0062	0.9942		430.75	428.287	2.0457	0.9784		393	428.45	2.0846	0.9940
381.25	428.143	2.0114	0.9968		477.50	428.376	2.0669	0.9889		418	428.48	2.0917	0.9976
412.25	428.156	2.0145	0.9983		525.50	428.453	2.0853	0.9980		438	428.5	2.0965	1.0000
428.00	428.17	2.0179	1.0000		554.50	428.47	2.0893	1.0000					

					sample-2		2*l* =0.06 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0.00	341.934	0.0000	0.0000		0.00	341.941	0.0020	0.0000		0	342.04	0.0310	0.0000
0.50	342.608	0.1971	0.0780		0.33	342.396	0.1351	0.0544		0.25	342.223	0.0845	0.0209
1.00	343.012	0.3153	0.1247		0.83	342.715	0.2284	0.0925		0.75	342.687	0.2202	0.0739
2.00	343.67	0.5077	0.2008		1.83	343.482	0.4527	0.1841		1.75	343.246	0.3837	0.1377
3.50	344.22	0.6686	0.2644		2.33	343.859	0.5630	0.2292		3.25	343.687	0.5127	0.1880
5.50	344.641	0.7917	0.3131		4.33	344.665	0.7987	0.3255		7	344.32	0.6978	0.2603
8.50	345.231	0.9642	0.3813		6.75	345.298	0.9838	0.4011		10	344.77	0.8294	0.3116
10.75	345.6	1.0721	0.4240		21.75	346.564	1.3541	0.5524		13	345.231	0.9642	0.3643
25.75	346.786	1.4190	0.5612		46.50	347.1	1.5108	0.6164		30	347	1.4816	0.5662
50.75	348.33	1.8705	0.7398		96.00	347.98	1.7682	0.7216		55	348.67	1.9700	0.7568
72.75	348.987	2.0627	0.8158		143.00	348.87	2.0285	0.8279		78	349.23	2.1337	0.8208
98.08	349.4	2.1835	0.8635		195.50	349.5	2.2127	0.9032		126.2	349.765	2.2902	0.8818
125.75	349.89	2.3268	0.9202		221.50	349.7	2.2712	0.9271		178	350.21	2.4204	0.9326
169.50	350.2	2.4174	0.9560		261.50	349.876	2.3227	0.9481		229.7	350.51	2.5081	0.9669
218.25	350.35	2.4613	0.9734		308.00	350	2.3589	0.9630		281.5	350.61	2.5373	0.9783
264.42	350.45	2.4905	0.9850		364.75	350.098	2.3876	0.9747		333.2	350.7	2.5637	0.9886
332.75	350.51	2.5081	0.9919		430.75	350.165	2.4072	0.9827		393	350.75	2.5783	0.9943
381.25	350.54	2.5169	0.9954		477.50	350.243	2.4300	0.9920		418	350.789	2.5897	0.9987
412.25	350.568	2.5250	0.9986		525.50	350.28	2.4408	0.9964		438	350.8	2.5929	1.0000
428.00	350.58	2.5286	1.0000		554.50	350.31	2.4496	1.0000					

					sample-3		2*l* =0.04 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞		Time, h	Weight, mg	Water Content, wt%	M_t/M_∞
0.00	287.561	0.0000	0.0000		0.00	287.674	0.0393	0.0000		0	287.678	0.0407	0.0000
0.50	287.745	0.0640	0.0220		0.33	287.875	0.1092	0.0243		0.25	287.887	0.1134	0.0247
1.00	287.932	0.1290	0.0443		0.83	288.369	0.2810	0.0840		0.75	288.429	0.3018	0.0889
2.00	288.267	0.2455	0.0843		1.83	289.154	0.5540	0.1788		1.75	288.889	0.4618	0.1433
3.50	288.77	0.4204	0.1444		2.33	289.397	0.6385	0.2081		3.25	289.512	0.6785	0.2171
5.50	289.21	0.5734	0.1969		4.33	289.969	0.8374	0.2772		7	290.13	0.8934	0.2902
8.50	289.89	0.8099	0.2781		6.75	290.545	1.0377	0.3468		10	290.786	1.1215	0.3679
10.75	290.23	0.9282	0.3187		21.75	291.489	1.3660	0.4609		13	291.2	1.2655	0.4169
25.75	292	1.5437	0.5301		46.50	292.654	1.7711	0.6016		30	293.089	1.9224	0.6404
50.75	293.67	2.1244	0.7295		96.00	293.536	2.0778	0.7081		55	294.112	2.2781	0.7615
72.75	294.567	2.4364	0.8366		143.00	294.166	2.2969	0.7842		78	294.689	2.4788	0.8298
98.08	295.245	2.6721	0.9176		195.50	294.841	2.5316	0.8658		126.2	295.574	2.7865	0.9345
125.75	295.443	2.7410	0.9412		221.50	295.264	2.6787	0.9169		178	295.788	2.8610	0.9599
169.50	295.654	2.8144	0.9664		261.50	295.454	2.7448	0.9398		229.7	295.922	2.9076	0.9757
218.25	295.732	2.8415	0.9758		308.00	295.646	2.8116	0.9630		281.5	296.043	2.9496	0.9901
264.42	295.765	2.8530	0.9797		364.75	295.785	2.8599	0.9798		333.2	296.076	2.9611	0.9940
332.75	295.854	2.8839	0.9903		430.75	295.865	2.8877	0.9895		393	296.109	2.9726	0.9979
381.25	295.889	2.8961	0.9945		477.50	295.889	2.8961	0.9924		418	296.121	2.9768	0.9993
412.25	295.912	2.9041	0.9973		525.50	295.922	2.9076	0.9964		438	296.127	2.9788	1.0000
428.00	295.935	2.9121	1.0000		554.50	295.952	2.9180	1.0000					

Table 23. Desorption Data of Polyester Samples containing 5 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

				sample-1		2*l* =0.06 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	428.18	2.0202	2.1017	0	428.48	2.0917	2.11746	0	428.51	2.0989	2.11866
0.25	427.98	1.9726	2.0769	0.5	428.12	2.0060	2.07317	0.25	428.321	2.0538	2.09568
0.75	427.32	1.8153	1.9906	0.75	427.878	1.9483	2.04226	0.5	428	1.9774	2.0554
1.75	426.569	1.6364	1.8824	1.75	427.342	1.8206	1.97018	0.75	427.769	1.9223	2.02538
3.25	425.879	1.4720	1.7714	4.75	426.654	1.6567	1.86934	1.25	427.624	1.8878	2.00606
5.25	425.312	1.3369	1.6700	7.25	425.765	1.4448	1.72187	1.75	427.031	1.7465	1.92293
8.58	424.786	1.2116	1.5657	9.25	424.482	1.1391	1.4614	2.25	426.113	1.5278	1.77884
10.42	424.564	1.1587	1.5182	11	423.563	0.9202	1.22171	3.25	425.114	1.2897	1.59412
24.50	423.372	0.8747	1.2155	71.25	422.252	0.6078	0.73333	4.25	424.482	1.1391	1.45675
47.00	422.811	0.7410	1.0335	95.25	421.897	0.5232	0.54639	5.25	423.913	1.0036	1.31453
70.75	422.478	0.6617	0.9075	119.25	421.554	0.4415	0.32498	6.25	422.752	0.7269	0.94079
94.75	421.854	0.5130	0.6173	176	421.231	0.3645	0.05921	8.5833	422.439	0.6524	0.81049
139.75	421.312	0.3838	0.2716	200	421	0.3095	-0.1863	10.417	422.216	0.5992	0.70606
187.50	420.88	0.2809	-0.1278	250	420.797	0.2611	-0.4668	22.417	421.632	0.4601	0.36603
234.50	420.688	0.2352	-0.3740	292	420.6	0.2142	-0.844	24.5	421.3	0.3810	0.10436
285.75	420.5	0.1904	-0.6931	345	420.5	0.1904	-1.1087	47	420.9	0.2857	-0.3425
380.25	420.245	0.1296	-1.4065	413	420.412	0.1694	-1.4188	91.5	420.765	0.2535	-0.5534
477.50	420.132	0.1027	-2.0250	507.25	420.34	0.1523	-1.772	165.75	420.532	0.1980	-1.0729
501.50	420.076	0.0893	-2.5770	536.25	420.287	0.1396	-2.1456	260.25	420.343	0.1530	-1.8773
549.50	420	0.0712	#NUM!	581.25	420.23	0.1260	-2.8134	310.75	420.24	0.1284	-2.9957
				623.25	420.2	0.1189	-3.5066	381.5	420.2	0.1189	-4.6052
				646.25	420.189	0.1163	-3.9633	429.5	420.198	0.1184	-4.8283
				671.25	420.17	0.1117	#NUM!	453.75	420.19	0.1165	#NUM!

					sample-2		2*l*=0.06 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)
0.00	350.59	2.5315	2.1567		0.00	350.32	2.4525	2.1126		0.00	350.564	2.5239	2.1294
0.25	350	2.3589	2.0860		0.50	350	2.3589	2.0732		0.25	350.1122	2.3917	2.0742
0.75	349.675	2.2639	2.0449		0.75	349.786	2.2963	2.0459		0.50	349.876	2.3227	2.0441
1.75	349.43	2.1922	2.0126		1.75	349.521	2.2188	2.0110		0.75	349.54	2.2244	1.9996
3.25	349.21	2.1279	1.9828		4.75	348.418	1.8963	1.8513		1.25	349	2.0665	1.9237
5.25	348.898	2.0367	1.9389		7.25	347.342	1.5816	1.6662		1.75	348.418	1.8963	1.8348
8.58	348.745	1.9919	1.9166		9.25	346.624	1.3716	1.5204		2.25	347.342	1.5816	1.6463
10.42	348.496	1.9191	1.8793		11.00	346	1.1891	1.3737		3.25	346.624	1.3716	1.4974
24.50	347.706	1.6880	1.7508		71.25	344.589	0.7765	0.9318		4.25	346.047	1.2029	1.3592
47.00	346.534	1.3453	1.5232		95.25	344.101	0.6337	0.7183		5.25	344.589	0.7765	0.8899
70.75	345.764	1.1201	1.3395		119.25	343.679	0.5103	0.4880		6.25	344.101	0.6337	0.6663
94.75	345.081	0.9204	1.1423		176.00	343.23	0.3790	0.1655		8.58	343.679	0.5103	0.4220
139.75	344.026	0.6118	0.7319		200.00	342.978	0.3053	-0.0747		10.42	343.23	0.3790	0.0733
187.50	343.283	0.3945	0.2897		250.00	342.745	0.2372	-0.3638		22.42	342.899	0.2822	-0.2944
234.50	342.787	0.2495	-0.1744		292.00	342.632	0.2041	-0.5413		24.50	342.8	0.2533	-0.4370
285.75	342.461	0.1541	-0.6655		345.00	342.412	0.1398	-1.0161		47.00	342.545	0.1787	-0.9390
380.25	342.101	0.0488	-1.8708		413.00	342.3	0.1070	-1.3863		91.50	342.41	0.1392	-1.3626
477.50	341.996	0.0181	-3.0159		507.25	342.2	0.0778	-1.8971		165.75	342.32	0.1129	-1.7958
501.50	341.986	0.0152	-3.2442		536.25	342.15	0.0632	-2.3026		260.25	342.276	0.1000	-2.1037
549.50	341.947	0.0038	#NUM!		581.25	342.11	0.0515	-2.8134		310.75	342.223	0.0845	-2.6736
					623.25	342.089	0.0453	-3.2442		381.50	342.189	0.0746	-3.3524
					646.25	342.06	0.0368	-4.6052		429.50	342.176	0.0708	-3.8167
					671.25	342.05	0.0339	#NUM!		453.75	342.154	0.0643	#NUM!

				sample-3		2*l* =0.04 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0.00	295.951	2.9176	2.1128	0	295.944	2.9152	2.11106	0	294.947	2.5685	1.9526
0.25	295.612	2.7998	2.0709	0.5	295.63	2.8060	2.07229	0.25	294.155	2.2931	1.83338
0.75	295.043	2.6019	1.9965	0.75	294.947	2.5685	1.98238	0.5	293.953	2.2228	1.80055
1.75	294.364	2.3658	1.8997	1.75	293.953	2.2228	1.83514	0.75	293.372	2.0208	1.69964
3.25	293.532	2.0764	1.7668	4.75	292.255	1.6323	1.51908	1.25	292.255	1.6323	1.47132
5.25	292.664	1.7746	1.6062	7.25	291.8	1.4741	1.41415	1.75	291.8	1.4741	1.36098
8.58	291.845	1.4898	1.4267	9.25	291.231	1.2763	1.26526	2.25	291.231	1.2763	1.20327
10.42	291.533	1.3813	1.3489	11	290.698	1.0909	1.10227	3.25	290.698	1.0909	1.0289
24.50	290.387	0.9827	0.9958	71.25	289.388	0.6353	0.53122	4.25	289.788	0.7744	0.63552
47.00	289.612	0.7132	0.6586	95.25	288.999	0.5001	0.27155	5.25	289.53	0.6847	0.48858
70.75	289.064	0.5227	0.3250	119.25	288.673	0.3867	-0.0141	6.25	289.232	0.5811	0.28668
94.75	288.815	0.4361	0.1266	176	288.476	0.3182	-0.237	8.5833	288.967	0.4889	0.06485
139.75	288.521	0.3338	-0.1732	200	288.387	0.2872	-0.3567	10.417	288.743	0.4110	-0.1708
187.50	288.311	0.2608	-0.4604	250	288.203	0.2233	-0.6616	22.417	288.632	0.3724	-0.312
234.50	288.086	0.1826	-0.9014	292	288.112	0.1916	-0.8557	24.5	288.53	0.3370	-0.462
285.75	287.932	0.1290	-1.3783	345	287.977	0.1447	-1.2379	47	288.412	0.2959	-0.6694
380.25	287.812	0.0873	-2.0250	413	287.855	0.1022	-1.7838	91.5	288.3	0.2570	-0.9163
477.50	287.734	0.0602	-2.9188	507.25	287.8	0.0831	-2.1804	165.75	288.2	0.2222	-1.204
501.50	287.689	0.0445	-4.7105	536.25	287.776	0.0748	-2.4191	260.25	288.087	0.1829	-1.6766
549.50	287.68	0.0414	#NUM!	581.25	287.743	0.0633	-2.8824	310.75	287.998	0.1520	-2.3228
				623.25	287.723	0.0563	-3.3242	381.5	287.956	0.1374	-2.8824
				646.25	287.7	0.0483	-4.3428	429.5	287.932	0.1290	-3.442
				671.25	287.687	0.0438	#NUM!	453.75	287.9	0.1179	#NUM!

Table 24. Sorption Data of Epoxy Samples containing 0 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

					sample-1		2*l* =0.104 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞
0	791.108	0.0000	0.0000		0.00	791.251	0.0181	0.0000		0	791.336	0.0288	0.0000
0.5	791.262	0.0194	0.0116		0.50	791.693	0.0739	0.0338		0.25	791.618	0.0644	0.0216
1.5	791.859	0.0948	0.0566		1.00	792.015	0.1145	0.0583		0.75	791.915	0.1019	0.0443
4	791.954	0.1068	0.0638		1.50	792	0.1126	0.0572		1.25	791.942	0.1053	0.0464
5.5	792.459	0.1706	0.1019		2.50	792.426	0.1664	0.0897		2.25	792.45	0.1695	0.0853
7	792.795	0.2130	0.1272		3.50	792.87	0.2225	0.1236		4.25	792.679	0.1984	0.1028
8	792.81	0.2149	0.1283		5.50	793.21	0.2655	0.1496		6.75	793.043	0.2444	0.1307
10.75	793.089	0.2502	0.1494		7.50	793.52	0.3046	0.1733		8.75	793.423	0.2924	0.1598
11.75	793.553	0.3088	0.1843		8.50	793.89	0.3513	0.2015		10.75	793.743	0.3328	0.1842
25.75	794.64	0.4460	0.2663		10.50	794.123	0.3807	0.2193		22.75	794.659	0.4484	0.2544
32.75	795.803	0.5929	0.3540		11.50	794.316	0.4051	0.2341		44.25	796.856	0.7259	0.4225
49.75	796.88	0.7289	0.4352		12.50	794.437	0.4204	0.2433		67.5	797.684	0.8305	0.4859
75.25	798.026	0.8736	0.5216		24.50	795.613	0.5689	0.3331		192.5	801.231	1.2784	0.7574
95.25	798.972	0.9931	0.5929		45.00	796.372	0.6648	0.3911		435.25	803.21	1.5283	0.9089
122.75	799.667	1.0809	0.6453		75.50	797.707	0.8334	0.4931		501.25	803.654	1.5844	0.9429
149.25	800.383	1.1713	0.6993		94.00	798.502	0.9338	0.5538		581.25	804	1.6281	0.9694
166.25	800.764	1.2194	0.7280		118.50	799.245	1.0276	0.6105		627.25	804.213	1.6550	0.9857
192	801.246	1.2803	0.7643		150.50	800.173	1.1448	0.6814		675.25	804.31	1.6672	0.9931
218.25	801.696	1.3371	0.7983		172.50	800.672	1.2078	0.7195		723.25	804.35	1.6723	0.9962
244.75	802.122	1.3909	0.8304		188.50	801.095	1.2612	0.7518		747.25	804.39	1.6773	0.9992
271.25	802.441	1.4312	0.8544		221.00	801.745	1.3433	0.8014		771.25	804.4	1.6786	1.0000
291.25	802.782	1.4743	0.8801		271.00	802.472	1.4351	0.8570					
313.5	802.946	1.4950	0.8925		314.50	803.102	1.5147	0.9051					
337	803.091	1.5133	0.9034		364.00	803.445	1.5580	0.9313					
365	803.304	1.5402	0.9195		417.00	803.702	1.5904	0.9509					
387	803.445	1.5580	0.9301		462.00	803.926	1.6187	0.9680					
409	803.572	1.5740	0.9397		509.00	804.122	1.6435	0.9830					
437.75	803.713	1.5918	0.9503		549.00	804.193	1.6524	0.9884					
486.25	803.890	1.6142	0.9637		601.00	804.232	1.6574	0.9914					
538.25	804.075	1.6375	0.9776		650.00	804.292	1.6649	0.9960					
579.75	804.237	1.6580	0.9898		675.00	804.315	1.6678	0.9977					
629.25	804.299	1.6658	0.9945		702.00	804.345	1.6716	1.0000					
671.25	804.339	1.6709	0.9975										
700.25	804.335	1.6704	0.9972										
752.67	804.350	1.6723	0.9983										
793.75	804.381	1.6762	1.0007										
818.25	804.372	1.6750	1.0000										

