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Influence of High Doping of TiO_2 of Polymeric Foam for Acoustic Study

Anika Zafiah M. Rus [1], Bainun Akmal M. A.[1], N.N. Mat Hassan[1]

[1]Sustainable Polymer Engineering,

Advanced Manufacturing and Material Centar (AMMC),

Faculty of Mechanical and Manufacturing Engineering,

Universiti Tun Hussein Onn Malaysia,

86400, Parit Raja, Batu Pahat, Johor, MALAYSIA.

zafiah@uthm.edu.my

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Abstract. Titanium dioxide represents an effective photocatalyst for water and air purification and for self-cleaning surfaces. The purpose of this study is to determine sound absorption property of polymer foam of high doping of Titanium Dioxide (TiO_2) which are 20%, 40%, 60%, 80% and 100%. The acoustic study of the samples was measured by using impedance tube test according to the ASTM E-1050 to determined sound absorption coefficient (α) and noise reduction coefficient method (NRC). The highest α is 0.999 observed from the polymer foam doped with 60% of TiO_2 at high frequency level of 4000 Hz. Meanwhile, the highest doping of TiO_2 polymer foam shows remarkable characteristic of low level frequency absorption at 2000 Hz. Thus, different percentage of TiO_2 doped in polymer foam can be used successfully to alter the characteristic of sound absorption property in a systematic way according to the request application.

Introduction

Polyurethane (PU) foam are versatile engineering materials which find a wide range of applications because of their properties can be readily tailored by the type and composition of their component. However, the main market for PU foam is flexible and rigid [1]. Flexible polymer foam recently has been researched extensively as a sound absorbing material. With the advancement in technology, sound absorption is one of the major requirements to enhance quality of living where the sound insulation developed should be efficient by means of getting the sound reduce and in economically ways of producing sound absorbing materials.

Many studies have reported that incorporated fillers to flexible polyurethane foam can improve its acoustic properties and thus reduce noise when it is applied in applications [2]. In this current research, the aim is to study the effect of high doping of TiO_2 on polyurethane foam microstructure to find a relation between corresponding parameters such as cell size and foam apparent density. Many researchers found various kinds of fillers to improve the acoustic performance of polyurethane foams. Titanium dioxide represents an effective photocatalyst for water and air purification and for self-cleaning surfaces [3-8]. Additionally, it can be used as antibacterial agent because of strong oxidation activity and superhydrophilicity [3-8].

The research conducted to determine the foam's mechanical properties (sound absorption coefficient, α) and physical properties (porosity and density) of high doping TiO_2 of flexible polymer foam by increasing doped of TiO_2 in the epoxy foam matrix, the reduction of α were observed but the frequency level were shifted from high to low consistently. This shows that the influence of high doping of TiO_2 in polymer foam to successfully achieved the lower level frequency down to 2000 Hz.

Experimental

Material. Flexible Polyol, Flexible Isocyanate and TiO_2 (Kronos with high doping of 20%, 40%, 60%, 80% and 100%).

Sample Preparations. The flexible polyol and flexible isocyanate were stirred by Multiple Speeds Handmixer in a cup for 15 seconds. The mixture was then immediately cast into open mould before the foam is expended out. It was left for 12 hours to cure at room temperature [7, 9-11].

Scanning Electron Microscope (SEM). The polymer foam was cut into small cube size to have proximate by 10*10*10 mm in size. High doping of TiO_2 polymeric foam surfaces were examined by using SEM, JEOL-JSM6380LA operated at 15kV with 30 µm magnification under low vacuum. The high doping of TiO_2 of polymeric foam sample was mounted on the holder and sputter-coated with gold to impart electrical conductivity and reduce charging artifacts [12] by using Auto Fined Coater of JEOL-JFC1600.

Density test. The density test of polymeric foam was conducted by prepared a cube of 10*10*10 mm. The weights of the polymeric foam were measured using Mettler Toledo Laboratory Weighting. This test was carried out according to ASTM D3574-08. The density of high doping of TiO2 polymeric foam were calculated as Eq. (1), where *m* = mass of foam and *v* = volume of foam.

$$\text{Density, } \rho = m/v \quad (1)$$

Sound absorption test. Impedance tube, two microphone locations, and a digital frequency analysis system was used to determine the normal incidence sound absorption coefficients and normal specific acoustic impedance ratios for materials. Two-microphone impedance method is based on measuring sound pressure in an impedance tube at two flush-mounted microphone positions. It determines the acoustical characteristic quantities such as the absorption coefficient, reflection coefficient, surface impedance and surface admittance for small size objects exposed to plane waves at normal sound incidence.

