MATERIALS

Study of some electrical properties for PMMA-TiO_2 composites

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SUMMARY. – In the present work, the effect of the addition of TiO_2 on some electrical properties of poly-methyl methacrylate has been studied. For such a purpose, many samples have been prepared by adding TiO_2 on the poly-methyl methacrylate by different weight percentages of TiO_2 and with different thickness. The experimental results show that the D.C. electrical conductivity changes when the concentration of additional TiO_2 increases and when the temperature increases. Also the activation energy changes when the additional TiO_2 increases.

1. Introduction

Recently polymer matrix-ceramic filler composites are receiving increased attention due to their interesting electrical and electronic properties. Integrated decoupling capacitors, angular acceleration accelerometers, acoustic emission sensors and electronic packaging are some potential applications. Ceramic materials are typically brittle, possess low dielectric strength and in many cases are difficult to be processed requiring high temperature. On the other hand, polymers are flexible, can be easily processed at low temperatures and exhibit high dielectric break-down fields (Kontos *et al.*, 2007).

Poly methyl methacrylate is one of the best organic optical materials, and has been widely used to make a variety of optical devices, such as optical lenses. It is known that its refractive index changes upon UV irradiation, either in the pure or doped state, which provides a means to fabricate structures, such as gratings or waveguides (Ahmed, 2008). Electrical conductivity measurement is one of the most convenient tools in studying such structural changes of powder compacts, and has the advantage that the conductivity can be measured continuously

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throughout the whole densification process (Kuno and Senna, 1977). Al-Ramadhan, in 2008, studied the electrical properties of the composites poly-methyl methacrylate-nickel as a function of temperature and concentration of the additive. She explained that the electrical conductivity is increasing with the increase of the concentration of the additive Ni and temperature. This paper deals with the effect of TiO_2 on the some electrical properties of poly-methyl methacrylate.

2. Experiment

The material used in the present paper is the poly-methyl methacrylate as matrix and TiO_2 as a filler.

Electronic balances of accuracy 10^{-4} have been used to obtain a weight amount of TiO_2 powder and polymer powder. These are mixed by hand lay up and the microscopic examination is used to obtain homogenized mixture. The weight percentages of TiO_2 are 0, 10, 20, 30, 40 wt.% The Hot Press method is used to press the powder mixture. The mixture of different TiO_2 percentages have been compacted at temperature 145°C under a pressure of 100 par for 10 minutes. It is cooled to room temperature, the samples were disc shaped of a diameter of about 15 mm and thickness ranging between 2.4 and 3 mm. The resistivity was measured over the range of temperature from 30°C to 90°C using Keithly electrometer type 616C. The volume electrical conductivity σ_v is defined as:

$$\sigma_v = \frac{1}{\rho_v} = \frac{L}{RA}$$

where:

A = guard electrode effective area.
R = volume resistance (Ohm).
L = average thickness of sample (cm).

In this model the electrodes have circular area $A = D^2\pi/4$ where $D = 1.1$ cm.

3. Results and discussion

Figure 1 shows the electrical volume conductivity as a function of the concentration of TiO_2 at a temperature of 30°C, it appears that the conductivity increases with the increase of the TiO_2 additive concentration.

The increase of conductivity with increasing concentration of TiO_2 is due to the increase of the charge carriers, which increase with the increase of filler contact, where the TiO_2 particles at low concentrations are represented by small darker regions. They become large when the TiO_2 content increases and the networks connect each other as illustrated in the microscopic photographs in Fig. 2,

taken for samples of different concentrations (Bhattacharya *et. al*, 2008, He *et. al*, 2005, Srivastava and Mehra, 2003).

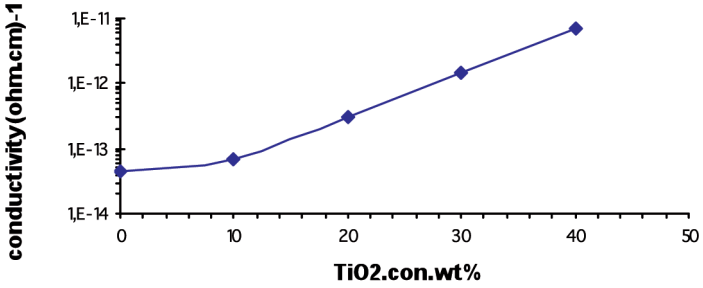

FIG. 1

Variation of D.C. electrical conductivity with TiO_2 wt concentration for PMMA-TiO_2 composite