					sample-2		2*l*=0.104 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞
0	691.349	0.0000	0.0000		0.00	692.059	0.1025	0		0	692.192	0.1218	0
0.5	691.875	0.0760	0.0423		0.50	692.21	0.1244	0.0126		0.25	692.518	0.1688	0.02803
1.5	692.371	0.1476	0.0821		1.00	692.261	0.1317	0.0168		0.75	692.661	0.1895	0.04033
4	692.876	0.2205	0.1227		1.50	692.596	0.1801	0.0448		1.25	692.928	0.2281	0.06329
5.5	693.026	0.2422	0.1347		2.50	692.942	0.2301	0.0736		2.25	693.321	0.2848	0.09708
7	693.289	0.2802	0.1558		3.50	693.185	0.2652	0.0939		4.25	693.765	0.3489	0.13527
8	693.376	0.2928	0.1628		5.50	693.562	0.3196	0.1253		6.75	694	0.3829	0.15547
10.75	693.511	0.3123	0.1737		7.50	693.917	0.3709	0.1549		8.75	694.564	0.4643	0.20397
11.75	693.883	0.3660	0.2036		8.50	694.083	0.3949	0.1688		10.75	695	0.5273	0.24147
25.75	695	0.5273	0.2933		10.50	694.441	0.4466	0.1986		22.75	695.643	0.6202	0.29676
32.75	695.6	0.6140	0.3415		11.50	694.661	0.4784	0.217		44.25	696.879	0.7987	0.40304
49.75	696.2	0.7006	0.3897		12.50	694.793	0.4974	0.228		67.5	698	0.9606	0.49944
75.25	697	0.8162	0.4540		24.50	695.465	0.5945	0.284		192.5	700.786	1.3630	0.73901
95.25	698	0.9606	0.5343		45.00	696.574	0.7547	0.3765		435.25	702.976	1.6793	0.92734
122.75	698.41	1.0198	0.5672		75.50	697.793	0.9307	0.4781		501.25	703.423	1.7439	0.96578
149.25	698.943	1.0968	0.6101		94.00	698.476	1.0294	0.5351		581.25	703.611	1.7710	0.98194
166.25	699.2	1.1339	0.6307		118.50	699.018	1.1076	0.5803		627.25	703.7	1.7839	0.98959
192	699.4	1.1628	0.6468		150.50	699.702	1.2064	0.6373		675.25	703.743	1.7901	0.99329
218.25	699.8	1.2206	0.6789		172.50	700.221	1.2814	0.6806		723.25	703.768	1.7937	0.99544
244.75	700.222	1.2815	0.7128		188.50	700.527	1.3256	0.7061		747.25	703.791	1.7970	0.99742
271.25	700.918	1.3821	0.7687		221.00	701.083	1.4059	0.7524		771.25	703.821	1.8013	1
291.25	701.155	1.4163	0.7878		271.00	702.002	1.5386	0.8291					
313.5	701.486	1.4641	0.8143		314.50	702.588	1.6233	0.8779					
337	701.716	1.4973	0.8328		364.00	702.916	1.6706	0.9053					
365	702.097	1.5523	0.8634		417.00	703.216	1.7140	0.9303					
387	702.331	1.5861	0.8822		462.00	703.482	1.7524	0.9525					
409	702.554	1.6184	0.9001		509.00	703.671	1.7797	0.9682					
437.75	702.793	1.6529	0.9193		549.00	703.827	1.8022	0.9812					
486.25	703.013	1.6846	0.9370		601.00	703.972	1.8232	0.9933					
538.25	703.174	1.7079	0.9500		650.00	704.032	1.8318	0.9983					
579.75	703.355	1.7340	0.9645		675.00	704.043	1.8334	0.9992					
629.25	703.464	1.7498	0.9732		702.00	704.052	1.8347	1.0000					
671.25	703.575	1.7658	0.9822										
700.25	703.641	1.7753	0.9875										
752.67	703.730	1.7882	0.9946										
793.75	703.780	1.7954	0.9986										
818.25	703.797	1.7979	1.0000										

					sample-3		2*l*=0.099 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞
0	630.593	0.0000	0.0000		0.00	630.9	0.0486	0		0	631.089	0.0786	0
0.5	630.702	0.0173	0.0097		0.50	631.155	0.0891	0.0221		0.25	631.432	0.1329	0.03076
1.5	631.08	0.0772	0.0433		1.00	631.565	0.1540	0.0577		0.75	631.677	0.1718	0.05273
4	631.665	0.1699	0.0952		1.50	631.898	0.2068	0.0865		1.25	631.8	0.1913	0.06376
5.5	631.84	0.1976	0.1108		2.50	632.356	0.2794	0.1262		2.25	632.21	0.2562	0.10053
7	632.51	0.3038	0.1703		3.50	632.915	0.3679	0.1747		4.25	632.546	0.3095	0.13066
8	632.646	0.3253	0.1824		5.50	633.355	0.4377	0.2128		6.75	632.98	0.3782	0.16958
10.75	632.718	0.3367	0.1888		7.50	633.656	0.4854	0.2389		8.75	633.543	0.4675	0.22007
11.75	632.532	0.3073	0.1722		8.50	633.83	0.5129	0.254		10.75	633.987	0.5378	0.25989
25.75	633.593	0.4754	0.2665		10.50	634.356	0.5963	0.2996		22.75	635	0.6983	0.35073
32.75	634.422	0.6067	0.3401		11.50	634.544	0.6261	0.3159		44.25	636	0.8568	0.44041
49.75	635.18	0.7268	0.4075		12.50	634.856	0.6755	0.343		67.5	637	1.0152	0.53009
75.25	636.371	0.9156	0.5133		24.50	635.605	0.7942	0.4079		192.5	639.216	1.3664	0.72881
95.25	637.377	1.0750	0.6026		45.00	636.922	1.0029	0.5221		435.25	641.213	1.6828	0.9079
122.75	637.876	1.1541	0.6470		75.50	637.675	1.1222	0.5873		501.25	641.712	1.7619	0.95265
149.25	638.2	1.2054	0.6758		94.00	638.213	1.2075	0.634		581.25	641.968	1.8025	0.97561
166.25	638.675	1.2807	0.7180		118.50	638.764	1.2948	0.6818		627.25	642.154	1.8319	0.99229
192	638.9	1.3163	0.7379		150.50	639.1	1.3480	0.7109		675.25	642.19	1.8376	0.99552
218.25	639.2	1.3639	0.7646		172.50	639.563	1.4214	0.751		723.25	642.21	1.8408	0.99731
244.75	639.42	1.3987	0.7841		188.50	639.911	1.4765	0.7812		747.25	642.23	1.8440	0.9991
271.25	639.65	1.4352	0.8046		221.00	640.213	1.5244	0.8074		771.25	642.24	1.8456	1
291.25	639.912	1.4767	0.8278		271.00	640.876	1.6294	0.8648					
313.5	640.213	1.5244	0.8546		314.50	641.12	1.6681	0.886					
337	640.444	1.5610	0.8751		364.00	641.4	1.7125	0.9103					
365	640.732	1.6066	0.9007		417.00	641.7	1.7600	0.9363					
387	640.921	1.6366	0.9175		462.00	641.987	1.8055	0.9612					
409	641.12	1.6681	0.9352		509.00	642.12	1.8266	0.9727					
437.75	641.320	1.6998	0.9529		549.00	642.231	1.8441	0.9823					
486.25	641.476	1.7245	0.9668		601.00	642.312	1.8570	0.9893					
538.25	641.560	1.7378	0.9742		650.00	642.387	1.8689	0.9958					
579.75	641.620	1.7473	0.9796		675.00	642.412	1.8728	0.9980					
629.25	641.700	1.7600	0.9867		702.00	642.435	1.8765	1.0000					
671.25	641.750	1.7679	0.9911										
700.25	641.790	1.7743	0.9947										
752.67	641.810	1.7774	0.9964										
793.75	641.831	1.7808	0.9983										
818.25	641.850	1.7838	1.0000										

Table 25. Desorption Data of Epoxy Samples containing 0 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

					sample-1		2*l*=0.104 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0	804.383	1.6764	2.5751		0	804.36	1.6735	2.56649		0	804.423	1.6815	2.52429
0.5	804.055	1.6350	2.5498		0.25	804.101	1.6408	2.54639		0.25	804	1.6281	2.48981
1	803.971	1.6244	2.5432		0.75	803.769	1.5989	2.52003		0.75	803.561	1.5726	2.45273
1.75	803.935	1.6199	2.5403		1.25	803.55	1.5712	2.50226		1.25	803	1.5018	2.40324
2.75	803.416	1.5543	2.4986		2	803.012	1.5033	2.45719		2	802.567	1.4471	2.3633
3.25	803.302	1.5399	2.4891		2.75	802.669	1.4600	2.42737		2.5	802.121	1.3908	2.32043
3.5	802.905	1.4898	2.4556		4	802.337	1.4181	2.39762		3	801.87	1.3591	2.29546
4.5	802.572	1.4477	2.4267		5	801.906	1.3636	2.35764		3.5	801.234	1.2788	2.22926
5.5	802.366	1.4217	2.4083		6.5	801.57	1.3212	2.32532		6	800	1.1229	2.08679
6.5	802.115	1.3900	2.3855		8	801.234	1.2788	2.29193		9	799	0.9966	1.9543
8.5	801.905	1.3635	2.3659		9.5	800.891	1.2354	2.25665		43	796.23	0.6468	1.45605
10.5	801.424	1.3028	2.3197		11	800.553	1.1928	2.22062		72	795.213	0.5184	1.1854
11.5	800.907	1.2375	2.2676		23	799.112	1.0108	2.05053		101	794.215	0.3924	0.82154
19.75	800.297	1.1604	2.2023		48	797.885	0.8558	1.8787		106	793.89	0.3513	0.66732
30.5	799.137	1.0139	2.0651		73.5	796.725	0.7093	1.68362		135	793.44	0.2945	0.4048
45.25	798.095	0.8824	1.9234		99.5	795.778	0.5898	1.4902		164	792.864	0.2218	-0.0801
74	796.696	0.7057	1.6947		125	794.67	0.4498	1.20297		217	792.412	0.1647	-0.7529
105.75	794.804	0.4667	1.2678		142	794.086	0.3761	1.01015		275	792.1	0.1253	-1.8389
124.75	794.012	0.3667	1.0156		172	793.659	0.3222	0.84114		304	792.05	0.1190	-2.2164
152.5	793.18	0.2617	0.6570		199.5	793.14	0.2566	0.58779		381	792	0.1126	-2.8302
169	792.674	0.1978	0.3528		219	792.869	0.2224	0.42461		434	791.965	0.1082	-3.7297
196	792.329	0.1542	0.0751		248	792.45	0.1695	0.10436		511	791.95	0.1063	-4.7105
202.5	792.124	0.1283	-0.1358		297.5	792.095	0.1246	-0.281		564	791.941	0.1052	#NUM!
244.5	791.991	0.1115	-0.3011		340.5	791.785	0.0855	-0.8097					
268.5	791.879	0.0974	-0.4652		382	791.624	0.0652	-1.2588					
292.25	791.78	0.0849	-0.6368		437.5	791.491	0.0484	-1.8905					
310	791.712	0.0763	-0.7744		483	791.423	0.0398	-2.4889					
337.5	791.622	0.0649	-0.9916		503.5	791.403	0.0373	-2.7646					
385.25	791.513	0.0511	-1.3394		583.5	791.369	0.0330	-3.5405					
433.5	791.421	0.0395	-1.772		663.5	791.359	0.0317	-3.9633					
484	791.36	0.0318	-2.2164		743.5	791.34	0.0293	#NUM!					
533.25	791.315	0.0261	-2.7489										
574.5	791.299	0.0241	-3.0366										
625.75	791.284	0.0222	-3.4112										
645.25	791.268	0.0202	-4.0745										
680	791.251	0.0181	#NUM!										

					sample-2		$2l$=0.104 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)
0	703.804	1.7989	2.4627		0	703.84	1.8041	2.4544		0	703.84	1.8041	2.5047
0.5	703.443	1.7468	2.4314		0.25	703.712	1.7856	2.4434		0.25	703.423	1.7439	2.4700
1	703.341	1.7320	2.4224		0.75	703.423	1.7439	2.4180		0.75	702.952	1.6758	2.4294
1.75	702.701	1.6396	2.3640		1.25	703.331	1.7306	2.4097		1.25	702.671	1.6353	2.4043
2.75	702.274	1.5779	2.3230		2	702.952	1.6758	2.3751		2	702.24	1.5730	2.3646
3.25	702.177	1.5639	2.3134		2.75	702.671	1.6353	2.3486		2.5	701.184	1.4205	2.2601
3.5	702.014	1.5404	2.2972		4	702.502	1.6108	2.3323		3	700.32	1.2957	2.1656
4.5	701.84	1.5152	2.2795		5	702.24	1.5730	2.3066		3.5	700	1.2495	2.1282
5.5	701.626	1.4843	2.2574		6.5	702.132	1.5574	2.2958		6	699.675	1.2025	2.0888
6.5	701.332	1.4419	2.2261		8	702.02	1.5412	2.2844		9	697.9	0.9462	1.8405
8.5	701.028	1.3979	2.1928		9.5	701.814	1.5115	2.2632		43	697	0.8162	1.6864
10.5	700.635	1.3412	2.1479		11	701.44	1.4575	2.2235		72	696.321	0.7181	1.5520
11.5	700.335	1.2979	2.1123		23	700.34	1.2986	2.0968		101	694	0.3829	0.8755
19.75	699.614	1.1937	2.0210		48	699.33	1.1527	1.9643		106	693.333	0.2866	0.5499
30.5	699.197	1.1335	1.9642		73.5	698.285	1.0018	1.8058		135	693.228	0.2714	0.4874
45.25	698.311	1.0055	1.8315		99.5	697.231	0.8495	1.6156		164	692.972	0.2344	0.3163
74	697.485	0.8862	1.6895		125	696.54	0.7497	1.4679		217	692.2	0.1229	-0.5108
105.75	696.311	0.7167	1.4453		142	695.776	0.6394	1.2742		275	691.889	0.0780	-1.2413
124.75	695.597	0.6135	1.2610		172	695.161	0.5506	1.0855		304	691.789	0.0635	-1.6660
152.5	695.074	0.5380	1.1006		199.5	694.34	0.4320	0.7608		381	691.7	0.0507	-2.3026
169	694.584	0.4672	0.9227		219	693.672	0.3355	0.3866		434	691.656	0.0443	-2.8824
196	694.210	0.4132	0.7617		248	693.2	0.2673	0.0000		511	691.612	0.0380	-4.4228
202.5	694.074	0.3936	0.69614		297.5	692.972	0.2344	-0.2588		564	691.6	0.0363	#NUM!
244.5	693.383	0.2938	0.27384		340.5	692.761	0.2039	-0.5780					
268.5	693.074	0.2491	0.00598		382	692.521	0.1693	-1.1363					
292.25	692.807	0.2106	-0.3025		437.5	692.334	0.1423	-2.0099					
310	692.678	0.1919	-0.4943		483	692.289	0.1358	-2.4191					
337.5	692.578	0.1775	-0.6733		503.5	692.265	0.1323	-2.7334					
385.25	692.4	0.1518	-1.1026		583.5	692.245	0.1294	-3.1011					
433.5	692.3	0.1374	-1.461		663.5	692.23	0.1272	-3.5066					
484	692.21	0.1244	-1.9519		743.5	692.2	0.1229	#NUM!					
533.25	692.132	0.1131	-2.7489										
574.5	692.099	0.1083	-3.4738										
625.75	692.09	0.1070	-3.8167										
645.25	692.08	0.1056	-4.4228										
680	692.068	0.1038	#NUM!										

				sample-3		2*l* =0.099 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0	641.86	1.7854	2.3878	0	642.441	1.8774	2.42842	0	642.241	1.8457	2.3274
0.5	641.56	1.7378	2.3599	0.25	642.123	1.8270	2.39998	0.25	642	1.8075	2.3036
1	641.432	1.7175	2.3477	0.75	641.875	1.7877	2.37723	0.75	641.78	1.7727	2.2814
1.75	641.213	1.6828	2.3266	1.25	641.611	1.7459	2.35242	1.25	641.512	1.7302	2.2536
2.75	641	1.6491	2.3056	2	641.321	1.6999	2.32444	2	641.231	1.6857	2.2237
3.25	640.732	1.6066	2.2785	2.75	641	1.6491	2.29253	2.5	640.889	1.6315	2.1859
3.5	640.543	1.5767	2.2589	4	640.732	1.6066	2.26509	3	640.53	1.5746	2.1448
4.5	640.312	1.5401	2.2345	5	640.432	1.5591	2.23345	3.5	640.213	1.5244	2.1069
5.5	640.1	1.5065	2.2116	6.5	640.12	1.5096	2.19944	6	640	1.4906	2.0807
6.5	639.87	1.4700	2.1861	8	639.867	1.4695	2.17099	9	639	1.3322	1.9473
8.5	639.621	1.4306	2.1577	9.5	639.711	1.4448	2.15304	43	637.865	1.1523	1.7707
10.5	639.4	1.3955	2.1318	11	639.521	1.4147	2.13073	72	637	1.0152	1.6114
11.5	639.1	1.3480	2.0956	23	639.241	1.3703	2.09691	101	636.211	0.8902	1.4401
19.75	638.9	1.3163	2.0707	48	638.365	1.2315	1.98307	106	635.456	0.7706	1.2430
30.5	638.567	1.2635	2.0278	73.5	637.245	1.0541	1.81564	135	634.787	0.6646	1.0285
45.25	637.459	1.0880	1.8701	99.5	636.266	0.8989	1.6421	164	633.999	0.5397	0.6976
74	635.956	0.8498	1.6066	125	635.208	0.7313	1.41294	217	633	0.3814	0.0100
105.75	634.497	0.6186	1.2604	142	634.213	0.5736	1.13559	275	632.453	0.2947	-0.7700
124.75	633.845	0.5153	1.0561	172	633.034	0.3868	0.65959	304	632.35	0.2784	-1.0217
152.5	633.275	0.4250	0.8351	199.5	632.476	0.2984	0.31918	381	632.12	0.2420	-2.0402
169	632.767	0.3445	0.5861	219	632.256	0.2635	0.14497	434	632.1	0.2388	-2.2073
196	632.356	0.2794	0.3264	248	632.065	0.2333	-0.0356	511	632	0.2230	-4.6052
202.5	632.167	0.2494	0.17982	297.5	631.809	0.1927	-0.3439	564	631.99	0.2214	#NUM!
244.5	631.82	0.1944	-0.1625	340.5	631.687	0.1734	-0.5327				
268.5	631.656	0.1684	-0.3769	382	631.587	0.1575	-0.7195				
292.25	631.532	0.1488	-0.5763	437.5	631.4	0.1279	-1.204				
310	631.43	0.1326	-0.7765	483	631.3	0.1120	-1.6094				
337.5	631.34	0.1184	-0.9943	503.5	631.21	0.0978	-2.2073				
385.25	631.26	0.1057	-1.2379	583.5	631.178	0.0927	-2.551				
433.5	631.2	0.0962	-1.4697	663.5	631.15	0.0883	-2.9957				
484	631.11	0.0819	-1.9661	743.5	631.1	0.0803	#NUM!				
533.25	631.088	0.0784	-2.1371								
574.5	631.02	0.0677	-2.9957								
625.75	631	0.0645	-3.5066								
645.25	630.98	0.0613	-4.6052								
680	630.97	0.0597	#NUM!								