Five polymer foam samples with different percentages of high doping of TiO_2 which are 20%, 40%, 60%, 80% and 100% were tested by using impedance tube test according to ASTM E-1050 for horizontally mounted orientation sensitive materials at frequency range of 100-6000 Hz [13]. Impedance tube is used to test sound absorption of the samples at low frequency level by 100 mm sample diameter, while sound absorption at high frequency were determined by using 28 mm sample diameter.

Result and discussion

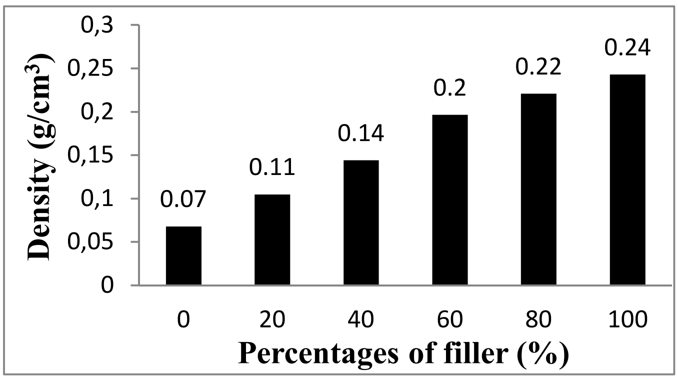

Figure 1: Density of polymer foam with different percentages of high doped of TiO_2.

As refer to Fig. 1, the average density of the polymer foam doped with highest percentage of filler give highest density of 0.2429 g/cm^3 followed by polymer foam doped with 80% TiO_2 of 0.2207 g/cm^3. This results show systematic decreases of density as the decreasing of filler loading in the polymer foam. It showed that the increase of sound absorption value in the middle and higher frequency level is affected by the density of the sample [14].

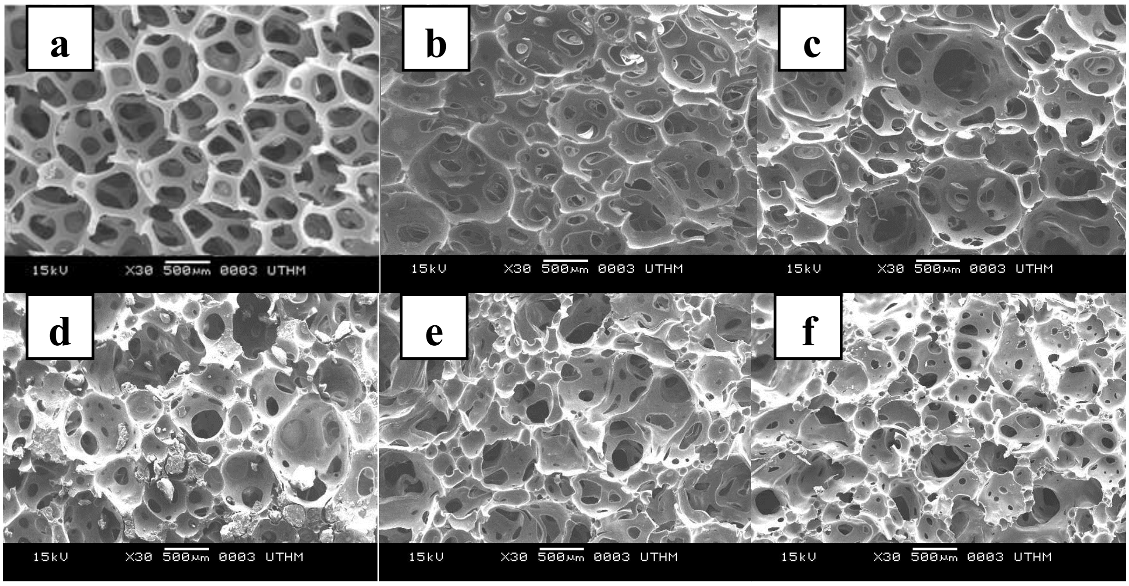

Figure 2 : Morphology structures of; (a) pure synthetic polymer foam and synthetic polymer foam doping with (b) 20% (c) 40% (d) 60% (e) 80% and (f) 100% of TiO_2.

The number and the size of the pores are the important factors as they will influence the sound absorption mechanism [15]. Referring to Fig. 2(a) – Fig. 2(f). Fig. 2(a) of neat polymer foam shows uniform pore distribution, homogenous and interconnected pore size. Obviously, the relationships of pore size to TiO_2 content become nonuniform as more TiO_2 was introduced in the polymer foam. In addition, by increasing the TiO_2 doping in the polymer foam, the cell sizes of the pore was decreased as shows in Fig. 2(b) – Fig. 2(f).

