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Electrical Behaviour of Polyethylene Vinyl Acetate / ZnO Nanocomposite

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Recently, nanoscale materials have attracted material scientists because of their unique size dependent magnetic, optical, electrical and thermal properties. Homogeneous dispersion of nanoparticles in the polymer matrix and control of their size are vital to achieve many of these properties. In the present work, Zinc Oxide (ZnO) nanoparticles were prepared by solvothermal route. Chemical replacement reaction was chosen for the homogeneous dispersion of prepared ZnO nanoparticles into polymer matrix. Zinc oxide is an inorganic material with a large direct band gap (3.34 eV), high exciton binding energy (60 meV) and having a unique combination of properties. In inorganic/polymetric composite, the semiconducting nanoclusters enhances the electrical and thermal properties. The dielectric properties of the composites were studied using HIOKI 3532-50 LCR Hitester. The dielectric constant was found to increase with increasing the concentration of nano filler. DC electrical conductivity as a function of temperature was studied using Keithley picoammeter 6485.

Keywords: EVA / ZnO nanocomposite, Solvothermal, XRD, Dielectric, DC conductivity.

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1. INTRUDUCTION

In recent years, the microelectronics industry has invested heavily,with some success, in the development of dielectric materials [1]. These materials are required because of the continuing reduction of both horizontal and vertical dimensions of the system. Even though Polymers have found extensive applications in cables and capacitors as dielectric materials[2, 3, 4], they posses low thermal and dielectric properties. But, polymer nanocomposites can exhibit novel properties such as electrical, thermal and optical, in between polymer and the inorganic filler dispersed. Thus it appears inevitable that the dielectric properties of nanoscale materials and structures are critical to developing novel devices.

Due to their excellent flexibility, tractable processibility, good chemical stability and readily tunable properties Ethylene vinyl acetate(EVA) polymer can be considered as a good dielectric material for electrical and optical applications [5-8]. Among various semiconducting nanoparticles, nano-sized ZnO is the most studied [16, 17] because it shows the presence of more sites for surface reactivity.It is a good dispersant and its presence enhances dielectric and thermal properties of polymer [9-15]. Their combination could readily geared towards miniaturization of electronic devices fabrication.

In the present work we prepared EVA / ZnO nanocomposites with various amounts of ZnO nano filler by chemical replacement mechanism. Determination of particle size was achieved through powder XRD. Dielectric and DC conductivity studies at various temperatures and filler concentrations were carried out.

2. EXPERIMENTAL

2.1 Synthesis of ZnO nanoparticles

Solvothermal synthesis was the method chosen for the preparation of ZnO nanoparticles. Zinc acetate and Sodium hydroxide was chosen as parent material for Zn and O respectively. The solutions of 0.2 molar zinc acetate ($(CH_3COO)_2Zn{\cdot}2H_2O$) in 100 ml methanol and 0.5 molar sodium hydroxide (NaOH) 25 ml methanol were prepared and mixed up under vigourous stirring for half an hour. These solutions were transferred into teflon lined sealed stainless steel autoclave and heated at 240°C for 5 hrs in a muffle furnace. It was then allowed to cool naturally to room temperature. After the reaction was complete, the resulting white solid products were washed with methanol, filtered and then dried at 80°C. The ZnO nanoparticles thus formed were collected.

2.2 Synthesis of EVA/ZnO nanocomposite

Ethylene Vinyl Acetate (EVA) is a less crystalline, flexible and rubbery copolymer obtained from the copolymerisation of Ethylene and Vinyl Acetate. EVA is a widely accepted adhesive in polymer processing and was procured from DUPONT for this Experiment. In order to synthesise the EVA nanocomposite, the copolymer was first dissolved in toluene and at a temperature of 120°C. The EVA-Toluene mixture was used as the matrix to which the Nano size fillers were incorporated and dispersed. Magnetic stirrer and Ultrasonicator were used to get uniform dispersion of the ZnO nanoparticles homogeneously throughout the matrix. Fillers at the required ratio (1% and 4% by weight of EVA) was added and stirred. Sonication was provided for 2 hours for the uniform distribution. After this, the

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nano filled EVA was transfered to a teflon coated glass mould and spread with uniform thickness. The Solvent was removed by keeping in an air oven with a temperature of 100°C for 24 hours to get a thin film of EVA / ZnO Nanocomposites of micrometer thickness.

3. RESULTS AND DISCUSSION

3.1 Electrical Conductivity

It is well established that the charge transport properties of conjugated nanocomposites strongly depend on the nanoparticles being dispersed. The plots of d.c.conductivity of pure EVA and 1% & 4% ZnO nano filler dispersed decrease with increase in temperature, but the conductivity is found to be increased with the concentration of ZnO nanofiller. The graph of dc conductivity vs temperature shows that the polymer nanocomposites have the positive temperature co-efficient of resistance.