Table 26. Sorption Data of Epoxy Samples containing 2 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

					sample-1		2*l*=0.11 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞
0.00	694.84	0.0000	0.0000		0.00	695.22	0.0547	0		0	695.4	0.0806	0.0000
0.50	694.932	0.0132	0.0068		0.25	695.4	0.0806	0.0132		0.25	695.601	0.1095	0.0161
1.50	695.056	0.0311	0.0160		1.00	695.691	0.1224	0.0346		0.75	695.873	0.1486	0.0379
4.00	695.389	0.0790	0.0407		1.25	695.902	0.1528	0.0501		1.25	696.311	0.2116	0.0729
5.50	695.598	0.1091	0.0562		1.75	696.465	0.2338	0.0915		2.25	696.51	0.2403	0.0889
8.00	695.857	0.1463	0.0754		2.25	696.665	0.2626	0.1062		4.25	696.973	0.3069	0.1260
10.75	696.147	0.1880	0.0969		2.75	696.794	0.2811	0.1156		6.75	697.189	0.3380	0.1432
11.75	696.284	0.2078	0.1071		4.08	697.092	0.3240	0.1375		8.75	697.461	0.3771	0.1650
25.75	697.265	0.3489	0.1798		5.08	697.31	0.3554	0.1535		10.75	697.733	0.4162	0.1868
32.75	697.834	0.4308	0.2220		6.25	697.487	0.3808	0.1665		22.75	699.032	0.6031	0.2908
49.75	698.575	0.5374	0.2770		7.25	697.601	0.3972	0.1749		44.25	700.203	0.7716	0.3846
75.25	699.557	0.6787	0.3498		8.25	697.891	0.4390	0.1962		91.5	702.456	1.0957	0.5650
95.25	700.248	0.7781	0.4010		31.50	699.325	0.6453	0.3016		192.5	704.776	1.4295	0.7507
122.75	700.927	0.8758	0.4514		68.50	701.284	0.9271	0.4455		220.5	705.423	1.5226	0.8025
149.25	701.563	0.9673	0.4986		80.25	701.898	1.0155	0.4906		237.5	705.879	1.5882	0.8391
166.25	702.149	1.0516	0.5420		103.50	703.333	1.2219	0.596		290.5	706.321	1.6518	0.8744
192.00	702.59	1.1150	0.5747		140.50	704.433	1.3802	0.6768		316.25	706.654	1.6997	0.9011
218.25	703.309	1.2185	0.6280		163.50	705.127	1.4800	0.7278		367.5	706.911	1.7367	0.9217
271.25	704.501	1.3900	0.7164		194.50	705.653	1.5557	0.7665		394.5	707.321	1.7957	0.9545
313.50	705.131	1.4806	0.7631		214.25	705.998	1.6053	0.7918		456.75	707.542	1.8275	0.9722
387.00	705.868	1.5866	0.8178		239.00	706.463	1.6722	0.826		504.5	707.675	1.8466	0.9829
434.67	706.178	1.6312	0.8408		264.00	706.834	1.7256	0.8532		576.5	707.771	1.8604	0.9906
460.42	706.384	1.6609	0.8561		291.00	707.121	1.7669	0.8743		656.5	707.832	1.8692	0.9954
507.42	706.775	1.7171	0.8851		332.50	707.586	1.8338	0.9085		722.50	707.865	1.8739	0.9981
532.75	706.891	1.7338	0.8937		386.50	707.987	1.8915	0.9379		772.50	707.889	1.8774	1.0000
575.00	707.131	1.7683	0.9115		432.25	708.187	1.9203	0.9526					
627.75	707.311	1.7942	0.9248		478.00	708.366	1.9460	0.9658					
675.42	707.517	1.8239	0.9401		530.00	708.512	1.9670	0.9765					
767.00	707.984	1.8911	0.9747		570.00	708.632	1.9843	0.9853					
827.50	708.124	1.9112	0.9851		622.00	708.711	1.9957	0.9911					
874.25	708.224	1.9256	0.9925		667.5	708.752	2.0016	0.9941					
917.25	708.278	1.9334	0.9965		714.5	708.798	2.0082	0.9975					
969.00	708.312	1.9383	0.9990		762	708.811	2.0101	0.9985					
994.25	708.325	1.9401	1.0000		817	708.832	2.0131	1					

					sample-2		$2l$=0.0877 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞
0	521.93	0.0000	0.0000		0.00	522	0.0134	0		0	522.365	0.0833	0.0000
0.5	522.053	0.0236	0.0136		0.25	522.134	0.0391	0.015		0.25	522.54	0.1168	0.0210
1.5	522.189	0.0496	0.0286		1.00	522.278	0.0666	0.0311		0.75	522.748	0.1566	0.0460
4	522.568	0.1222	0.0706		1.25	522.398	0.0896	0.0445		1.25	522.904	0.1865	0.0647
5.5	522.781	0.1630	0.0941		1.75	522.567	0.1220	0.0634		2.25	523.07	0.2183	0.0846
8	523.184	0.2401	0.1387		2.25	522.616	0.1314	0.0689		4.25	523.288	0.2601	0.1108
10.75	523.345	0.2710	0.1565		2.75	522.734	0.1540	0.0821		6.75	523.586	0.3171	0.1465
11.75	523.478	0.2964	0.1712		4.08	522.812	0.1689	0.0908		8.75	523.734	0.3455	0.1643
25.75	524.289	0.4518	0.2609		5.08	523.187	0.2407	0.1328		10.75	524.037	0.4035	0.2006
32.75	524.624	0.5159	0.2980		6.25	523.395	0.2805	0.156		22.75	525.206	0.6274	0.3409
49.75	525.241	0.6341	0.3662		7.25	523.538	0.3079	0.172		44.25	526.244	0.8261	0.4655
75.25	525.892	0.7587	0.4382		8.25	523.687	0.3365	0.1887		91.5	527.482	1.0632	0.6141
95.25	526.398	0.8556	0.4942		31.50	524.838	0.5569	0.3174		192.5	528.325	1.2247	0.7152
122.75	526.831	0.9385	0.5421		68.50	526.231	0.8236	0.4732		220.5	529.205	1.3932	0.8208
149.25	527.301	1.0286	0.5941		80.25	526.726	0.9184	0.5286		237.5	529.432	1.4366	0.8481
166.25	527.414	1.0502	0.6066		103.50	527.348	1.0376	0.5981		290.5	529.673	1.4828	0.8770
192	527.562	1.0785	0.6229		140.50	527.991	1.1607	0.6701		316.25	529.911	1.5284	0.9056
218.25	527.912	1.1456	0.6617		163.50	528.669	1.2905	0.7459		367.5	530.321	1.6069	0.9548
271.25	528.524	1.2628	0.7293		194.50	529.032	1.3600	0.7865		394.5	530.421	1.6260	0.9668
313.5	528.867	1.3284	0.7673		214.25	529.331	1.4173	0.8199		456.75	530.511	1.6433	0.9776
387	529.526	1.4546	0.8402		239.00	529.521	1.4537	0.8412		504.5	530.589	1.6582	0.9869
434.667	529.786	1.5044	0.8689		264.00	529.713	1.4905	0.8627		576.5	530.612	1.6626	0.9897
460.417	529.865	1.5196	0.8777		291.00	529.898	1.5259	0.8833		656.5	530.667	1.6731	0.9963
507.417	530.025	1.5502	0.8954		332.50	530.165	1.5770	0.9132		722.50	530.687	1.6770	0.9987
532.75	530.154	1.5749	0.9096		386.50	530.376	1.6174	0.9368		772.50	530.698	1.6791	1.0000
575	530.281	1.5992	0.9237		432.25	530.586	1.6576	0.9603					
627.75	530.462	1.6339	0.9437		478.00	530.732	1.6856	0.9766					
675.42	530.596	1.6596	0.9585		530.00	530.811	1.7007	0.9855					
767.00	530.798	1.6982	0.9809		570.00	530.854	1.7090	0.9903					
827.50	530.869	1.7118	0.9887		622.00	530.897	1.7172	0.9951					
874.25	530.908	1.7193	0.9930		667.50	530.912	1.7201	0.9968					
917.25	530.934	1.7243	0.9959		714.5	530.921	1.7218	0.9978					
969.00	530.959	1.7291	0.9987		762	530.929	1.7233	0.9987					
994.25	530.971	1.7314	1.0000		817	530.941	1.7256	1					

					sample-3		$2l$=0.0889 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞
0.00	685.34	0.0000	0.0000		0.00	685.644	0.0443	0		0	685.67	0.0481	0.0000
0.50	685.43	0.0131	0.0077		0.25	685.781	0.0643	0.012		0.25	685.8	0.0671	0.0120
1.50	685.677	0.0491	0.0288		1.00	686.003	0.0967	0.0315		0.75	686.209	0.1267	0.0497
4.00	685.968	0.0916	0.0536		1.25	686.411	0.1562	0.0672		1.25	686.348	0.1470	0.0625
5.50	686.167	0.1206	0.0706		1.75	686.722	0.2016	0.0944		2.25	686.916	0.2298	0.1149
8.00	686.611	0.1854	0.1085		2.25	686.9	0.2275	0.11		4.25	687.567	0.3248	0.1750
10.75	686.934	0.2325	0.1361		2.75	687.1	0.2567	0.1276		6.75	687.502	0.3153	0.1690
11.75	687.212	0.2730	0.1598		4.08	687.305	0.2866	0.1455		8.75	687.769	0.3542	0.1936
25.75	688.011	0.3895	0.2280		5.08	687.6	0.3296	0.1714		10.75	688.116	0.4049	0.2256
32.75	688.578	0.4722	0.2764		6.25	687.72	0.3471	0.1819		22.75	689.694	0.6350	0.3712
49.75	689.443	0.5984	0.3503		7.25	687.832	0.3634	0.1917		44.25	690.401	0.7381	0.4364
75.25	690.317	0.7259	0.4249		8.25	687.989	0.3863	0.2054		91.5	692.101	0.9860	0.5933
95.25	690.879	0.8078	0.4729		31.50	690.24	0.7146	0.4027		192.5	693.495	1.1893	0.7219
122.75	691.423	0.8872	0.5193		68.50	691.739	0.9332	0.534		220.5	693.757	1.2275	0.7460
149.25	691.912	0.9585	0.5610		80.25	692.558	1.0527	0.6057		237.5	694.538	1.3414	0.8181
166.25	692.105	0.9866	0.5775		103.50	693.259	1.1549	0.6672		290.5	694.884	1.3919	0.8500
192.00	692.467	1.0394	0.6084		140.50	693.911	1.2500	0.7243		316.25	695.327	1.4565	0.8909
218.25	692.674	1.0696	0.6261		163.50	694.538	1.3414	0.7792		367.5	695.621	1.4994	0.9180
271.25	693.357	1.1692	0.6844		194.50	694.884	1.3919	0.8095		394.5	695.854	1.5334	0.9395
313.50	693.621	1.2077	0.7069		214.25	695.327	1.4565	0.8483		456.75	695.994	1.5538	0.9524
387.00	694.192	1.2910	0.7557		239.00	695.621	1.4994	0.8741		504.5	696.221	1.5869	0.9733
434.67	694.636	1.3557	0.7936		264.00	695.854	1.5334	0.8945		576.5	696.396	1.6124	0.9895
460.42	694.872	1.3902	0.8137		291.00	695.994	1.5538	0.9068		656.5	696.453	1.6207	0.9947
507.42	695.165	1.4329	0.8387		332.50	696.321	1.6015	0.9354		722.50	696.498	1.6273	0.9989
532.75	695.347	1.4594	0.8543		386.50	696.585	1.6400	0.9586		772.50	696.510	1.6290	1.0000
575.00	695.512	1.4835	0.8684		432.25	696.734	1.6617	0.9716					
627.75	695.772	1.5214	0.8906		478.00	696.823	1.6747	0.9794					
675.42	696.054	1.5625	0.9146		530.00	696.884	1.6836	0.9848					
767.00	696.523	1.6309	0.9547		570.00	696.912	1.6877	0.9872					
827.50	696.812	1.6731	0.9793		622.00	696.956	1.6941	0.9911					
874.25	696.932	1.6906	0.9896		667.50	696.997	1.7001	0.9947					
917.25	696.965	1.6954	0.9924		714.50	697.032	1.7052	0.9977					
969.00	697.020	1.7034	0.9971		762.00	697.054	1.7084	0.9996					
994.25	697.054	1.7084	1.0000		817.00	697.058	1.7090	1					

Table 27. Desorption Data of Epoxy Samples containing 2 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

					sample-1		2*l* =0.11 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0	708.341	1.9424	2.5735		0.00	708.842	2.0145	2.59764		0	707.678	1.8470	2.51915
0.25	708.081	1.9050	2.5534		0.25	708.686	1.9921	2.58596		0.25	707.364	1.8019	2.49354
0.5	707.791	1.8633	2.5306		0.75	708.304	1.9371	2.55676		0.75	707.089	1.7623	2.47055
0.75	707.207	1.7793	2.4830		1.25	708.048	1.9003	2.53671		1.25	706.821	1.7237	2.44764
1.25	706.955	1.7430	2.4617		2.25	707.678	1.8470	2.50699		2	706.629	1.6961	2.43089
1.75	706.549	1.6846	2.4265		3.75	707.364	1.8019	2.48107		2.5	706.355	1.6567	2.40649
2.25	706.233	1.6391	2.3982		5.25	707.089	1.7623	2.45779		3	705.232	1.4951	2.29978
3.25	705.826	1.5806	2.3605		7.25	706.821	1.7237	2.43458		3.5	704.604	1.4048	2.23473
4.25	705.371	1.5151	2.3166		9.25	706.629	1.6961	2.41761		6	703	1.1740	2.0464
5.25	705.2	1.4905	2.2996		11.25	706.355	1.6567	2.39288		9	700.222	0.7743	1.60181
6.25	704.781	1.4302	2.2566		22.17	705.232	1.4951	2.28462		43	698	0.4546	1.00796
8.5	704.062	1.3268	2.1784		29.00	704.604	1.4048	2.21855		72	697.3	0.3539	0.71295
10.25	703.532	1.2505	2.1165		52.50	703	1.1740	2.02683		101	696.89	0.2949	0.48858
22.25	702.273	1.0694	1.9520		95.75	700.222	0.7743	1.57111		106	696.789	0.2804	0.42461
28.75	701.182	0.9124	1.7837		120.75	699.323	0.6450	1.3643		135	696.2	0.1957	-0.0619
46.75	700.151	0.7641	1.5935		148.50	698.23	0.4877	1.03674		164	695.6	0.1093	-1.0788
70.75	698.213	0.4853	1.0929		166.75	697.532	0.3873	0.75236		217	695.47	0.0906	-1.5606
94.5	697.674	0.4077	0.8936		194.50	696.789	0.2804	0.32136		246	695.38	0.0777	-2.1203
112.25	697.217	0.3420	0.6866		224.00	696.453	0.2321	0.0421		275	695.34	0.0719	-2.5257
139.75	696.697	0.2672	0.3832		242.50	696.211	0.1973	-0.2219		304	695.31	0.0676	-2.9957
170	696	0.1669	-0.2614		270.00	695.889	0.1509	-0.7361		381	695.287	0.0643	-3.6119
235.75	695.511	0.0965	-1.2694		289.50	695.7	0.1237	-1.2379		434	695.274	0.0624	-4.2687
303.75	695.4	0.0806	-1.772		322.50	695.532	0.0996	-2.1037		511	695.268	0.0616	-4.8283
355	695.323	0.0695	-2.3752		357.00	695.489	0.0934	-2.5383		564	695.26	0.0604	
404.75	695.298	0.0659	-2.6882		410.50	695.467	0.0902	-2.8647					
447.5	695.278	0.0630	-3.0366		456.00	695.45	0.0878	-3.2189					
482.25	695.266	0.0613	-3.3242		484.50	695.432	0.0852	-3.8167					
504.25	695.254	0.0596	-3.7297		509.00	695.41	0.0820	#NUM!					
543.25	695.248	0.0587	-4.0174										
595.75	695.238	0.0573	-4.8283										
617.25	695.23	0.0561	#NUM!										

				sample-2		$2l$=0.0877 cm					
		Cycle-1				Cycle-2				Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt-M∞)
0	530.985	1.7340	2.1730	0	530.948	1.7270	2.14908	0	530.703	1.6800	2.11372
0.25	530.949	1.7272	2.1689	0.25	530.956	1.7285	2.15002	0.25	530.557	1.6521	2.09593
0.5	530.543	1.6494	2.1214	0.75	530.754	1.6898	2.12621	0.75	530.418	1.6255	2.07869
0.75	530.015	1.5483	2.0560	1.25	530.557	1.6521	2.10243	1.25	529.926	1.5312	2.01517
1.25	529.646	1.4776	2.0077	2.25	530.418	1.6255	2.0853	2	529.54	1.4573	1.96235
1.75	529.348	1.4206	1.9668	3.75	529.926	1.5312	2.02221	2.5	529.35	1.4209	1.93528
2.25	529.009	1.3556	1.9182	5.25	529.54	1.4573	1.96977	3	529.123	1.3775	1.90196
3.25	528.554	1.2685	1.8491	7.25	529.35	1.4209	1.94291	3.5	528.879	1.3307	1.86486
4.25	528.187	1.1982	1.7896	9.25	529.123	1.3775	1.90984	6	528.263	1.2128	1.76456
5.25	527.912	1.1456	1.7426	11.25	528.879	1.3307	1.87303	9	527.626	1.0908	1.64904
6.25	527.534	1.0732	1.6741	22.16667	528.263	1.2128	1.7736	43	526.306	0.8380	1.35635
8.5	526.975	0.9661	1.5634	29	527.626	1.0908	1.65918	72	524.966	0.5814	0.93295
10.25	526.446	0.8648	1.4460	52.5	526.306	0.8380	1.36991	101	524.328	0.4592	0.64396
22.25	525.233	0.6325	1.1096	95.75	524.966	0.5814	0.95359	106	523.937	0.3843	0.41409
28.75	524.771	0.5441	0.9443	120.75	524.328	0.4592	0.67141	135	523.675	0.3342	0.22394
46.75	523.956	0.3880	0.5630	148.5	523.932	0.3834	0.44533	164	523.415	0.2844	-0.009
70.75	523.343	0.2706	0.1337	166.75	523.673	0.3338	0.2639	217	523.126	0.2290	-0.3538
94.5	523.143	0.2323	-0.0587	194.5	523.411	0.2836	0.03922	246	522.934	0.1923	-0.6733
112.25	523.012	0.2072	-0.2083	224	523.122	0.2283	-0.2863	275	522.813	0.1691	-0.9442
139.75	522.869	0.1798	-0.4020	242.5	522.93	0.1915	-0.5816	304	522.703	0.1480	-1.2765
170	522.712	0.1498	-0.6694	270	522.81	0.1685	-0.8233	381	522.643	0.1365	-1.5187
235.75	522.533	0.1155	-1.0996	289.5	522.703	0.1480	-1.1026	434	522.5	0.1092	-2.577
303.75	522.433	0.0963	-1.4567	322.5	522.643	0.1365	-1.302	511	522.465	0.1025	-3.1942
355	522.367	0.0837	-1.7898	357	522.5	0.1092	-2.0479	564	522.424	0.0946	
404.75	522.321	0.0749	-2.112	410.5	522.465	0.1025	-2.3645				
447.5	522.289	0.0687	-2.4191	456	522.421	0.0940	-2.9957				
482.25	522.267	0.0645	-2.7031	484.5	522.389	0.0879	-4.0174				
504.25	522.254	0.0620	-2.9188	509	522.371	0.0845	#NUM!				
543.25	522.24	0.0594	-3.2189								
595.75	522.21	0.0536	-4.6052								
617.25	522.2	0.0517	#NUM!								