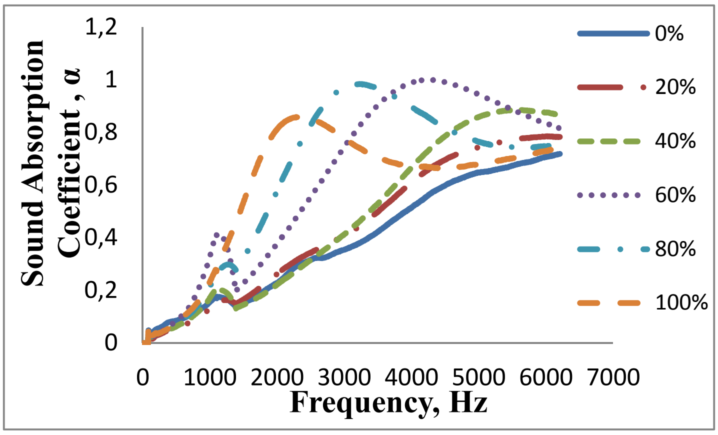

Figure 3(a): Effect of high doping TiO_2 polymer foam on sound absorption coefficient.

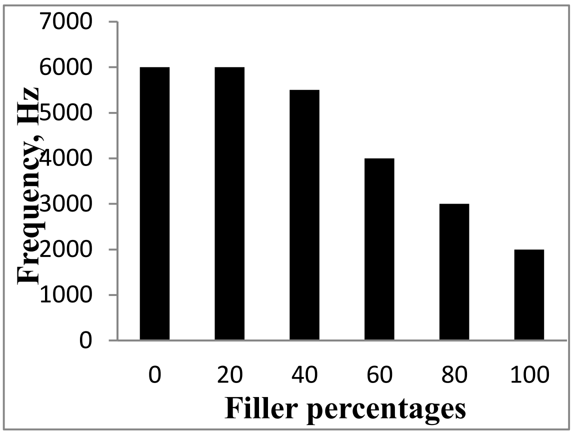

Figure 3(b) : Effect of high doping TiO_2 polymer foam on frequency level, Hz.

Fig. 3(a) and Fig. 3(b) show the ability of the polymer foam doped with different percentages of TiO_2. The polymer foam doped with 60% of TiO_2 shows remarkable characteristics of the highest sound absorption coefficient at 4000 Hz. This impedance test results also revealed that the consistency of the increasing percentage of TiO_2 doping in the polymer foam, was able to shift the frequency level down to 2000 Hz as shown in Fig. 3(b).

The NRC of different percentages of TiO_2 of polymer foam was calculated based on Eq. 2 [13] as shows in Fig. 4. Although this equation seems to be used to determine the NRC at low frequency (250 Hz-2000 Hz), however it is considered very effective at any situation in acoustical field. Fig. 4 of calculated NRC of polymer foam doped with 60% of TiO_2 gives highest value of NRC. The result showed that the NRC increases with the increase of TiO_2 percentages. Based on the previous study [1], this variation may be due to the factor of porosity as well as morphological structure, and filler of the foam being developed. Even though the result is inconsistent in value, the different of NRC values are small and can used in many situations.

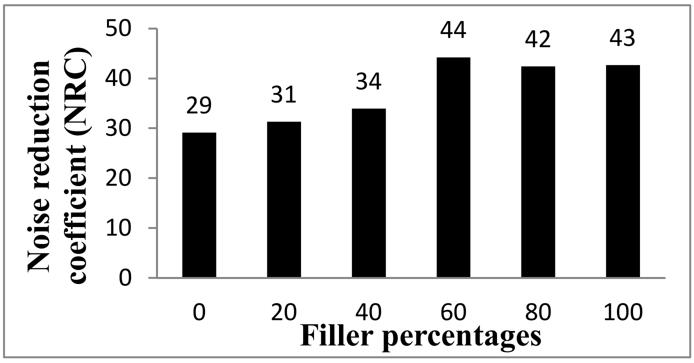

Figure 4: NRC of polymer foam doped with different percentage of TiO_2.

$$NRC, \% = [(\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000}) / 4] * 100 \quad (2)$$

Conclusion

Different percentages of high doping of TiO_2 doping were influence the sound absorption coefficient of the polymer foam. The effectiveness of the polymer foam eventually determined by the doped of percentage of TiO_2. The higher percentage of TiO_2 loading in the polymer foam, the lowest the frequency absorption level with acceptable sound absorption coefficient. Thus, TiO_2 can be used as functional filler to produce flexible sound absorption material based on the selected frequency level.

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