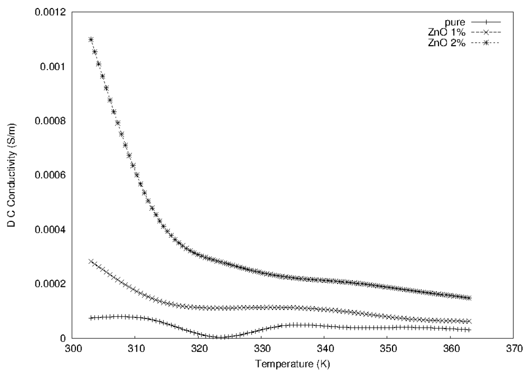

Fig. 1 – Variation of DC Conductivity with temperature

3.2 Dielectric Study

The study of dielectric behaviour of different samples of EVA / ZnO nanocomposite were carried out using HIOKI 3532-50 LCR HITESTER. The dielectric constant of nanocomposites were calculated using the relation,

$$\varepsilon_r = C \cdot d / \varepsilon_0 \cdot A \qquad (3.1)$$

Where the nanocomposite acts as a dielectric with ε_0 absolute permittivity, C is the capacitance, d is the thickness and A is the area. The dielectric constant found to be high at lower frequencies (Fig. 2) and Fig. 3 shows that it decreases with increase in frequency for all temperatures and for all filler concentrations.

A high dielectric constant reflects a high value of dipole moment as per the relation

$$\mathbf{P} = \varepsilon_0(\varepsilon_r - 1) \cdot \mathbf{E_R} \qquad (3.2)$$

Where $\mathbf{E_R}$ is the resultant electric field. But at high frequencies, the nanocomposites fail to keep up with rapid variations of electric field, hence no dispersion and low dielectric constant results. Further, from Fig. 2 we can infer that dielectric constant increases with the increase of ZnO nano filler dispersed in the polymer matrix. Fig. 3 indicates that dielectric constant decreases with increasing temperature.

Fig. 4 shows the variations of dielectric loss co-efficient with frequency. The loss factor of nanocomposites are decreased with both frequency and concentrations of filler in polymer matrix. It is due to the strong interaction between EVA and nano fillers added. The energy loss is typically due to the presence of viscous drag of moving dipoles. In the EVA / ZnO composite the number of moving dipole are less than the pure EVA due to the strong interaction between EVA and ZnO, thus the dielectric loss was expected to reduce as observed experimently. The characteristics of low dielectric constant and dielectric loss are of vital importance for various non-linear optical materials and their applications.

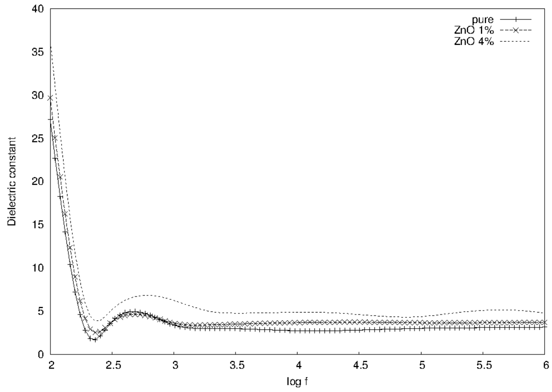

Fig. 2 – The variation of dielectric constant with frequency

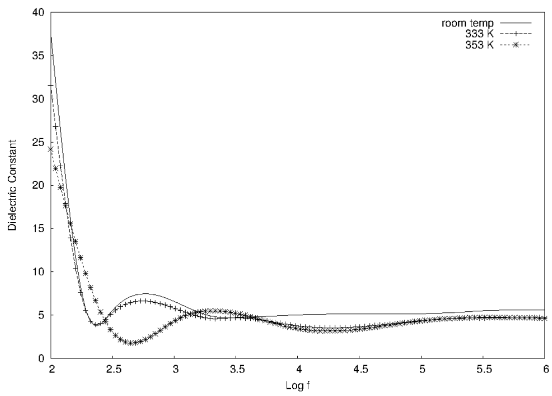

Fig. 3 – The graph of dielectric constant vs log frequency of 4%ZnO / EVA nanocomposite at different temperatures

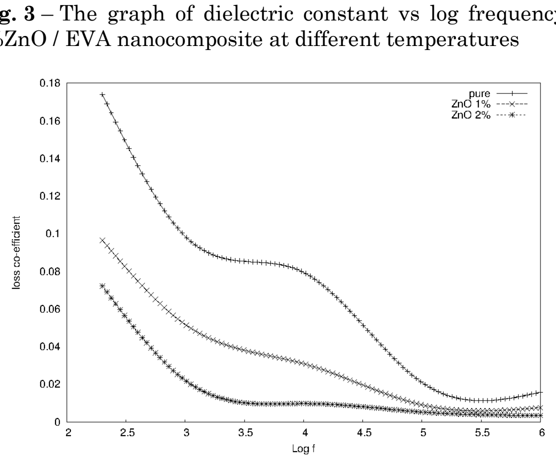

Fig. 4 – The plot of dielectric loss co-efficient as function of log frequency

4. CONCLUSION

We successfully prepared ZnO nanoparticles by solvothermal route and dispersed it in EVA polymer with various concentrations. Experiments showed that dielectric constant and dc conductivity are strongly influenced by the concentration of nanofiller and temperature. The prepared nanocomposite showed positive temperature co-efficient of resistance.

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