					sample-3		2*l* =0.0889 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0	697.071	1.7109	2.4351		0	697.06	1.7093	2.433		0	696.52	1.6305	2.38417
0.25	696.568	1.6375	2.3900		0.25	696.843	1.6776	2.41377		0.25	696.188	1.5821	2.35309
0.5	696.187	1.5819	2.3545		0.75	696.761	1.6657	2.4064		0.75	695.961	1.5490	2.33127
0.75	695.781	1.5227	2.3152		1.25	696.536	1.6328	2.38591		1.25	695.604	1.4969	2.29596
1.25	695.464	1.4765	2.2834		2.25	696.188	1.5821	2.35337		2	695.379	1.4641	2.27305
1.75	695.106	1.4243	2.2462		3.75	695.961	1.5490	2.33156		2.5	694.929	1.3985	2.2256
2.25	694.785	1.3775	2.2117		5.25	695.604	1.4969	2.29627		3	694.544	1.3423	2.18313
3.25	694.333	1.3116	2.1609		7.25	695.379	1.4641	2.27336		3.5	693.753	1.2270	2.08976
4.25	693.935	1.2535	2.1140		9.25	694.929	1.3985	2.22592		6	692.966	1.1122	1.98733
5.25	693.675	1.2156	2.0821		11.25	694.562	1.3449	2.18549		9	691.589	0.9114	1.77817
6.25	693.284	1.1586	2.0321		22.16667	693.786	1.2318	2.09421		43	689.8	0.6505	1.41828
8.5	692.704	1.0740	1.9530		29	692.985	1.1150	1.99034		72	688.677	0.4867	1.10094
10.25	692.083	0.9834	1.8608		52.5	691.608	0.9141	1.78188		101	688.1	0.4025	0.88789
22.25	690.752	0.7893	1.6288		95.75	689.844	0.6569	1.42959		106	687.3	0.2858	0.48858
28.75	690.164	0.7035	1.5063		120.75	688.672	0.4859	1.10028		135	686.777	0.2096	0.10165
46.75	688.996	0.5332	1.2066		148.5	688	0.3879	0.84715		164	686.554	0.1771	-0.1233
70.75	688.265	0.4266	0.9597		166.75	687.321	0.2889	0.5032		217	686.321	0.1431	-0.4292
94.5	687.534	0.3200	0.6313		194.5	686.777	0.2096	0.10436		246	686.12	0.1138	-0.7985
112.25	686.965	0.2370	0.2708		224	686.564	0.1785	-0.1087		275	685.98	0.0933	-1.1712
139.75	686.721	0.2014	0.0649		242.5	686.321	0.1431	-0.4246		304	685.87	0.0773	-1.6094
170	686.423	0.1579	-0.2627		270	686.12	0.1138	-0.7919		381	685.8	0.0671	-2.0402
235.75	686.154	0.1187	-0.6931		289.5	685.98	0.0933	-1.1616		434	685.743	0.0588	-2.6173
303.75	685.941	0.0877	-1.2483		322.5	685.87	0.0773	-1.5945		511	685.7	0.0525	-3.5066
355	685.812	0.0688	-1.8452		357	685.8	0.0671	-2.0174					
404.75	685.789	0.0655	-2.0025		410.5	685.743	0.0588	-2.5770					
447.5	685.754	0.0604	-2.3026		456	685.7	0.0525	-3.4112					
482.25	685.721	0.0556	-2.7031		484.5	685.687	0.0506	-3.9120					
504.25	685.7	0.0525	-3.0791		509	685.667	0.0477	#NUM!					
543.25	685.689	0.0509	-3.3524										
595.75	685.667	0.0477	-4.3428										
617.25	685.654	0.0458	#NUM!										

Table 28. Sorption Data of Epoxy Samples containing 5 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

					sample-1		2*l*=0.115 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞
0	630.815	0.0000	0.0000		0	631.587	0.1222	0		0	631.48	0.1052	0.0000
0.5	631.279	0.0734	0.0275		0.25	631.732	0.1451	0.0092		0.5	631.487	0.1064	0.0004
1.5	631.83	0.1606	0.0601		0.75	631.9	0.1717	0.0199		0.75	631.632	0.1293	0.0096
4	632.276	0.2312	0.0866		2.25	632.342	0.2417	0.0479		1.25	631.81	0.1575	0.0208
5.5	632.63	0.2873	0.1075		3.75	632.45	0.2588	0.0548		2.75	632.252	0.2274	0.0487
7	632.905	0.3308	0.1238		5.25	632.688	0.2964	0.0699		4.25	632.325	0.2390	0.0533
10.75	633.476	0.4212	0.1577		7.25	632.849	0.3219	0.0801		5.75	632.588	0.2806	0.0699
11.75	633.6	0.4408	0.1650		9.25	633.308	0.3946	0.1093		7.75	632.749	0.3061	0.0800
25.75	634.743	0.6217	0.2328		11.25	633.593	0.4397	0.1274		9.75	633.248	0.3851	0.1115
49.75	636	0.8206	0.3072		22	634.659	0.6084	0.195		11.75	633.493	0.4238	0.1269
75.25	636.89	0.9615	0.3600		29	635.514	0.7437	0.2493		22.5	634.559	0.5926	0.1942
95.25	637.654	1.0824	0.4053		52	636.739	0.9376	0.3271		29.5	635.414	0.7279	0.2481
122.75	638.423	1.2041	0.4508		76	638.518	1.2192	0.44		52.5	636.639	0.9218	0.3253
166.25	639.132	1.3163	0.4928		101	639.272	1.3385	0.4879		76.5	638.418	1.2033	0.4375
218.25	640.213	1.4874	0.5569		124	639.564	1.3847	0.5064		100.5	639.172	1.3227	0.4851
271.25	641	1.6120	0.6035		173	640.445	1.5241	0.5624		125.5	639.464	1.3689	0.5035
313.5	641.488	1.6892	0.6324		222	641.488	1.6892	0.6286		172.5	640.345	1.5083	0.5590
387	642.823	1.9005	0.7115		292	642.823	1.9005	0.7134		226.5	641.378	1.6718	0.6242
485.417	644.157	2.1116	0.7906		364	644.157	2.1116	0.798		292.5	642.733	1.8863	0.7096
575	644.856	2.2223	0.8320		439	645.356	2.3014	0.8742		367.5	644.047	2.0942	0.7925
675.417	645.548	2.3318	0.8730		538	646.145	2.4263	0.9243		432.5	645.236	2.2824	0.8674
767	645.951	2.3956	0.8969		602	646.399	2.4665	0.9404		531.5	646.055	2.4120	0.9191
874.25	646.287	2.4488	0.9168		651	646.623	2.5019	0.9546		604.5	646.296	2.4502	0.9343
990	646.798	2.5296	0.9471		724	646.91	2.5474	0.9728		657.50	646.521	2.4858	0.9485
1083	647.169	2.5884	0.9691		823	647.1	2.5774	0.9849		724.50	646.850	2.5379	0.9692
1199.25	647.451	2.6330	0.9858		868	647.17	2.5885	0.9893		824.50	647.030	2.5664	0.9806
1300.25	647.586	2.6544	0.9938		916	647.23	2.5980	0.9931		863.50	647.056	2.5705	0.9822
1399.75	647.678	2.6689	0.9992		964	647.29	2.6075	0.9970		916.5	647.121	2.5808	0.9863
1468.25	647.666	2.6670	0.9985		1011	647.31	2.6107	0.9982		961.5	647.187	2.5912	0.9905
1489.25	647.672	2.6680	0.9989		1060	647.33	2.6138	0.9995		1010.5	647.204	2.5939	0.9916
1516.25	647.680	2.6692	0.9993		1108	647.338	2.6151	1.0000		1062.5	647.223	2.5969	0.9927
1537.75	647.685	2.6700	0.9996							1107.5	647.338	2.6151	1.0000
1565.75	647.691	2.6710	1.0000										

					sample-2		2*l* =0.11 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞
0	702.79	0.0000	0.0000		0	703.08	0.0412	0		0	702.996	0.0293	0.0000
0.5	703.056	0.0378	0.0142		0.25	703.333	0.0772	0.0148		0.5	703.139	0.0496	0.0083
1.5	703.351	0.0798	0.0300		0.75	703.521	0.1039	0.0257		0.75	703.342	0.0785	0.0201
4	703.958	0.1661	0.0625		2.25	704.158	0.1945	0.0629		1.25	703.554	0.1086	0.0324
5.5	704.254	0.2081	0.0783		3.75	704.576	0.2539	0.0873		2.75	704.178	0.1973	0.0686
7	704.489	0.2416	0.0909		5.25	704.834	0.2906	0.1024		4.25	704.591	0.2561	0.0926
10.75	705.384	0.3688	0.1388		7.25	704.989	0.3126	0.1114		5.75	704.823	0.2890	0.1061
11.75	705.604	0.4001	0.1506		9.25	705.369	0.3667	0.1336		7.75	704.976	0.3108	0.1150
25.75	706.832	0.5747	0.2163		11.25	705.727	0.4176	0.1545		9.75	705.354	0.3645	0.1369
49.75	708.137	0.7602	0.2861		22	706.76	0.5644	0.2148		11.75	705.703	0.4142	0.1572
75.25	708.996	0.8823	0.3320		29	707.744	0.7043	0.2722		22.5	706.75	0.5630	0.2180
95.25	709.865	1.0059	0.3785		52	708.822	0.8576	0.3351		29.5	707.751	0.7053	0.2761
122.75	710.546	1.1027	0.4150		76	710.686	1.1226	0.4439		52.5	708.831	0.8589	0.3388
166.25	711.993	1.3085	0.4924		101	711.469	1.2340	0.4896		76.5	710.671	1.1205	0.4456
218.25	713.102	1.4661	0.5517		124	711.993	1.3085	0.5202		100.5	711.4695	1.2340	0.4920
271.25	714.543	1.6710	0.6288		173	713.102	1.4661	0.5849		125.5	711.986	1.3075	0.5219
313.5	715.464	1.8019	0.6781		222	714.543	1.6710	0.669		172.5	713.11	1.4673	0.5872
387	716.943	2.0122	0.7572		292	716.123	1.8956	0.7612		226.5	714.551	1.6721	0.6709
485.417	718.024	2.1659	0.8151		364	717.247	2.0554	0.8268		292.5	716.118	1.8949	0.7618
575	718.564	2.2427	0.8440		439	718.308	2.2063	0.8888		367.5	717.262	2.0576	0.8283
675.417	719.123	2.3222	0.8739		538	719.3	2.3473	0.9467		432.5	718.318	2.2077	0.8896
767	719.507	2.3768	0.8944		602	719.507	2.3768	0.9587		531.5	719.332	2.3519	0.9484
874.25	719.857	2.4265	0.9132		651	719.796	2.4179	0.9756		604.5	719.518	2.3783	0.9592
990	720.382	2.5012	0.9413		724	719.897	2.4322	0.9815		657.50	719.791	2.4171	0.9751
1083	720.673	2.5425	0.9568		823	720.067	2.4564	0.9914		724.50	719.889	2.4311	0.9808
1199.25	720.934	2.5797	0.9708		868	720.11	2.4625	0.9939		824.50	720.053	2.4544	0.9903
1300.25	721.223	2.6207	0.9862		916	720.14	2.4668	0.9957		863.50	720.140	2.4668	0.9954
1399.75	721.354	2.6394	0.9933		964	720.176	2.4719	0.9978		916.5	720.17	2.4710	0.9971
1468.25	721.432	2.6505	0.9974		1011	720.19	2.4739	0.9986		961.5	720.191	2.4740	0.9983
1489.25	721.451	2.6532	0.9984		1060	720.204	2.4759	0.9994		1010.5	720.21	2.4767	0.9994
1516.25	721.463	2.6549	0.9991		1108	720.214	2.4773	1.0000		1062.5	720.2041	2.4759	0.9991
1537.75	721.470	2.6559	0.9995							1107.5	720.22	2.4781	1.0000
1565.75	721.480	2.6573	1.0000										

					sample-3		2*l*=0.115 cm						
		Cycle-1					Cycle-2					Cycle-3	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Time, h	Weight, mg	Water Content, wt%	Mt/M∞
0	667.1	0.0000	0.0000		0	667.37	0.0405	0		0	667.47	0.0554	0.0000
0.5	667.341	0.0361	0.0134		0.25	667.612	0.0767	0.014		0.5	667.6512	0.0826	0.0106
1.5	667.45	0.0524	0.0195		0.75	667.975	0.1311	0.0349		0.75	667.865	0.1146	0.0231
4	667.874	0.1160	0.0431		2.25	668.503	0.2102	0.0654		1.25	668.413	0.1967	0.0551
5.5	668.367	0.1898	0.0705		3.75	668.801	0.2549	0.0826		2.75	668.721	0.2429	0.0731
7	668.771	0.2504	0.0930		5.25	669.432	0.3494	0.119		4.25	669.322	0.3329	0.1082
10.75	669.389	0.3429	0.1274		7.25	669.673	0.3855	0.1329		5.75	669.563	0.3690	0.1223
11.75	669.602	0.3749	0.1392		9.25	669.829	0.4089	0.1419		7.75	669.739	0.3954	0.1325
25.75	670.823	0.5578	0.2071		11.25	670.112	0.4513	0.1582		9.75	670.022	0.4378	0.1491
49.75	671.789	0.7025	0.2609		22	670.814	0.5564	0.1987		11.75	670.724	0.5430	0.1901
75.25	672.563	0.8185	0.3039		29	671.83	0.7087	0.2574		22.5	671.873	0.7151	0.2572
95.25	673.451	0.9515	0.3533		52	672.811	0.8556	0.314		29.5	672.711	0.8407	0.3061
122.75	674.589	1.1220	0.4167		76	674.586	1.1216	0.4164		52.5	674.466	1.1036	0.4086
166.25	676.398	1.3931	0.5173		101	675.299	1.2284	0.4576		76.5	675.199	1.2134	0.4515
218.25	678.11	1.6496	0.6126		124	676.398	1.3931	0.521		100.5	676.288	1.3766	0.5151
271.25	679.282	1.8252	0.6778		173	678.11	1.6496	0.6198		125.5	678.01	1.6346	0.6157
313.5	680.123	1.9512	0.7245		222	679.282	1.8252	0.6874		172.5	679.182	1.8102	0.6841
387	680.787	2.0506	0.7615		292	680.556	2.0160	0.7609		226.5	680.456	2.0010	0.7585
485.417	681.423	2.1459	0.7969		364	681.423	2.1459	0.811		292.5	681.323	2.1309	0.8092
575	681.993	2.2313	0.8286		439	682.397	2.2919	0.8672		367.5	682.297	2.2769	0.8661
675.417	682.673	2.3332	0.8664		538	683.3	2.4271	0.9193		432.5	683.213	2.4141	0.9196
767	683.058	2.3909	0.8878		602	683.371	2.4378	0.9234		531.5	683.261	2.4213	0.9224
874.25	683.371	2.4378	0.9053		651	683.711	2.4887	0.943		604.5	683.621	2.4752	0.9434
990	683.872	2.5128	0.9331		724	684	2.5320	0.9597		657.50	683.910	2.5185	0.9603
1083	684.164	2.5566	0.9494		823	684.321	2.5801	0.9782		724.50	684.221	2.5651	0.9784
1199.25	684.576	2.6183	0.9723		868	684.412	2.5938	0.9834		824.50	684.302	2.5773	0.9832
1300.25	684.816	2.6543	0.9856		916	684.5	2.6069	0.9885		863.50	684.400	2.5920	0.9889
1399.75	684.987	2.6799	0.9952		964	684.587	2.6200	0.9935		916.5	684.487	2.6050	0.9940
1468.25	685.023	2.6853	0.9972		1011	684.612	2.6237	0.9950		961.5	684.502	2.6072	0.9949
1489.25	685.040	2.6878	0.9981		1060	684.667	2.6320	0.9982		1010.5	684.567	2.6170	0.9987
1516.25	685.055	2.6901	0.9989		1108	684.699	2.6368	1.0000		1062.5	684.599	2.6218	1.0005
1537.75	685.065	2.6916	0.9995							1107.5	684.59	2.6204	1.0000
1565.75	685.074	2.6929	1.0000										

Table 29. Desorption Data of Epoxy Samples containing 5 wt% Cloisite 10A at 25ºC During Three Cycles of Absorption

		sample-1			2*l*=0.115 cm			
		Cycle-1					Cycle-2	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0	647.691	2.6710	2.7786		0	647	2.5616	2.73722
0.25	647.398	2.6246	2.7602		0.5	646.78	2.5268	2.72287
0.75	646.872	2.5413	2.7263		0.75	646.54	2.4888	2.70698
1.5	646.403	2.4671	2.6952		1.75	646	2.4033	2.67028
3.25	645.891	2.3861	2.6600		2.5	645.89	2.3859	2.66263
5.25	645.056	2.2539	2.5998		3.5	645.53	2.3289	2.6372
7.25	644.224	2.1222	2.5360		6.5	645.484	2.3217	2.6339
12	642.574	1.8611	2.3960		9.5	644.593	2.1806	2.56779
29.25	641.056	1.6208	2.2472		43.5	641.561	1.7008	2.30308
53.25	639.308	1.3442	2.0429		72.5	640.21	1.4870	2.15802
80	637.664	1.0840	1.8032		101.5	639.112	1.3132	2.02234
104.75	636.71	0.9330	1.6322		135.5	638.12	1.1562	1.8816
133.25	636.263	0.8623	1.5407		164.5	637.235	1.0161	1.73678
162	635.662	0.7671	1.4029		217.5	635.641	0.7638	1.40732
234	634.867	0.6413	1.1854		294.5	633.568	0.4357	0.69913
348.25	633.821	0.4758	0.8002		363.5	633	0.3458	0.36742
440.75	633.121	0.3650	0.4226		438.5	632.5	0.2667	-0.0576
540.25	632.765	0.3086	0.1570		532.5	632.2	0.2192	-0.4401
631.75	632.412	0.2528	-0.2021		630.5	632	0.1876	-0.8119
732.25	632.112	0.2053	-0.6597		673.5	631.78	0.1527	-1.4961
820.25	631.912	0.1736	-1.1489		768.5	631.689	0.1383	-2.0174
921.75	631.780	0.1527	-1.6874		822.5	631.621	0.1276	-2.7334
971.75	631.721	0.1434	-2.0715		909.5	631.589	0.1225	-3.4112
1063.75	631.67	0.1353	-2.5903		966.5	631.556	0.1173	#NUM!
1120.75	631.652	0.1325	-2.8647		1016.5	631.512	0.110314483	#NUM!
1157.75	631.637	0.1301	-3.1701		1062.5	631.498	0.108098697	#NUM!
1207.75	631.628	0.1287	-3.4112					
1277.75	631.62	0.1274	-3.6889					
1303.75	631.6	0.1242	-5.2983					
1327.75	631.595	0.1235	#NUM!					