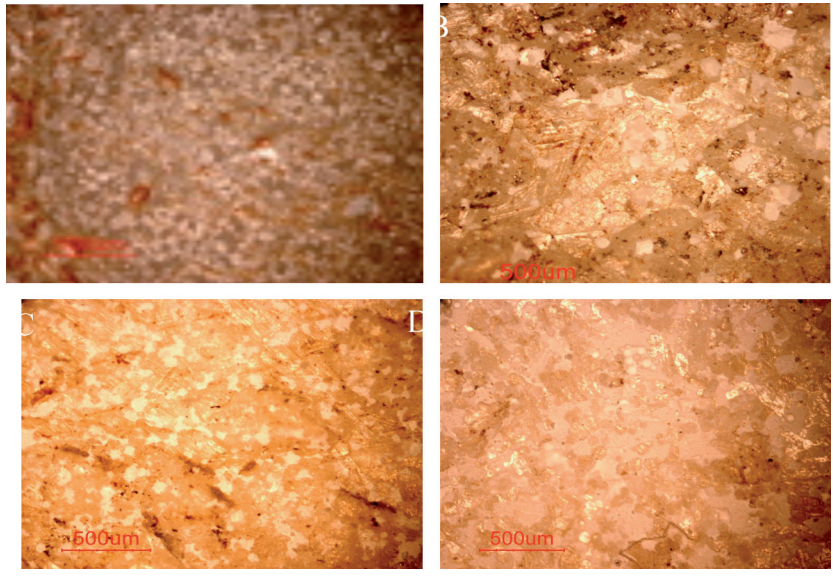

FIG. 2

Photomicrographs for PMMA-TiO_2 composite
(a) for pure (×50), (b) for 10 wt.% TiO_2 (×50), (c) for 30 wt.% TiO_2 (×50)
(d) for 40 wt.% TiO_2 (×50)

Figure 3 shows the behavior of electrical volume conductivity of the samples with the temperature. Note that the electrical conductivity increases with the increasing of temperature, and that any of these materials has a negative thermal coefficient of resistance. The interpretation of this fact is that the polymeric chains and TiO_2 particles act as traps for the charge carriers which transited by hopping

process: on increasing the temperature, segments of the polymer begin to move, releasing the trapped charges.

The release of trapped charges is intimately associated with molecular motion. The increase of current with temperature is attributed to two main parameters, charge carriers and mobility of these charges. The increase of temperature will increase the number of charge carriers exponentially. The mobility depends on the structure and the temperature (Al-Ramadhan, 2008; Majdi and Fadhal, 1997).

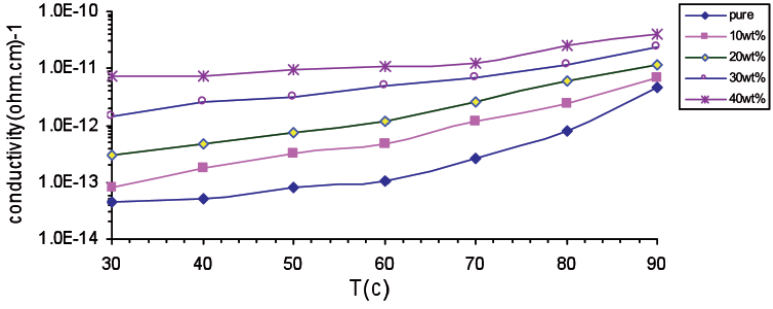

FIG. 3

Variation of D.C. electrical conductivity with temperature for PMMA-TiO_2 composite

Figure 4 shows the relationship between the natural logarithm of the conductivity and the inverted absolute temperature of the PMMA-TiO_2 composites. By using the equation

$$\sigma = \sigma_0 \exp\left(-E_a / k_B T\right)$$

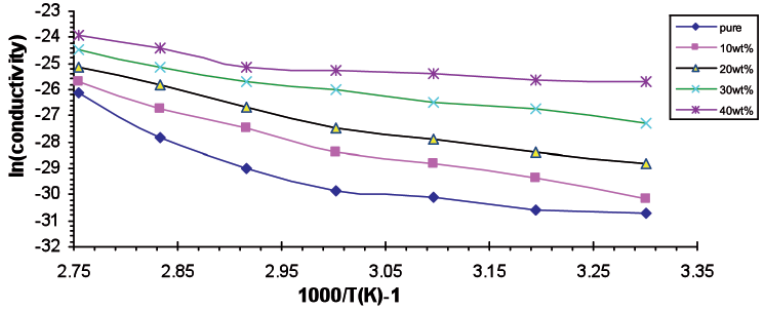

FIG. 4

Variation of D.C. electrical conductivity with reciprocal absolute temperature for PMMA-TiO2 composite

the activation energy was calculated. The high activation energy values for neat sample and low TiO_2 concentration sample can be attributed to the thermal movement of ions and molecules, whereas the low activation energy values for

the samples of higher TiO_2 content can be attributed to the electronic conduction mechanism which is related to the decreasing of the distance among the TiO_2 particles. (Hamzah *et al.*, 2008)

The concentration increasing of TiO_2 less the result of the activation energy as shown in Fig. 5 of PMMA-TiO_2 composites which is a reasonable support for the above discussion (Ahmed and Zihilif, 1992).

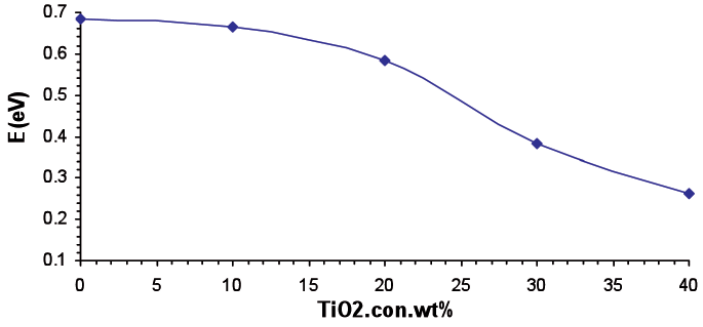

FIG. 5

Variation of activation energy for D.C. electrical conductivity with TiO_2 wt% concentration for PMMA-TiO_2 composite

4. Conclusions

1. The D.C electrical conductivity of the PMMA increases by increasing TiO_2 concentrations and temperature.

2. The activation energy of D.C electrical conductivity is decreases by increasing TiO_2 concentrations.

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