		sample-2			2*l*=0.11 cm			
		Cycle-1					Cycle-2	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)		Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0	721.48	2.6573	2.9120		0	720.224	2.4787	2.83925
0.25	721.223	2.6207	2.8980		0.5	720	2.4469	2.82607
0.75	720.401	2.5039	2.8516		0.75	719.678	2.4011	2.80681
1.5	720.003	2.4473	2.8283		1.75	719	2.3047	2.765
3.25	719.38	2.3587	2.7908		2.5	718.789	2.2747	2.75162
5.25	718.474	2.2299	2.7336		3.5	718.232	2.1955	2.71542
7.25	717.824	2.1375	2.6904		6.5	717.677	2.1166	2.678
12	716.352	1.9282	2.5852		9.5	717.453	2.0847	2.66249
29.25	714.864	1.7166	2.4662		43.5	714.986	1.7340	2.47359
53.25	713.189	1.4785	2.3128		72.5	712.468	1.3760	2.23506
80	711.415	1.2263	2.1197		101.5	711	1.1673	2.0642
104.75	710.568	1.1058	2.0125		135.5	709.867	1.0062	1.90895
133.25	709.587	0.9664	1.8720		164.5	708.216	0.7714	1.62826
162	708.425	0.8012	1.6750		217.5	707.356	0.6492	1.44338
234	707	0.5986	1.3646		294.5	706.213	0.4867	1.12882
348.25	705	0.3142	0.6492		363.5	705.222	0.3458	0.74241
440.75	704.561	0.2518	0.3887		438.5	704.556	0.2511	0.36116
540.25	704.103	0.1867	0.0169		532.5	704	0.1720	-0.129
631.75	703.779	0.1406	-0.3667		630.5	703.512	0.1027	-0.939
732.25	703.456	0.0947	-0.9943		673.5	703.33	0.0768	-1.5654
820.25	703.313	0.0744	-1.4828		768.5	703.22	0.0611	-2.3126
921.75	703.256	0.0663	-1.7720		822.5	703.168	0.0537	-3.0576
971.75	703.21	0.0597	-2.0875		909.5	703.142	0.0500	-3.8632
1063.75	703.168	0.0537	-2.501		966.5	703.121	0.0471	#NUM!
1120.75	703.146	0.0506	-2.8134		1016.5	703.11	0.045496488	#NUM!
1157.75	703.123	0.0473	-3.2968		1062.5	703.1	0.044074722	#NUM!
1207.75	703.112	0.0458	-3.6497					
1277.75	703.1	0.0441	-4.2687					
1303.75	703.092	0.0429	-5.116					
1327.75	703.086	0.0421	#NUM!					

		sample-3		2*l*=0.115 cm			
		Cycle-1				Cycle-2	
Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)	Time, h	Weight, mg	Water Content, wt%	ln(Mt- M∞)
0	667.1	0.0000	0.0000	0	684.345	2.5837	2.82471
0.25	667.341	0.0361	0.0134	0.5	684	2.5320	2.80403
0.75	667.45	0.0524	0.0195	0.75	683.657	2.4806	2.78303
1.5	667.874	0.1160	0.0431	1.75	682.786	2.3501	2.72766
3.25	668.367	0.1898	0.0705	2.5	682.342	2.2836	2.6982
5.25	668.771	0.2504	0.0930	3.5	681.675	2.1837	2.65226
7.25	669.389	0.3429	0.1274	6.5	681	2.0826	2.6035
12	669.602	0.3749	0.1392	9.5	680.789	2.0509	2.58776
29.25	670.823	0.5578	0.2071	43.5	679.232	1.8177	2.46326
53.25	671.789	0.7025	0.2609	72.5	677	1.4833	2.25245
80	672.563	0.8185	0.3039	101.5	676.453	1.4013	2.19322
104.75	673.451	0.9515	0.3533	135.5	675.437	1.2491	2.07292
133.25	674.589	1.1220	0.4167	164.5	674.897	1.1682	2.00256
162	676.398	1.3931	0.5173	217.5	673.677	0.9854	1.82261
234	678.11	1.6496	0.6126	294.5	671.612	0.6760	1.41658
348.25	679.282	1.8252	0.6778	363.5	670.344	0.4860	1.04907
440.75	680.123	1.9512	0.7245	438.5	669.564	0.3692	0.72996
540.25	680.787	2.0506	0.7615	532.5	668.564	0.2193	0.07232
631.75	681.423	2.1459	0.7969	630.5	667.898	0.1196	-0.894
732.25	681.993	2.2313	0.8286	673.5	667.7	0.0899	-1.5559
820.25	682.673	2.3332	0.8664	768.5	667.587	0.0730	-2.3228
921.75	683.058	2.3909	0.8878	822.5	667.547	0.0670	-2.8473
971.75	683.371	2.4378	0.90525	909.5	667.5	0.0599	-4.5099
1063.75	683.872	2.5128	0.93313	966.5	667.489	0.0583	#NUM!
1120.75	684.164	2.5566	0.94937	1016.5	667.476	0.056333808	#NUM!
1157.75	684.576	2.6183	0.97229	1062.5	667.466	0.054835568	#NUM!
1207.75	684.816	2.6543	0.98565				
1277.75	684.987	2.6799	0.99516				
1303.75	685.023	2.6853	0.99716				
1327.75	685.04	2.6878	0.99811				
	685.055	2.6901	0.99894				

Table 30. Sorption Data of neat vinyl ester Samples exposed to 40% RH at 25ºC

	sample-1	2*l* =0.07 cm			sample-2	2*l* =0.07 cm			sample-3	2*l* =0.072 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	510.656	0.0000	0.0000		624.88	0.0000	0		661.596	0.0000	0.0000
0.25	510.942	0.0560	0.1197		624.909	0.0046	0.0117		661.786	0.0287	0.0641
0.75	511.056	0.0783	0.1674		624.974	0.0150	0.0378		661.898	0.0456	0.1019
1.25	511.262	0.1187	0.2537		625.067	0.0299	0.0753		662.054	0.0692	0.1545
2.25	511.34	0.1339	0.2863		625.15	0.0432	0.1087		662.155	0.0845	0.1886
4.25	511.503	0.1659	0.3545		625.39	0.0816	0.2053		662.371	0.1171	0.2615
6.25	511.63	0.1907	0.4077		625.515	0.1016	0.2556		662.499	0.1365	0.3047
15.75	512.016	0.2663	0.5693		625.968	0.1741	0.438		662.963	0.2066	0.4612
24.25	512.331	0.3280	0.7011		626.227	0.2156	0.5423		663.333	0.2625	0.5860
45	512.561	0.3730	0.7974		626.586	0.2730	0.6868		663.706	0.3189	0.7119
89.25	512.932	0.4457	0.9527		627.133	0.3605	0.907		664.222	0.3969	0.8860
148	513.012	0.4614	0.9862		627.29	0.3857	0.9702		664.518	0.4417	0.9858
213.5	513.023	0.4635	0.9908		627.311	0.3890	0.9787		664.523	0.4424	0.9875
237.5	513.036	0.4661	0.9962		627.323	0.3910	0.9835		664.53	0.4435	0.9899
285.5	513.04	0.4669	0.9979		627.338	0.3934	0.9895		664.536	0.4444	0.9919
329	513.035	0.4659	0.9958		627.345	0.3945	0.9924		664.549	0.4463	0.9963
363	513.045	0.4678	1.0000		627.364	0.3975	1		664.56	0.4480	1.0000

	sample-4	2*l* =0.08 cm			sample-5	2*l* =0.085 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	703.823	0.0000	0.0000		788.249	0.0000	0
0.25	703.853	0.0043	0.0104		788.48	0.0293	0.0678
0.75	703.981	0.0224	0.0550		788.591	0.0434	0.1004
1.25	704.16	0.0479	0.1172		788.714	0.0590	0.1365
2.25	704.266	0.0629	0.1541		788.818	0.0722	0.167
4.25	704.462	0.0908	0.2223		789.133	0.1121	0.2595
6.25	704.589	0.1088	0.2664		789.157	0.1152	0.2665
15.75	705.061	0.1759	0.4306		789.626	0.1747	0.4042
24.25	705.382	0.2215	0.5423		789.982	0.2199	0.5087
45	705.763	0.2756	0.6748		790.386	0.2711	0.6272
89.25	706.358	0.3602	0.8817		791.11	0.3630	0.8397
148	706.602	0.3948	0.9666		791.485	0.4105	0.9498
213.5	706.635	0.3995	0.9781		791.562	0.4203	0.9724
237.5	706.645	0.4010	0.9816		791.586	0.4233	0.9795
285.5	706.659	0.4029	0.9864		791.602	0.4254	0.9842
329	706.687	0.4069	0.9962		791.632	0.4292	0.993
363	706.698	0.4085	1.0000		791.656	0.4322	1

Table 31. Sorption Data of vinyl ester samples containing 2 wt% Cloisite 10A® exposed to 40% RH at 25ºC

	sample-1	2*l*=0.0732 cm			sample-2	2*l*=0.0655 cm			sample-3	2*l*=0.07 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	838.301	0.0000	0.0000		613.714	0.0000	0		679.131	0.0000	0.0000
0.25	838.375	0.0088	0.0223		613.746	0.0052	0.0116		679.271	0.0206	0.0440
0.75	838.525	0.0267	0.0674		613.925	0.0344	0.0763		679.486	0.0523	0.1115
1.25	838.682	0.0454	0.1146		614.106	0.0639	0.1418		679.615	0.0713	0.1521
2.25	838.769	0.0558	0.1408		614.19	0.0776	0.1722		679.73	0.0882	0.1882
4.25	839.013	0.0849	0.2141		614.379	0.1084	0.2406		679.972	0.1238	0.2642
6.25	839.13	0.0989	0.2493		614.482	0.1251	0.2779		680.025	0.1316	0.2809
15.75	839.698	0.1666	0.4202		615.037	0.2156	0.4787		680.515	0.2038	0.4348
24.25	839.994	0.2020	0.5092		615.18	0.2389	0.5304		680.777	0.2424	0.5171
45	840.546	0.2678	0.6752		615.532	0.2962	0.6577		681.138	0.2955	0.6305
89.25	841.038	0.3265	0.8232		616.02	0.3757	0.8343		681.668	0.3736	0.7970
148	841.367	0.3657	0.9221		616.212	0.4070	0.9038		681.95	0.4151	0.8856
213.5	841.423	0.3724	0.9389		616.292	0.4201	0.9327		682.218	0.4546	0.9698
237.5	841.456	0.3764	0.9489		616.325	0.4254	0.9446		682.255	0.4600	0.9815
285.5	841.471	0.3781	0.9534		616.356	0.4305	0.9559		682.265	0.4615	0.9846
329	841.521	0.3841	0.9684		616.391	0.4362	0.9685		682.271	0.4624	0.9865
363	841.534	0.3857	0.9723		616.421	0.4411	0.9794		682.283	0.4641	0.9903
382.00	841.568	0.3897	0.9826		616.435	0.4434	0.9844		682.294	0.4657	0.9937
408.00	841.598	0.3933	0.9916		616.451	0.4460	0.9902		682.3	0.4666	0.9956
425.00	841.612	0.3950	0.9958		616.459	0.4473	0.9931		682.305	0.4674	0.9972
457.00	841.620	0.3959	0.9982		616.467	0.4486	0.9960		682.31	0.4681	0.9987
477	841.626	0.3966	1.0000		616.478	0.4504	1.0000		682.314	0.4687	1.0000

	sample-4	2*l*=0.08 cm			sample-5	2*l*=0.085 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	663.72	0.0000	0.0000		588.712	0.0000	0
0.25	663.898	0.0268	0.0610		588.81	0.0166	0.037
0.75	663.928	0.0313	0.0713		588.958	0.0418	0.0929
1.25	664.04	0.0482	0.1096		589.077	0.0620	0.1378
2.25	664.175	0.0686	0.1559		589.188	0.0809	0.1798
4.25	664.324	0.0910	0.2069		589.43	0.1220	0.2711
6.25	664.469	0.1128	0.2566		589.527	0.1384	0.3078
15.75	664.928	0.1820	0.4138		589.96	0.2120	0.4713
24.25	665.164	0.2176	0.4947		590.223	0.2567	0.5706
45	665.504	0.2688	0.6112		590.57	0.3156	0.7017
89.25	666.107	0.3596	0.8177		591.01	0.3903	0.8678
148	666.318	0.3914	0.8900		591.131	0.4109	0.9135
213.5	666.51	0.4204	0.9558		591.284	0.4369	0.9713
237.5	666.535	0.4241	0.9644		591.291	0.4381	0.9739
285.5	666.565	0.4286	0.9746		591.3	0.4396	0.9773
329	666.581	0.4311	0.9801		591.31	0.4413	0.9811
363	666.594	0.4330	0.9846		591.32	0.4430	0.9849
382.00	666.600	0.4339	0.9866		591.331	0.4449	0.989
408.00	666.612	0.4357	0.9908		591.345	0.4472	0.9943
425.00	666.620	0.4369	0.9935		591.35	0.4481	0.9962
457.00	666.631	0.4386	0.9973		591.355	0.4489	0.9981
477	666.639	0.4398	1.0000		591.36	0.4498	1.0000

Table 32. Sorption Data of vinyl ester samples containing 5 wt% Cloisite 10A® exposed to 40% RH at 25ºC

	sample-1	2*l*=0.062 cm			sample-2	2*l*=0.067 cm			sample-3	2*l*=0.0585 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	650.515	0.0000	0.0000		705.438	0.0000	0		616.742	0.0000	0.0000
0.25	650.573	0.0089	0.0190		705.513	0.0106	0.0241		616.801	0.0096	0.0219
0.75	650.778	0.0404	0.0863		705.658	0.0312	0.0707		616.971	0.0371	0.0850
1.25	650.847	0.0510	0.1090		705.505	0.0095	0.0215		617.084	0.0555	0.1270
2.25	650.938	0.0650	0.1388		705.835	0.0563	0.1276		617.21	0.0759	0.1738
4.25	651.093	0.0889	0.1897		706.089	0.0923	0.2093		617.368	0.1015	0.2325
6.25	651.248	0.1127	0.2406		706.141	0.0997	0.226		617.513	0.1250	0.2863
15.75	651.605	0.1676	0.3577		706.588	0.1630	0.3697		617.854	0.1803	0.4129
24.25	652.04	0.2344	0.5005		706.881	0.2046	0.4638		618.187	0.2343	0.5366
45	652.271	0.2699	0.5763		707.337	0.2692	0.6104		618.417	0.2716	0.6220
89.25	652.76	0.3451	0.7368		707.793	0.3338	0.757		618.899	0.3497	0.8010
148	653.165	0.4074	0.8697		708.05	0.3703	0.8396		619.191	0.3971	0.9094
213.5	653.295	0.4274	0.9124		708.302	0.4060	0.9206		619.296	0.4141	0.9484
237.5	653.366	0.4383	0.9357		708.35	0.4128	0.936		619.323	0.4185	0.9584
285.5	653.435	0.4489	0.9583		708.398	0.4196	0.9515		619.356	0.4238	0.9707
329	653.456	0.4521	0.9652		708.425	0.4234	0.9601		619.372	0.4264	0.9766
363	653.485	0.4566	0.9747		708.468	0.4295	0.974		619.388	0.4290	0.9825
382.00	653.500	0.4589	0.9797		708.498	0.4338	0.9836		619.402	0.4313	0.9877
408.00	653.510	0.4604	0.9829		708.51	0.4355	0.9875		619.41	0.4326	0.9907
425.00	653.521	0.4621	0.9865		708.521	0.4370	0.9910		619.415	0.4334	0.9926
457.00	653.536	0.4644	0.9915		708.528	0.4380	0.9932		619.421	0.4344	0.9948
477	653.546	0.4659	0.9947		708.533	0.4387	0.9949		619.421	0.4344	0.9948
519.00	653.56	0.4675	0.9980		708.54	0.4399	0.9974		619.43	0.4362	0.9989
568.00	653.56	0.4684	1.0000		708.55	0.4410	1.0000		619.44	0.4366	1.0000

	sample-4	2*l*=0.0575 cm			sample-5	2*l*=0.08 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	546.687	0.0000	0.0000		534.02	0.0000	0
0.25	546.759	0.0132	0.0268		534.115	0.0178	0.0396
0.75	546.912	0.0412	0.0836		534.223	0.0380	0.0846
1.25	547.051	0.0666	0.1353		534.264	0.0457	0.1017
2.25	547.144	0.0836	0.1698		534.575	0.1039	0.2313
4.25	547.358	0.1227	0.2493		534.596	0.1079	0.2401
6.25	547.468	0.1429	0.2902		534.732	0.1333	0.2968
15.75	547.728	0.1904	0.3868		534.968	0.1775	0.3952
24.25	548.017	0.2433	0.4942		535.165	0.2144	0.4773
45	548.405	0.3143	0.6384		535.496	0.2764	0.6153
89.25	548.87	0.3993	0.8112		535.894	0.3509	0.7812
148	549.065	0.4350	0.8837		536.11	0.3914	0.8712
213.5	549.154	0.4513	0.9168		536.27	0.4213	0.9379
237.5	549.198	0.4593	0.9331		536.298	0.4266	0.9496
285.5	549.235	0.4661	0.9469		536.312	0.4292	0.9554
329	549.265	0.4716	0.9580		536.325	0.4316	0.9608
363	549.284	0.4750	0.9651		536.352	0.4367	0.9721
382.00	549.299	0.4778	0.9706		536.368	0.4397	0.9787
408.00	549.312	0.4802	0.9755		536.381	0.4421	0.9842
425.00	549.335	0.4844	0.9840		536.398	0.4453	0.9912
457.00	549.351	0.4873	0.9900		536.405	0.4466	0.9942
477	549.365	0.4899	0.9952		536.41	0.4475	0.9962
519.00	549.37	0.4910	0.9974		536.42	0.4487	0.9987
568.00	549.38	0.4922	1.0000		536.42	0.4492	1.0000

Table 33. Sorption Data of neat vinyl ester Samples exposed to 60% RH at 25ºC

	sample-1	2*l*=0.11 cm			sample-2	2*l*=0.1043 cm			sample-3	2*l*=0.1 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	594.208	0.0000	0.0000		597.801	0.0000	0		577.489	0.0000	0.0000
0.25	594.32	0.0188	0.0328		597.921	0.0201	0.0339		577.621	0.0229	0.0391
0.75	594.45	0.0407	0.0709		598.035	0.0391	0.0661		577.712	0.0386	0.0661
1.75	594.598	0.0656	0.1142		598.235	0.0726	0.1226		577.889	0.0693	0.1185
3.75	594.8	0.0996	0.1734		598.397	0.0997	0.1683		578.11	0.1075	0.1839
5.75	594.998	0.1330	0.2313		598.511	0.1188	0.2005		578.265	0.1344	0.2299
15.25	595.365	0.1947	0.3388		598.91	0.1855	0.3132		578.635	0.1984	0.3395
23.75	595.556	0.2269	0.3947		599.31	0.2524	0.4262		578.798	0.2267	0.3877
44.5833	595.968	0.2962	0.5154		599.678	0.3140	0.5301		579.321	0.3172	0.5427
88.8333	596.568	0.3972	0.6911		600.302	0.4184	0.7063		579.998	0.4345	0.7432
147.833	597.1	0.4867	0.8469		600.711	0.4868	0.8218		580.368	0.4985	0.8528
213.333	597.3	0.5204	0.9054		601	0.5351	0.9034		580.689	0.5541	0.9479
328.833	597.54	0.5607	0.9757		601.256	0.5780	0.9757		580.8	0.5733	0.9807
362.333	597.59	0.5692	0.9903		601.299	0.5851	0.9879		580.815	0.5759	0.9852
381.333	597.599	0.5707	0.9930		601.339	0.5918	0.9992		580.832	0.5789	0.9902
407.333	597.623	0.5747	1.0000		601.342	0.5923	1		580.865	0.5846	1.0000

	sample-4	2*l*=0.114 cm			sample-5	2*l*=0.121 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	718.105	0.0000	0.0000		597.775	0.0000	0
0.25	718.284	0.0249	0.0425		597.958	0.0306	0.0512
0.75	718.39	0.0397	0.0676		598.089	0.0525	0.0878
1.75	718.52	0.0578	0.0984		598.189	0.0693	0.1158
3.75	718.711	0.0844	0.1437		598.308	0.0892	0.1491
5.75	718.898	0.1104	0.1881		598.465	0.1154	0.193
15.25	719.432	0.1848	0.3148		598.786	0.1691	0.2828
23.75	719.689	0.2206	0.3757		598.999	0.2048	0.3424
44.5833	720.356	0.3135	0.5339		599.489	0.2867	0.4794
88.8333	721.12	0.4199	0.7151		600.215	0.4082	0.6825
147.833	721.601	0.4868	0.8292		600.721	0.4928	0.8241
213.333	721.921	0.5314	0.9051		601.02	0.5428	0.9077
328.833	722.245	0.5765	0.9820		601.285	0.5872	0.9818
362.333	722.27	0.5800	0.9879		601.3	0.5897	0.986
381.333	722.298	0.5839	0.9945		601.33	0.5947	0.9944
407.333	722.321	0.5871	1.0000		601.35	0.5981	1

Table 34. Sorption Data of vinyl ester samples containing 2 wt% Cloisite 10A® exposed to 60% RH at 25ºC

	sample-1	2*l*=0.124 cm			sample-2	2*l*=0.1051 cm			sample-3	2*l*=0.1063 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	704.082	0.0000	0.0000		670.244	0.0000	0		700.756	0.0000	0.0000
0.25	704.211	0.0183	0.0304		670.356	0.0167	0.0273		700.921	0.0235	0.0370
0.75	704.312	0.0327	0.0541		670.465	0.0330	0.0539		701	0.0348	0.0548
1.75	704.421	0.0481	0.0798		670.578	0.0498	0.0815		701.112	0.0508	0.0799
3.75	704.521	0.0624	0.1033		670.67	0.0636	0.104		701.278	0.0745	0.1172
5.75	704.663	0.0825	0.1367		670.865	0.0927	0.1515		701.44	0.0976	0.1535
15.25	705.06	0.1389	0.2301		671.2	0.1426	0.2333		701.856	0.1570	0.2469
23.75	705.29	0.1716	0.2842		671.5	0.1874	0.3065		702.21	0.2075	0.3264
44.5833	705.71	0.2312	0.3831		672	0.2620	0.4285		702.703	0.2778	0.4370
88.8333	706.32	0.3179	0.5266		672.6	0.3515	0.5749		703.321	0.3660	0.5758
147.833	706.721	0.3748	0.6209		672.87	0.3918	0.6408		703.687	0.4183	0.6579
213.333	707.12	0.4315	0.7148		673.342	0.4622	0.756		704	0.4629	0.7282
328.833	707.78	0.5252	0.8701		673.897	0.5450	0.8914		704.543	0.5404	0.8501
362.333	707.82	0.5309	0.8795		674.032	0.5652	0.9244		704.712	0.5645	0.8880
381.333	707.88	0.5394	0.8936		674.098	0.5750	0.9405		704.833	0.5818	0.9152
407.333	708.043	0.5626	0.9320		674.132	0.5801	0.9488		704.921	0.5944	0.9349
424.333	708.101	0.5708	0.9456		674.154	0.5834	0.9541		704.988	0.6039	0.9499
456.33	708.156	0.5786	0.9586		674.187	0.5883	0.9622		705	0.6056	0.9526
476.33	708.210	0.5863	0.9713		674.2	0.5902	0.9653		705.064	0.6148	0.9670
518.33	708.260	0.5934	0.9831		674.3	0.6052	0.9898		705.123	0.6232	0.9802
567.33	708.300	0.5991	0.9925		674.312	0.6069	0.9927		705.198	0.6339	0.9971
591.333	708.332	0.6036	1.0000		674.342	0.6114	1.0000		705.211	0.6357	1.0000

	sample-4	2*l*=0.1 cm			sample-5	2*l*=0.0965 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	560.671	0.0000	0.0000		638.418	0.0000	0
0.25	560.789	0.0210	0.0344		638.521	0.0161	0.0263
0.75	560.911	0.0428	0.0699		638.634	0.0338	0.0552
1.75	560.99	0.0569	0.0929		638.764	0.0542	0.0884
3.75	561.2	0.0944	0.1541		638.97	0.0865	0.1411
5.75	561.32	0.1158	0.1890		639.12	0.1100	0.1794
15.25	561.67	0.1782	0.2910		639.478	0.1660	0.271
23.75	561.91	0.2210	0.3609		639.7	0.2008	0.3277
44.5833	562.32	0.2941	0.4803		640.213	0.2812	0.4588
88.8333	562.8	0.3797	0.6202		640.732	0.3625	0.5915
147.833	563.321	0.4726	0.7719		641	0.4044	0.66
213.333	563.59	0.5206	0.8503		641.4	0.4671	0.7623
328.833	563.8	0.5581	0.9114		641.89	0.5438	0.8875
362.333	563.85	0.5670	0.9260		641.96	0.5548	0.9054
381.333	563.89	0.5741	0.9377		642.02	0.5642	0.9208
407.333	563.92	0.5795	0.9464		642.1	0.5767	0.9412
424.333	563.932	0.5816	0.9499		642.17	0.5877	0.9591
456.33	563.987	0.5914	0.9659		642.21	0.5940	0.9693
476.33	564.000	0.5938	0.9697		642.25	0.6002	0.9796
518.33	564.050	0.6027	0.9843		642.278	0.6046	0.9867
567.33	564.080	0.6080	0.9930		642.3	0.6081	0.9923
591.333	564.104	0.6123	1.0000		642.33	0.6128	1.0000

Table 35. Sorption Data of vinyl ester samples containing 5 wt% Cloisite 10A® exposed to 60% RH at 25ºC

	sample-1	$2l$=0.124 cm			sample-2	$2l$=0.1051 cm			sample-3	$2l$=0.1063 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	802.125	0.0000	0.0000		670.555	0.0000	0		558.289	0.0000	0.0000
0.25	802.231	0.0132	0.0208		670.67	0.0171	0.0283		558.399	0.0197	0.0326
0.75	802.355	0.0287	0.0452		670.78	0.0336	0.0554		558.51	0.0396	0.0656
1.75	802.53	0.0505	0.0796		670.843	0.0429	0.0708		558.62	0.0593	0.0982
3.75	802.6	0.0592	0.0934		670.954	0.0595	0.0982		558.73	0.0790	0.1308
5.75	802.89	0.0954	0.1504		671.132	0.0860	0.1419		558.823	0.0956	0.1584
15.25	803.2	0.1340	0.2114		671.4	0.1260	0.2079		559.133	0.1512	0.2504
23.75	803.65	0.1901	0.2999		671.8	0.1857	0.3063		559.476	0.2126	0.3521
44.5833	804.21	0.2599	0.4100		672.21	0.2468	0.4071		559.98	0.3029	0.5016
88.8333	804.87	0.3422	0.5398		672.71	0.3214	0.5301		560.4	0.3781	0.6262
147.833	805.444	0.4138	0.6527		673.2	0.3944	0.6507		560.798	0.4494	0.7443
213.333	805.81	0.4594	0.7247		673.5	0.4392	0.7245		561.1	0.5035	0.8339
328.833	806.321	0.5231	0.8252		673.88	0.4959	0.818		561.27	0.5340	0.8843
362.333	806.5	0.5454	0.8604		673.97	0.5093	0.8401		561.36	0.5501	0.9110
381.333	806.61	0.5591	0.8820		674	0.5138	0.8475		561.42	0.5608	0.9288
407.333	806.71	0.5716	0.9017		674.12	0.5316	0.877		561.49	0.5734	0.9496
424.333	806.81	0.5841	0.9213		674.19	0.5421	0.8942		561.52	0.5787	0.9585
456.33	806.920	0.5978	0.9430		674.298	0.5582	0.9208		561.56	0.5859	0.9703
476.33	806.990	0.6065	0.9567		674.398	0.5731	0.9454		561.59	0.5913	0.9792
518.33	807.060	0.6152	0.9705		674.476	0.5847	0.9646		561.61	0.5949	0.9852
567.33	807.120	0.6227	0.9823		674.512	0.5901	0.9734		561.63	0.5984	0.9911
591.333	807.167	0.6286	0.9915		674.567	0.5983	0.9870		561.645	0.6011	0.9956
621.333	807.19	0.6314	0.9961		674.611	0.6049	0.9978		561.65	0.6020	0.9970
646.333	807.21	0.6339	1.0000		674.62	0.6062	1.0000		561.66	0.6038	1.0000

	sample-4	$2l$=0.0886 cm			sample-5	$2l$=0.088 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	580.823	0.0000	0.0000		461.347	0.0000	0
0.25	580.921	0.0169	0.0272		461.456	0.0236	0.0385
0.75	581.032	0.0360	0.0579		461.546	0.0431	0.0702
1.75	581.156	0.0573	0.0923		461.633	0.0620	0.101
3.75	581.287	0.0799	0.1286		461.755	0.0884	0.144
5.75	581.4	0.0993	0.1600		461.89	0.1177	0.1917
15.25	581.791	0.1667	0.2684		462.15	0.1741	0.2834
23.75	582.03	0.2078	0.3346		462.51	0.2521	0.4105
44.5833	582.59	0.3042	0.4899		462.8	0.3149	0.5129
88.8333	583.1	0.3920	0.6313		463.2	0.4016	0.6541
147.833	583.47	0.4557	0.7339		463.4	0.4450	0.7247
213.333	583.78	0.5091	0.8198		463.61	0.4905	0.7988
328.833	584.1	0.5642	0.9085		463.85	0.5425	0.8835
362.333	584.2	0.5814	0.9362		463.92	0.5577	0.9082
381.333	584.27	0.5935	0.9556		463.95	0.5642	0.9188
407.333	584.31	0.6004	0.9667		463.97	0.5686	0.9259
424.333	584.34	0.6055	0.9750		464	0.5751	0.9365
456.33	584.360	0.6090	0.9806		464.04	0.5837	0.9506
476.33	584.378	0.6121	0.9856		464.08	0.5924	0.9647
518.33	584.390	0.6141	0.9889		464.11	0.5989	0.9753
567.33	584.400	0.6159	0.9917		464.13	0.6032	0.9824
591.333	584.42	0.6193	0.9972		464.15	0.6076	0.9894
621.333	584.44	0.6227	1.0028		464.17	0.6119	0.9965
646.333	584.43	0.6210	1.0000		464.18	0.6141	1.0000

Table 36. Sorption Data of neat vinyl ester Samples exposed to 70% RH at 25ºC

	sample-1	$2l$=0.11 cm			sample-2	$2l$=0.1043 cm			sample-3	$2l$=0.1 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	644.87	0.0000	0.0000		597.29	0.0000	0		730.07	0.0000	0.0000
0.5	645.21	0.0527	0.0644		597.64	0.0586	0.0713		730.359	0.0396	0.0498
1.5	645.63	0.1179	0.1439		597.98	0.1155	0.1405		730.66	0.0808	0.1017
3.5	645.92	0.1628	0.1989		598.28	0.1657	0.2016		730.943	0.1196	0.1505
13.3333	646.9	0.3148	0.3845		599	0.2863	0.3483		731.764	0.2320	0.2921
23.3333	647.456	0.4010	0.4898		599.675	0.3993	0.4857		732.4	0.3191	0.4017
42.8333	647.91	0.4714	0.5758		600.43	0.5257	0.6395		733.305	0.4431	0.5578
65.3333	648.465	0.5575	0.6809		600.87	0.5994	0.7291		733.98	0.5356	0.6741
91.3333	648.9	0.6249	0.7633		601.4	0.6881	0.8371		734.4	0.5931	0.7466
113.333	649.32	0.6901	0.8428		601.56	0.7149	0.8697		734.747	0.6406	0.8064
141.333	649.56	0.7273	0.8883		601.78	0.7517	0.9145		735.11	0.6903	0.8690
162.333	649.7	0.7490	0.9148		601.94	0.7785	0.947		735.2	0.7027	0.8845
171.333	649.74	0.7552	0.9223		602	0.7886	0.9593		735.4	0.7301	0.9190
219.333	649.8	0.7645	0.9337		602.1	0.8053	0.9796		735.621	0.7603	0.9571
245.333	649.92	0.7831	0.9564		602.16	0.8153	0.9919		735.7	0.7712	0.9707
269.333	650	0.7955	0.9716		602.18	0.8187	0.9959		735.765	0.7801	0.9819
293.33	650.050	0.8033	0.9811		602.19	0.8204	0.998		735.78	0.7821	0.9845
317.33	650.100	0.8110	0.9905		602.196	0.8214	0.9992		735.8	0.7849	0.9879
341.33	650.150	0.8188	1.0000		602.2	0.8220	1.0000		735.87	0.7944	1.0000

	sample-4	2*l*=0.102 cm			sample-5	2*l*=0.089 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	782.21	0.0000	0.0000		553.25	0.0000	0
0.5	782.64	0.0550	0.0692		553.59	0.0615	0.0786
1.5	782.879	0.0855	0.1077		553.78	0.0958	0.1225
3.5	783.28	0.1368	0.1723		554.3	0.1898	0.2428
13.3333	784	0.2288	0.2882		554.88	0.2946	0.3769
23.3333	784.96	0.3516	0.4428		555.432	0.3944	0.5045
42.8333	785.47	0.4168	0.5250		556	0.4971	0.6358
65.3333	786.231	0.5141	0.6475		556.476	0.5831	0.7459
91.3333	786.91	0.6009	0.7568		556.821	0.6455	0.8257
113.333	787.321	0.6534	0.8230		557.1	0.6959	0.8902
141.333	787.633	0.6933	0.8733		557.3	0.7320	0.9364
162.333	787.832	0.7187	0.9053		557.38	0.7465	0.9549
171.333	787.956	0.7346	0.9253		557.44	0.7573	0.9688
219.333	788.21	0.7671	0.9662		557.5	0.7682	0.9827
245.333	788.3	0.7786	0.9807		557.53	0.7736	0.9896
269.333	788.36	0.7862	0.9903		557.552	0.7776	0.9947
293.33	788.390	0.7901	0.9952		557.563	0.7796	0.9972
317.33	788.410	0.7926	0.9984		557.57	0.7808	0.9988
341.33	788.420	0.7939	1.0000		557.575	0.7817	1.0000

Table 37. Sorption Data of vinyl ester samples containing 2 wt% Cloisite 10A® exposed to 70% RH at 25ºC

	sample-1	2*l*=0.102 cm			sample-2	2*l*=0.101 cm			sample-3	2*l*=0.1019 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	720.817	0.0000	0.0000		709.768	0.0000	0		749.951	0.0000	0.0000
0.5	721.38	0.0781	0.0915		710.4	0.0890	0.1017		750.44	0.0652	0.0775
1.5	721.876	0.1469	0.1721		710.78	0.1426	0.1629		750.84	0.1185	0.1409
3.5	722	0.1641	0.1923		711.24	0.2074	0.237		751.003	0.1403	0.1667
13.3333	722.65	0.2543	0.2979		712.101	0.3287	0.3756		752	0.2732	0.3247
23.3333	723.49	0.3708	0.4344		712.471	0.3808	0.4351		752.786	0.3780	0.4492
42.8333	723.98	0.4388	0.5141		713.202	0.4838	0.5528		753.435	0.4646	0.5521
65.3333	724.67	0.5345	0.6262		714.1	0.6103	0.6974		754.432	0.5975	0.7100
91.3333	725.33	0.6261	0.7335		714.657	0.6888	0.787		755.121	0.6894	0.8192
113.333	725.67	0.6733	0.7887		714.932	0.7276	0.8313		755.679	0.7638	0.9076
141.333	725.98	0.7163	0.8391		715.243	0.7714	0.8814		756.01	0.8079	0.9601
162.333	726.2	0.7468	0.8749		715.532	0.8121	0.9279		756.089	0.8185	0.9726
171.333	726.43	0.7787	0.9122		715.66	0.8301	0.9485		756.154	0.8271	0.9829
219.333	726.704	0.8167	0.9568		715.832	0.8544	0.9762		756.19	0.8319	0.9886
245.333	726.87	0.8397	0.9837		715.91	0.8654	0.9887		756.21	0.8346	0.9918
269.333	726.9	0.8439	0.9886		715.94	0.8696	0.9936		756.22	0.8359	0.9933
293.333	726.92	0.8467	0.9919		715.956	0.8718	0.9961		756.228	0.8370	0.9946
317.33	726.940	0.8495	0.9951		715.966	0.8732	0.9977		756.236	0.8381	0.9959
341.33	726.950	0.8508	0.9967		715.973	0.8742	0.9989		756.241	0.8387	0.9967
389.33	726.958	0.8519	0.9980		715.984	0.8758	1.0006		756.25	0.8399	0.9981
437.33	726.966	0.8531	0.9993		715.99	0.8766	1.0016		756.257	0.8409	0.9992
485.333	726.97	0.8536	1.0000		715.98	0.8752	1.0000		756.262	0.8415	1.0000

	sample-1	2*l*=0.102 cm			sample-2	2*l*=0.101 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	757.599	0.0000	0.0000		672.78	0.0000	0
0.5	758	0.0529	0.0604		673.132	0.0523	0.0577
1.5	758.345	0.0985	0.1123		673.456	0.1005	0.1108
3.5	758.675	0.1420	0.1620		673.889	0.1648	0.1818
13.3333	759.421	0.2405	0.2744		674.665	0.2802	0.309
23.3333	760.043	0.3226	0.3680		675.121	0.3480	0.3838
42.8333	760.979	0.4461	0.5090		675.765	0.4437	0.4893
65.3333	761.675	0.5380	0.6138		676.668	0.5779	0.6374
91.3333	762.435	0.6383	0.7282		677.342	0.6781	0.7479
113.333	763.12	0.7287	0.8314		677.692	0.7301	0.8052
141.333	763.41	0.7670	0.8750		677.921	0.7641	0.8428
162.333	763.543	0.7846	0.8950		678.232	0.8104	0.8938
171.333	763.611	0.7936	0.9053		678.311	0.8221	0.9067
219.333	763.7	0.8053	0.9187		678.532	0.8550	0.943
245.333	764	0.8449	0.9639		678.645	0.8718	0.9615
269.333	764.098	0.8578	0.9786		678.721	0.8831	0.9739
293.333	764.177	0.8683	0.9905		678.798	0.8945	0.9866
317.33	764.210	0.8726	0.9955		678.832	0.8996	0.9921
341.33	764.220	0.8739	0.9970		678.854	0.9028	0.9957
389.33	764.226	0.8747	0.9979		678.868	0.9049	0.9980
437.33	764.234	0.8758	0.9991		678.878	0.9064	0.9997
485.333	764.24	0.8766	1.0000		678.88	0.9067	1.0000

Table 38. Sorption Data of vinyl ester samples containing 5 wt% Cloisite 10A® exposed to 70% RH at 25ºC

	sample-1	2*l* =0.11 cm			sample-2	2*l* =0.112 cm			sample-3	2*l* =0.11 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	828.45	0.0000	0.0000		921.38	0.0000	0		935.497	0.0000	0.0000
0.5	828.965	0.0622	0.0682		921.788	0.0443	0.0502		935.998	0.0536	0.0603
1.5	829.321	0.1051	0.1154		922.181	0.0869	0.0986		936.367	0.0930	0.1048
3.5	829.678	0.1482	0.1626		922.678	0.1409	0.1599		936.765	0.1355	0.1527
13.3333	830.563	0.2551	0.2799		923.878	0.2711	0.3076		937.789	0.2450	0.2760
23.3333	831.254	0.3385	0.3714		924.291	0.3159	0.3585		938.423	0.3128	0.3524
42.8333	832.003	0.4289	0.4706		924.789	0.3700	0.4198		939.39	0.4161	0.4689
65.3333	832.987	0.5476	0.6009		925.578	0.4556	0.517		940.234	0.5064	0.5705
91.3333	833.564	0.6173	0.6774		926.477	0.5532	0.6277		941	0.5882	0.6628
113.333	833.799	0.6457	0.7085		926.877	0.5966	0.677		941.5	0.6417	0.7230
141.333	834.333	0.7101	0.7792		927.564	0.6712	0.7616		941.856	0.6797	0.7659
162.333	834.666	0.7503	0.8233		927.878	0.7052	0.8002		941.999	0.6950	0.7831
171.333	834.86	0.7737	0.8490		927.998	0.7183	0.815		942.111	0.7070	0.7966
219.333	835.004	0.7911	0.8681		928.4	0.7619	0.8645		942.669	0.7667	0.8638
245.333	835.178	0.8121	0.8911		928.6	0.7836	0.8892		942.897	0.7910	0.8912
269.333	835.3	0.8268	0.9073		928.786	0.8038	0.9121		943.2	0.8234	0.9277
293.333	835.4	0.8389	0.9205		929	0.8270	0.9384		943.3	0.8341	0.9398
317.33	835.500	0.8510	0.9338		929.1	0.8379	0.9507		943.4	0.8448	0.9518
341.33	835.600	0.8631	0.9470		929.2	0.8487	0.9631		943.5	0.8555	0.9639
389.33	835.800	0.8872	0.9735		929.37	0.8672	0.9840		943.6	0.8662	0.9759
437.33	835.900	0.8993	0.9868		929.43	0.8737	0.9914		943.7	0.8769	0.9880
485.333	835.96	0.9065	0.9947		929.46	0.8769	0.9951		943.74	0.8811	0.9928
509.33	835.98	0.9087	0.9971		929.48	0.8791	0.9975		943.77	0.8843	0.9964
533.33	835.99	0.9100	0.9985		929.49	0.8802	0.9988		943.79	0.8865	0.9988
566.33	836.00	0.9113	1.0000		929.50	0.8813	1.0000		943.80	0.8875	1.0000

	sample-4	$2l$=0.089 cm			sample-5	$2l$=0.0845 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	687.04	0.0000	0.0000		664.144	0.0000	0
0.5	687.575	0.0779	0.0848		664.532	0.0584	0.0638
1.5	687.898	0.1249	0.1360		664.878	0.1105	0.1207
3.5	688.232	0.1735	0.1889		665.276	0.1704	0.1861
13.3333	688.876	0.2672	0.2910		665.878	0.2611	0.2851
23.3333	689.232	0.3190	0.3474		666.342	0.3310	0.3614
42.8333	689.987	0.4289	0.4670		666.934	0.4201	0.4587
65.3333	691.143	0.5972	0.6502		668.003	0.5810	0.6345
91.3333	691.563	0.6583	0.7168		668.564	0.6655	0.7267
113.333	691.887	0.7055	0.7681		668.878	0.7128	0.7784
141.333	692.212	0.7528	0.8197		668.998	0.7309	0.7981
162.333	692.435	0.7853	0.8550		669.356	0.7848	0.857
171.333	692.532	0.7994	0.8704		669.4	0.7914	0.8642
219.333	692.678	0.8206	0.8935		669.453	0.7994	0.8729
245.333	692.732	0.8285	0.9021		669.6	0.8215	0.8971
269.333	692.854	0.8462	0.9214		669.721	0.8397	0.917
293.333	692.949	0.8601	0.9365		669.798	0.8513	0.9296
317.33	693.000	0.8675	0.9445		669.832	0.8564	0.9352
341.33	693.100	0.8820	0.9604		669.876	0.8631	0.9425
389.33	693.200	0.8966	0.9762		669.943	0.8732	0.9535
437.33	693.265	0.9061	0.9865		670.1	0.8968	0.9793
485.333	693.3	0.9112	0.9921		670.165	0.9066	0.9900
509.33	693.33	0.9155	0.9968		670.20	0.9125	0.9964
533.33	693.34	0.9170	0.9984		670.22	0.9143	0.9984
566.33	693.35	0.9184	1.0000		670.23	0.9158	1.0000

Table 39. Sorption Data of neat vinyl ester Samples exposed to 80% RH at 25ºC

	sample-1	$2l$=0.0872 cm			sample-2	$2l$=0.11 cm			sample-3	$2l$=0.11 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	492.98	0.0000	0.0000		659.33	0.0000	0		718.2	0.0000	0.0000
0.5	493.51	0.1075	0.0993		659.654	0.0491	0.0607		718.66	0.0640	0.0808
1.5	493.86	0.1785	0.1648		660	0.1016	0.1255		718.869	0.0931	0.1176
3.5	494.063	0.2197	0.2028		660.235	0.1373	0.1695		719.186	0.1373	0.1733
13.3333	494.9	0.3895	0.3596		661.03	0.2578	0.3184		719.98	0.2478	0.3128
23.3333	495.42	0.4949	0.4569		661.356	0.3073	0.3794		720.64	0.3397	0.4288
42.8333	496.13	0.6390	0.5899		662.64	0.5020	0.6199		721.68	0.4845	0.6116
65.3333	496.8	0.7749	0.7154		663.3	0.6021	0.7434		722.4	0.5848	0.7381
91.3333	497.21	0.8580	0.7921		663.8	0.6780	0.8371		722.94	0.6600	0.8330
113.333	497.46	0.9088	0.8390		664.12	0.7265	0.897		723.32	0.7129	0.8998
141.333	497.68	0.9534	0.8801		664.253	0.7467	0.9219		723.51	0.7393	0.9332
162.333	497.89	0.9960	0.9195		664.311	0.7555	0.9328		723.62	0.7547	0.9525
219.333	498.12	1.0426	0.9625		664.521	0.7873	0.9721		723.76	0.7742	0.9772
245.333	498.2	1.0589	0.9775		664.587	0.7973	0.9845		723.81	0.7811	0.9859
269.333	498.27	1.0731	0.9906		664.61	0.8008	0.9888		723.83	0.7839	0.9895
293.333	498.3	1.0792	0.9963		664.634	0.8045	0.9933		723.85	0.7867	0.9930
317.33	498.310	1.0812	0.9981		664.656	0.8078	0.9974		723.87	0.7895	0.9965
341.33	498.320	1.0832	1.0000		664.67	0.8099	1.0000		723.89	0.7923	1.0000

	sample-4	2*l*=0.102 cm			sample-5	2*l*=0.089 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	659.09	0.0000	0.0000		478.09	0.0000	0
0.5	659.7	0.0926	0.1242		478.8	0.1485	0.1342
1.5	660.09	0.1517	0.2037		479.21	0.2343	0.2117
3.5	660.352	0.1915	0.2570		479.36	0.2656	0.2401
13.3333	660.867	0.2696	0.3619		479.89	0.3765	0.3403
23.3333	661.213	0.3221	0.4324		480.564	0.5175	0.4677
42.8333	661.72	0.3990	0.5356		481.3	0.6714	0.6068
65.3333	662.19	0.4703	0.6314		481.786	0.7731	0.6987
91.3333	662.578	0.5292	0.7104		482	0.8178	0.7391
113.333	662.98	0.5902	0.7923		482.31	0.8827	0.7977
141.333	663.32	0.6418	0.8615		482.66	0.9559	0.8639
162.333	663.5	0.6691	0.8982		482.85	0.9956	0.8998
219.333	663.721	0.7026	0.9432		483.054	1.0383	0.9384
245.333	663.811	0.7163	0.9615		483.24	1.0772	0.9735
269.333	663.921	0.7330	0.9839		483.3	1.0898	0.9849
293.333	663.997	0.7445	0.9994		483.35	1.1002	0.9943
317.33	663.997	0.7445	0.9994		483.37	1.1044	0.9981
341.33	664.000	0.7450	1.0000		483.38	1.1065	1.0000

Table 40. Sorption Data of vinyl ester samples containing 2 wt% Cloisite 10A® exposed to 80% RH at 25ºC

	sample-1	2*l*=0.10895 cm			sample-2	2*l*=0.1 cm			sample-3	2*l*=0.1 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	645.78	0.0000	0.0000		642.85	0.0000	0		694.332	0.0000	0.0000
0.5	646.21	0.0666	0.0647		643.4	0.0856	0.1009		695	0.0962	0.1085
1.5	646.53	0.1161	0.1128		643.6	0.1167	0.1376		695.31	0.1409	0.1588
3.5	646.86	0.1672	0.1624		643.856	0.1565	0.1846		695.56	0.1769	0.1994
13.3333	647.65	0.2896	0.2812		644.568	0.2672	0.3152		696.3	0.2834	0.3196
23.3333	648.21	0.3763	0.3654		645	0.3344	0.3945		696.9	0.3699	0.4170
42.8333	648.689	0.4505	0.4374		645.654	0.4362	0.5145		697.56	0.4649	0.5242
65.3333	649.37	0.5559	0.5398		646.32	0.5398	0.6367		698.63	0.6190	0.6980
91.3333	650	0.6535	0.6346		646.836	0.6201	0.7314		699.12	0.6896	0.7775
113.333	650.46	0.7247	0.7038		647.12	0.6642	0.7835		699.457	0.7381	0.8323
141.333	651	0.8083	0.7850		647.5	0.7233	0.8532		699.611	0.7603	0.8573
162.333	651.32	0.8579	0.8331		647.72	0.7576	0.8936		699.797	0.7871	0.8875
219.333	651.856	0.9409	0.9137		647.91	0.7871	0.9284		700.1	0.8307	0.9367
245.333	651.978	0.9598	0.9320		648	0.8011	0.945		700.2	0.8451	0.9529
269.333	652.1	0.9787	0.9504		648.06	0.8105	0.956		700.27	0.8552	0.9643
293.333	652.187	0.9921	0.9635		648.12	0.8198	0.967		700.33	0.8639	0.9740
317.333	652.287	1.0076	0.9785		648.16	0.8260	0.9743		700.39	0.8725	0.9838
341.33	652.312	1.0115	0.9823		648.2	0.8322	0.9817		700.42	0.8768	0.9886
389.33	652.367	1.0200	0.9905		648.23	0.8369	0.9872		700.44	0.8797	0.9919
437.33	652.410	1.0267	0.9970		648.26	0.8416	0.9927		700.46	0.8826	0.9951
485.33	652.420	1.0282	0.9985		648.28	0.8447	0.9963		700.48	0.8855	0.9984
509.333	652.43	1.0298	1.0000		648.3	0.8478	1.0000		700.49	0.8869	1.0000

	sample-4	2*l* =0.1 cm			sample-5	2*l* =0.0903 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	644.43	0.0000	0.0000		593.81	0.0000	0
0.5	644.86	0.0667	0.0754		594.32	0.0859	0.0951
1.5	645	0.0885	0.1000		594.6	0.1330	0.1474
3.5	645.23	0.1241	0.1404		594.86	0.1768	0.1959
13.3333	646	0.2436	0.2754		595.45	0.2762	0.306
23.3333	646.53	0.3259	0.3684		595.84	0.3419	0.3787
42.8333	647.32	0.4485	0.5070		596.6	0.4698	0.5205
65.3333	648.12	0.5726	0.6474		597.213	0.5731	0.6349
91.3333	648.654	0.6555	0.7411		597.87	0.6837	0.7575
113.333	648.998	0.7088	0.8014		598.112	0.7245	0.8026
141.333	649.32	0.7588	0.8579		598.312	0.7582	0.8399
162.333	649.51	0.7883	0.8912		598.453	0.7819	0.8662
219.333	649.765	0.8279	0.9360		598.61	0.8083	0.8955
245.333	649.883	0.8462	0.9567		598.732	0.8289	0.9183
269.333	649.978	0.8609	0.9733		598.86	0.8504	0.9422
293.333	650.045	0.8713	0.9851		598.932	0.8626	0.9556
317.333	650.087	0.8778	0.9925		598.998	0.8737	0.9679
341.33	650.099	0.8797	0.9946		599.054	0.8831	0.9784
389.33	650.106	0.8808	0.9958		599.098	0.8905	0.9866
437.33	650.115	0.8822	0.9974		599.123	0.8947	0.9912
485.33	650.123	0.8834	0.9988		599.164	0.9016	0.9989
509.333	650.13	0.8845	1.0000		599.17	0.9026	1.0000

Table 41. Sorption Data of vinyl ester samples containing 5 wt% Cloisite 10A® exposed to 80% RH at 25ºC

	sample-1	2*l* =0.089 cm			sample-2	2*l* =0.0886 cm			sample-3	2*l* =0.09 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	891.092	0.0000	0.0000		823.79	0.0000	0		619.21	0.0000	0.0000
0.5	891.425	0.0374	0.0462		824.28	0.0595	0.0714		619.668	0.0740	0.0708
1.5	891.687	0.0668	0.0825		824.5	0.0862	0.1035		619.869	0.1064	0.1019
3.5	892	0.1019	0.1260		824.869	0.1310	0.1573		620.1	0.1437	0.1377
13.3333	892.98	0.2119	0.2619		825.7	0.2319	0.2784		621.012	0.2910	0.2787
23.3333	893.5	0.2702	0.3341		826.412	0.3183	0.3822		621.35	0.3456	0.3310
42.8333	894.289	0.3588	0.4435		827.42	0.4406	0.5292		622.35	0.5071	0.4857
65.3333	895.12	0.4520	0.5588		828	0.5111	0.6137		622.96	0.6056	0.5800
91.3333	895.879	0.5372	0.6641		828.67	0.5924	0.7114		623.54	0.6993	0.6698
113.333	896.5	0.6069	0.7503		829.32	0.6713	0.8061		623.98	0.7703	0.7378
141.333	897	0.6630	0.8196		829.76	0.7247	0.8703		624.356	0.8311	0.7960
162.333	897.32	0.6989	0.8640		829.99	0.7526	0.9038		624.621	0.8739	0.8370
219.333	897.732	0.7452	0.9212		830.2	0.7781	0.9344		625.12	0.9544	0.9142
245.333	897.86	0.7595	0.9390		830.3	0.7902	0.949		625.321	0.9869	0.9452
269.333	897.921	0.7664	0.9474		830.41	0.8036	0.965		625.41	1.0013	0.9590
293.333	897.996	0.7748	0.9578		830.5	0.8145	0.9781		625.51	1.0174	0.9745
317.333	898.12	0.7887	0.9750		830.56	0.8218	0.9869		625.54	1.0223	0.9791
341.33	898.168	0.7941	0.9817		830.58	0.8242	0.9898		625.589	1.0302	0.9867
389.33	898.220	0.7999	0.9889		830.6	0.8267	0.9927		625.6	1.0320	0.9884
437.33	898.245	0.8027	0.9924		830.612	0.8281	0.9945		625.621	1.0354	0.9916
485.33	898.256	0.8040	0.9939		830.621	0.8292	0.9958		625.64	1.0384	0.9946
509.333	898.271	0.8056	0.9960		830.632	0.8306	0.9974		625.651	1.0402	0.9963
533.333	898.28	0.8067	0.9972		830.641	0.8316	0.9987		625.663	1.0421	0.9981
566.333	898.3	0.8089	1.0000		830.65	0.8327	1.0000		625.675	1.0441	1.0000

	sample-4	2*l* =0.09 cm			sample-5	2*l* =0.1 cm	
Time, h	Weight, mg	Water Content, wt%	Mt/M∞		Weight, mg	Water Content, wt%	Mt/M∞
0	776.97	0.0000	0.0000		681.4	0.0000	0
0.5	777.57	0.0772	0.0892		681.869	0.0688	0.0703
1.5	777.74	0.0991	0.1144		682.12	0.1057	0.1079
3.5	777.96	0.1274	0.1471		682.412	0.1485	0.1517
13.3333	778.8	0.2355	0.2719		683.255	0.2722	0.2781
23.3333	779.21	0.2883	0.3328		683.865	0.3618	0.3695
42.8333	780.02	0.3926	0.4532		684.68	0.4814	0.4917
65.3333	780.689	0.4787	0.5526		685.231	0.5622	0.5743
91.3333	781.121	0.5343	0.6168		685.912	0.6622	0.6764
113.333	781.564	0.5913	0.6826		686.321	0.7222	0.7377
141.333	781.911	0.6359	0.7342		686.821	0.7956	0.8126
162.333	782.325	0.6892	0.7957		686.99	0.8204	0.838
219.333	782.798	0.7501	0.8660		687.412	0.8823	0.9012
245.333	782.9	0.7632	0.8811		687.621	0.9130	0.9325
269.333	783.1	0.7890	0.9108		687.732	0.9293	0.9492
293.333	783.31	0.8160	0.9421		687.812	0.9410	0.9612
317.333	783.421	0.8303	0.9585		687.889	0.9523	0.9727
341.33	783.500	0.8404	0.9703		687.968	0.9639	0.9846
389.33	783.589	0.8519	0.9835		687.998	0.9683	0.9891
437.33	783.621	0.8560	0.9883		688.012	0.9704	0.9912
485.33	783.654	0.8603	0.9932		688.032	0.9733	0.9942
509.333	783.678	0.8634	0.9967		688.051	0.9761	0.9970
533.333	783.69	0.8649	0.9985		688.06	0.9774	0.9984
566.333	783.7	0.8662	1.0000		688.071	0.9790	1.0000

Table 42. Sorption data of vinyl ester samples containing 0 wt% Cloisite 10A immersed in distilled water subjected to 17% UTS at 25 °C

Time,h	Thickness,2*l* ,cm	Weight mg	water content (%)	M_t/M_∞
sample-1				
0	0.12	804.631	0.0000	0.0000
0.5		805	0.0459	0.0498
sample-2	0.1	688.14		
1.5		688.94	0.1163	0.1080
sample-3	0.09	629.167		
6.25		630.632	0.2328	0.1978
sample-4	0.084	530.92		
9		532.654	0.3266	0.2341
sample-5	0.11	698.485		
12.25		700.51	0.2899	0.2734
sample-6	0.095	668.596		
17.25		670.89	0.3431	0.3097
sample-7	0.089	624.16		
20.25		626.854	0.4316	0.3637
sample-8	0.09	638.521		
23.25		641.287	0.4313	0.3734
sample-9	0.089	630.21		
27.5		633.213	0.4742	0.4054
sample-10	0.105	704.7		
31.75		707.889	0.4505	0.4305
sample-11	0.088	589.414		
36.75		593.07	0.6165	0.4935
sample-12	0.092			
0		650.412		
60.25		655.08	0.7177	0.6301
188.75		657.1	1.0283	0.9028
318.75		657.543	1.0964	0.9626
449.75		657.6	1.1051	0.9703
499.75		657.67	1.1159	0.9798
571.75		657.74	1.1267	0.9892
619.75		657.79	1.1344	0.9960
666.75		657.82	1.1390	1.0000

	sample-13	$2l$ =0.11cm			sample-14	$2l$ =0.09 cm			sample-15	$2l$ =0.084 cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	715.6	0	0		646.711	0	0		504.63	0.0000	0.0000
60.25	720.46	0.6792	0.5645		651.03	0.6678	0.5989		508.65	0.7966	0.7992
89.25											
134.25					652.19	0.8472	0.7597		509.64	0.9928	0.9960
160.25											
188.75					652.92	0.9601	0.8609		509.48	0.9611	0.9642
225.75	723	1.0341	0.8595								
318.75					653.5	1.0498	0.9413		509.54	0.9730	0.9761
405.25	723.564	1.1129	0.9250								
449.75					653.732	1.0856	0.9735		509.68	1.0007	1.0040
499.75	723.91	1.1613	0.9652		653.8	1.0962	0.9829				
571.75	723.99	1.1724	0.9744		653.86	1.1054	0.9913				
619.75	724.12	1.1906	0.9895								
666.75					653.923	1.1152	1.0000		509.66	0.9968	1.0000
669.75	724.21	1.2032	1.0000								

	sample-16	$2l$ =0.084 cm			sample-17	$2l$ =0.087 cm			sample-18	$2l$ =0.084 cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	503.378	0	0		584.5	0	0		530.08	0.0000	0.0000
60.25	507.25	0.7692	0.7915								
89.25					588.996	0.7692	0.7334		534.853	0.9004	0.7686
134.25	508	0.9182	0.9448								
160.25					589.54	0.8623	0.8222		535.18	0.9621	0.8213
188.75	507.77	0.8725	0.8978								
225.75					590.14	0.9649	0.9201		535.58	1.0376	0.8857
318.75	508.07	0.9321	0.9591								
405.25									536.26	1.1659	0.9952
449.75	508.12	0.9420	0.9693						536.19	1.1527	0.9839
499.75											
571.75											
619.75											
666.75	508.27	0.9718	1.0000		590.63	1.0488	1.0000		536.29	1.1715	1.0000
669.75											

Table 43. Sorption data of vinyl ester samples containing 5 wt% Cloisite 10A immersed in distilled water subjected to 17% UTS at 25 °C

Time,h	Thickness,2*l*,cm	W_t mg	M_t mg	Moisture uptake (%)
sample-1				
0	0.095	665.04	0	0.0000
0.25		665.213	0.369	0.0459
sample-2	0.12	777.28		
3.25		778.1	0.8	0.1163
sample-3	0.088	579.91		
5.5		581.1	1.465	0.2328
sample-4	0.012	808.96		
7.75		810.43	1.734	0.3266
sample-5	0.11	715.54		
8.75		717.21	2.025	0.2899
sample-6	0.089	617.2		
20.25		619.556	2.294	0.3431
sample-7	0.12	781.42		
28.25		784.23	2.694	0.4316
sample-8	0.115	743.51		
44.25		747.325	2.766	0.4313
sample-9	0.121	771.32		
50.25		775.456	3.003	0.4742
sample-10	0.115	722.37		
69.75		727.37	3.189	0.4505
sample-11	0.092	642.94		
125.25		649.32	6.38	0.9923
201.25				
244.75		650.23	7.29	1.1339
295.75				
485.75		650.823	7.883	1.2261
551.25		650.867	7.927	1.2329
605.75		650.9	7.96	1.2381
677.75		650.95	8.01	1.2458
701.75		650.99	8.05	1.2521
725.775		651.03	8.09	1.2583

	sample-12	2*l* =0.095 cm			sample-13	2*l* =0.088 cm			sample-14	2*l* =0.1cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	647.36	0	0		591.07	0	0		700.05	0.0000	0.0000
125.25	653.76	0.9886	0.8237		596.89	0.9847	0.8083		706.31	0.8942	0.7954
201.25											
244.75	654.435	1.0929	0.9106		597.78	1.1352	0.9319		707.02	0.9956	0.8856
295.75											
485.75	654.88	1.1616	0.9678		597.98	1.1691	0.9597		707.52	1.0671	0.9492
551.25	654.91	1.1663	0.9717		598.12	1.1928	0.9792		707.89	1.1199	0.9962
605.75	654.98	1.1771	0.9807		598.2	1.2063	0.9903		707.91	1.1228	0.9987
677.75	655.054	1.1885	0.9902		598.23	1.2114	0.9944		707.92	1.1242	1.0000
701.75	655.1	1.195625309	0.996139		598.25	1.2147	0.9972				
725.75	655.13	1.2003	1.0000		598.27	1.2181	1.0000				

	sample-15	2*l* =0.09 cm			sample-16	2*l* =0.089 cm			sample-17	2*l* =0.097 cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	646.14	0	0		598.86	0	0		671.78	0.0000	0.0000
125.25	652.09	0.9209	0.8263		604.43	0.9301	0.9042				
201.25									677.56	0.8604	52.5455
244.75	652.91	1.0478	0.9401		604.94	1.0153	0.9870				
295.75									677.75	0.8887	54.2727
485.75	653.29	1.1066	0.9929		604.96	1.0186	0.9903		677.7	0.8812	53.8182
551.25	653.31	1.1097	0.9957		604.98	1.0219	0.9935		671.85	0.0104	0.6364
605.75											
677.75											
701.75	653.33	1.1128	0.9985		605	1.0253	0.9968		671.87	0.0134	0.8182
725.75	653.341	1.1145	1.0000		605.02	1.0286	1.0000		671.89	0.0164	1.0000

Table 44. Sorption data of vinyl ester samples containing 0 wt% Cloisite 10A immersed in distilled water subjected to 30% UTS at 25 °C

Time,h	Thickness,2*l*,cm	W_t mg	M_t mg	Moisture uptake (%)
sample-10				
0	0.094	647.41		
0.5		647.79	0.38	0.0587
sample-2	0.086	559.62		
1.5		560.32	0.7	0.1251
sample-3	0.088	589.41		
4.5		590.62	1.21	0.2053
sample-4	0.09	638.8		
8.75		640.43	1.63	0.2552
sample-5	0.089	616.63		
12.25		618.51	1.88	0.3049
sample-6	0.087	551.27		
37.25		554.562	0.60	0.4735
sample-7	0.095	664.98		
66.25		669.41	0.67	0.6372
sample-8	0.084	519.69		
89.25		523.83	0.80	0.5955
sample-9	0.11	721.491		
111.25		727	0.76	0.7924
sample-10				
135.25	0.088	609.41	5.62	0.9308
165.25				
202.75				
308.25		610	6.21	1.0285
378.75				
427.25		610.52	6.73	1.1146
476.75				
500.75		610.674	6.884	1.1401
597.75		610.742	6.952	1.1514

	sample- 11	2*l* =0.088 cm			sample- 12	2*l* =0.11 cm			sample- 13	2*l* =0.095 cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	603.79	0	0		710.21				663.43		
135.25	609.41	0.9308	0.8084		716.643	0.9058	0.7807		669.21	0.8712	0.7536
165.25											
202.75											
308.25	610	1.0285	0.8933		717.678	1.0515	0.9063		670.2	1.0205	0.8827
378.75											
427.25	610.52	1.1146	0.9681		718.2	1.1250	0.9697		670.72	1.0988	0.9505
476.75											
500.75	610.674	1.1401	0.9902		718.42	1.1560	0.9964		670.89	1.1245	0.9726
597.75	610.742	1.151393696	1		718.45	1.1602	1.0000		671.1	1.1561	1.0000

	sample- 14	2*l* =0.089 cm			sample- 15	2*l* =0.1 cm			sample- 16	2*l* =0.088 cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	625.4				697.53				575.5		
135.25	631.21	0.9290	0.8532		703.02	0.7871	0.7593		581.1	0.9731	0.8615
165.25											
202.75											
308.25	631.6	0.9914	0.9104		703.76	0.8932	0.8617		581.657	1.0699	0.9472
378.75											
427.25	631.73	1.0122	0.9295		704.1	0.9419	0.9087		581.865	1.1060	0.9792
476.75											
500.75	631.98	1.0521	0.9662		704.54	1.0050	0.9696		581.9	1.1121	0.9846
597.75	632.21	1.0889	1.0000		704.76	1.0365	1.0000		582	1.1295	1.0000

Table 45. Sorption data of vinyl ester samples containing 5 wt% Cloisite 10A immersed in distilled water subjected to 30% UTS at 25 °C

Time,h	Thickness,2l,cm	W_t mg	M_t mg	Moisture uptake (%)	M_t/M_∞
sample-1					
0	0.09	639.16	0	0.0000	0.0000
1		639.66	0.5	0.0782	0.0707
sample-2	0.086	551.59			
2.5		552.374	0.784	0.1421	0.1109
sample-3	0.086	566.78			
14.5		568.61	1.83	0.3229	0.2588
sample-4	0.085	549.08			
17.5		551.178	2.098	0.3821	0.2967
sample-5	0.086	560.29			
22.5		562.7	2.41	0.4301	0.3409
sample-6	0.097	676.76			
38.5		679.91	3.15	0.4655	0.4455
sample-7	0.12	842.85			
44.5		846.89	4.04	0.4793	0.5714
sample-8	0.088	608.74			
64		612.48	3.74	0.6144	0.5290
sample-9	0.096	667.75			
71		671.8	4.05	0.7228	0.5728
sample-10	0.115	729.45			
119		734.43	4.98	0.7359	0.7044
sample-11	0.087	611.61			
193		617.32	5.71	0.9250	0.8076
216.5		617.58	5.97	0.9671	0.8444
288.5		617.98	6.37	1.0319	0.9010
313.5					
410		618.21	6.6	1.0691	0.9335
482.5		618.43	6.82	1.1048	0.9646
546		618.52	6.91	1.1194	0.9774
618		618.6	6.99	1.1323	0.9887
666		618.65	7.04	1.1404	0.9958
714		618.68	7.07	1.1453	1.0000

	sample-12	2l =0.093 cm			sample-13	2l =0.087 cm			sample-14	2l =0.097 cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	648.49				582.69				687.26		
193	655.31	1.0517	0.8148		588.3	0.9628	0.7926		693.81	0.9531	0.8863
216.5	655.67	1.1072	0.8578		588.6	1.0143	0.8350		693.94	0.9720	0.9039
288.5											
313.5											
410	656.38	1.2167	0.9427		589.1	1.1001	0.9056		694.48	1.0505	0.9770
482.5	656.53	1.2398	0.9606		589.42	1.1550	0.9508		695.14	1.1466	1.0663
546	656.62	1.2537	0.9713		589.5	1.1687	0.9621		694.59	1.0666	0.9919
618	656.73	1.2706	0.9845		589.7	1.2030	0.9904		694.61	1.0695	0.9946
666	656.81	1.282980462	0.994026		589.743	1.2104	0.9965		694.635	1.0731	0.9980
714	656.86	1.2907	1.0000		589.768	1.2147	1.0000		694.65	1.0753	1.0000

	sample-15	2*l* =0.089 cm			sample-16	2*l* =0.086 cm			sample-17	2*l* =0.088 cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	624.9				543.88				585.52		
193	630.89	0.9586	0.8062		548.72	0.8899	0.8521		591.04	0.9428	0.8686
216.5									591.01	0.9376	0.8639
288.5	631.4	1.0402	0.8748		549.06	0.9524	0.9120		591.08	0.9496	0.8749
313.5	631.54	1.0626	0.8937		549.02	0.9451	0.9049				
410					549.52	1.0370	0.9930		591.8	1.0726	0.9882
482.5											
546											
618	632.29	1.1826	0.9946								
666	632.31	1.1858	0.9973		549.542	1.0410	0.9968		591.86	1.0828	0.9976
714	632.33	1.1890	1.0000		549.56	1.0443	1.0000		591.875	1.0854	1.0000

Table 46. Sorption data of vinyl ester samples containing 0 wt% Cloisite 10A exposed to 60% RH at 25 °C subjected to 30% UTS

Time,h	Thickness,2*l*,cm	W_t mg	M_t mg	Moisture uptake (%)	M_t/M_∞
sample-1					
0	0.11	724.06	0	0.0000	0.0000
0.5		724.29	0.23	0.0318	0.0655
sample-2	0.089	621.08			
2.5		621.51	0.43	0.0692	0.1224
sample-3	0.09	642.25			
4.5		642.85	0.6	0.0934	0.1708
sample-4	0.1	697.12			
6.5		697.856	0.736	0.1056	0.2095
sample-5	0.095	665.03			
8		665.85	0.82	0.1233	0.2334
sample-6	0.1	700.628			
15.5		701.68	1.052	0.1502	0.2995
sample-7	0.09	630.76			
23		632.12	1.36	0.2156	0.3871
sample-8	0.09	640.83			
36.5		642.6	1.77	0.2762	0.5038
sample-9	0.088	593.53			
69.5		596.253	2.723	0.4588	0.7751
165.5					
236.5		596.98	3.45	0.5813	0.9821
357.5					
386.5		597.043	3.513	0.5919	1.0000
458.5		595.88	2.35	0.3959	0.6689
543		595.21	1.68	0.2831	0.4782
595		594.99	1.46	0.2460	0.4156

	sample- 10	2*l* =0.088 cm			sample- 11	2*l* =0.095 cm			sample- 12	2*l* =0.09 cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	593.53	0	0		653.61	0	0		638.21	0.0000	0.0000
69.5	596.253	0.4588	0.7751		656.1	0.3810	0.6605		640.89	0.4199	0.7322
165.5	596.65	0.5257	0.8881		656.75	0.4804	0.8329		641.423	0.5034	0.8779
236.5	596.93	0.5728	0.9678		657	0.5187	0.8992		641.75	0.5547	0.9672
308.5	597	0.5846	0.9878		657.15	0.5416	0.9390		641.789	0.5608	0.9779
357.5	597.012	0.5867	0.9912		657.21	0.550787167	0.95491		641.81	0.564077655	0.98361
386.5	597.043	0.591882466	1		657.38	0.576796561	1		641.87	0.573478949	1

	sample- 13	2*l* =0.087 cm			sample- 14	2*l* =0.087 cm			sample- 15	2*l* =0.09 cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	585.22	0	0		571.77	0	0		642.22	0.0000	0.0000
69.5	586.83	0.2751	0.4777		573.36	0.2781	0.4923		643.62	0.2180	0.4192
165.5	587.19	0.3366	0.5846		573.56	0.3131	0.5542		644.21	0.3099	0.5958
236.5	587.453	0.3816	0.6626		573.89	0.3708	0.6563		644.86	0.4111	0.7904
308.5	588	0.4750	0.8249		574.245	0.4329	0.7663		645.12	0.4516	0.8683
357.5	588.45	0.5519	0.9585		574.78	0.526435455	0.93189		645.456	0.503877176	0.96886
386.5	588.59	0.575851816	1		575	0.564912465	1		645.56	0.520071004	1

Table 47. Sorption data of vinyl ester samples containing 5 wt% Cloisite 10A exposed to 60% RH at 25 °C subjected to 30% UTS

Time,h	Thickness,2*l*, cm	W_t mg	M_t mg	Moisture uptake (%)	M_t/M_∞
sample-1					
0	0.088	612.87	0	0.0000	0.0000
2		613.34	0.47	0.0767	0.1240
sample-2	0.089	651.52			
5		652.213	0.693	0.1064	0.1828
sample-3	0.088	595.43			
8		596.342	0.912	0.1532	0.2406
sample-4	0.086	565.87			
16.5		566.989	1.119	0.1977	0.2953
sample-5	0.085	528.1			
21.5		529.456	1.356	0.2568	0.3578
sample-6	0.11	731.6			
33.5		733.3	1.7	0.2324	0.4485
sample-7	0.088	609.14			
119.5		611.98	2.84	0.4662	0.7493
sample-8	0.09	640.44			
143.5		643.45	3.01	0.4700	0.7942
sample-9	0.086	548.75			
240		551.9	3.15	0.5740	0.8311
sample-10	0.09	642.68			
324		646.287	3.607	0.5612	0.9517
sample-11	0.089	622.01			
374.5		625.7	3.69	0.5932	0.9736
449		625.75	3.74	0.6013	0.9868
646.5		625.8	3.79	0.6093	1.0000

	sample-12	2*l* =0.092 cm			sample-13	2*l* =0.09 cm			sample-14	2*l* =0.09 cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	693.5				637.12				631.89		
374.5	697.234	0.5384	0.924257		640.71	0.5635	0.9301		633.94	0.3244	0.6949
449	697.456	0.5704	0.979208		640.9	0.5933	0.9793		634.75	0.4526	0.9695
646.5	697.54	0.5826	1		640.98	0.6059	1.0000		634.84	0.4669	1.0000

	sample-15	2*l* =0.09 cm			sample-16	2*l* =0.091cm			sample-17	2*l* =0.09 cm	
Time,h	Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞		Weight mg	water content (%)	M_t/M_∞
0	658.96				667.2				631.89		
374.5	659.65	0.1047	0.401163		669.49	0.3432	0.8267		633.94	0.3244	0.6949
449	660.23	0.1927	0.738372		669.45	0.3372	0.8123		634.75	0.4526	0.9695
646.5	660.68	0.2610	1		669.97	0.4152	1.0000		634.84	0.4669	1.0000