Thermal Properties of UPE-PMMA Blend Reinforced by ZnO Nanoparticles

Fadhil K. Farhan, Zainab Al-Ramadhan, and Widad A. Abd-Al Hussein

Abstract—In this study, thermal analysis properties (Heat Transfer) have been studied for UPE-PMMA polymer blend reinforced with x-ZnO where x is (0wt%, 1wt%, 2wt%, 3wt%, 4wt% and 5wt %). Ultrasonic dispersion technique used to prepare the nanocomposites specimens follow with cold casting technique using Teflon molds at standard conditions. C - Thermostensor (TC i) technique was used to measure the heat transfer properties such as; (thermal conductivity, thermal effusivity, thermal diffusivity, heat capacity and thermal resistance). Results show that the values of conductivity, effusivity and diffusivity are increased by succession of weight percentage of fillers. While a heat capacity and thermal resistance results show that the values are decreased progressively by succession of weight percentage of fillers. Scanning electron microscopy was employed to aid interpretation results of thermal analyzer and to show the distribution of nanoparticles in polymer matrix.

Index Terms—Thermal Properties; Thermal Conductivity; Effusivity; Diffusivity; UPE-PMMA; ZnO; Blend; Nano Composites.

I. INTRODUCTION

The significance of polymers is primarily on the grounds that polymers are still viewed as a modest option material that is produced effortlessly. A lively improvement of polymer composite and broad use of polymer materials in innovation has driven as of late to the polymer composites. Polymer mix, are known as the aftereffect of blending at least two sorts of polymer, with no concoction response occurring. Subsequently, no covalent holding happens between the parts [1]. Polymer composite is ordinarily used to make materials with enhanced mechanical properties, yet the subsequent material properties can have a mind boggling reliance on organization and preparing conditions [2], so it’s have turned out to be critical subject for logical examination as of late in view of their developing business acknowledgment, and they can have bizarre blends of properties, these composites are for the most part delegated homogeneous and heterogeneous [3]. The properties of all mix parts are available, shortcoming of one polymer can to a specific degree be disguised by quality of the others [4]. There are a few strategies for delivering polymer composite, the methods utilized depend to a huge degree on the way of the polymer specifically, regardless of whether it is thermoplastic or thermosetting [5]. The mix of two distinct materials, for example polymeric, is a basic course to combine the appealing components of various materials keeping in mind the end goal to improve the inadequate qualities of a specific material [6]. Specifically, polymer composites strengthened with inorganic fillers of measurements in the nanometer extend, known as nanocomposites, have pulled in awesome enthusiasm from specialists, because of startling synergistic properties gotten from the two segments [7]. The most investigations of polymer nanocomposites are made out of thermoplastic or thermosetting framework. Polymer materials demonstrate a powerless warm conductivity [8]. For polymers strengthened with various sorts of fillers this is much more critical. Enhanced warm conductivity in polymers might be accomplished either by atomic introduction or by the expansion of exceedingly warmth conductive fillers (TiO2, Al2O3, ZnO, SiO2, CNT, MWCNT,…) [9]. Temperature, weight, thickness of the polymer, introduction of chain fragments, gem structure, the level of crystalline and numerous different elements may influence the warm conductivity of polymers [10]. The impacts of molecule volume division, scattering operator, curing specialist with various sub-atomic weights on the warmth move in ZnO strengthened UPE - PMMA mix has been researched [11]. The point of this review are to creation of ZnO fortified UPE20% PMMA based nanocomposite and to concentrate the impact of filler substance on warmth exchange properties of nanocomposite under different working conditions.

II. THEORY

Heat is transported in material by both lattice vibration waves (phonons) and free electrons. A thermal conductivity is associated with each of these mechanisms, and the total conductivity is the sum of the two contributions. The thermal energy associated with phonons or lattice waves is transported in the direction of their motion. Lattice wave contribution results from a net movement of phonons from high - to low temperature regions of a cross body, which a temperature gradient exists, heat transfer by conduction involves transfer of energy within a material without any motion of the material as a whole. Heat flow in this approach is measured using the thermal equivalent of Ohm's Law [12]. The C- Thermo - sensor is based on the modified transient plane source (MTPS) technique was used. It uses a one-sided, interfacial, heat reflectance sensor that applies a momentary, constant heat source to the sample. Both thermal conductivity and effusivity are measured directly and rapidly providing a detailed overview of the thermal characteristics of the sample material. Sample material can be a solid, liquid, paste or powder [13].

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i features multiple graphical and tabular display options, and provides direct, indirect (calculated), and user input capabilities for a number of thermal testing properties, including: thermal effusivity, thermal diffusivity, density, thermal conductivity, heat capacity and thermal resistance. Thermal conductivity can be calculated by [14]:

\[
\frac{dT}{dt} = -\lambda A \frac{dH}{dx}
\]  

(1)

Where: \( H \), heat (J), \( t \), time (sec), \( \lambda \), thermal conductivity (W/K. m), \( T \), temperature (K), \( x \), height of test specimen (m), and \( A \), cross-sectional area of the test specimen (m²).

The thermal diffusivity equation (m²/s) is [11]:

\[
\delta = \frac{1}{C_p \rho}
\]  

(2)

Where: \( C_p \), specific heat capacity (J/Kg.K), \( \rho \): density of sample (Kg/m³). The effusivity equation (W/s²/m².K) is [11]:

\[
\varepsilon = \sqrt{4\delta C_p}
\]  

(3)

And the thermal resistance equation (m².K/W) is [12]:

\[
R = \frac{dx}{\lambda}
\]  

(4)

III. EXPERIMENTAL

Nanocomposites are prepared by dispersing nano ZnO in kinetically by ultrasonic technique. To achieve better state of dispersion firstly the nano ZnO were treated with alcoholic medium (ethanol or acetone) for the deagglomeration of the particle bundles. The treated particles are then added to polymer blend [UPE 20 wt% - PMMA 80 wt%] and probe sonicated was used for 10 min at room temperature. The mixture is cured under vacuum at (333 K) for 10 h followed by hardener addition by using simultaneous magnetic stirring (250 rpm), for an hour to homogenization, this process’s name active mechanical method (AMM). The prepared samples are treated at (363 K) for 6 h in the oven to remove the moisture contents of the samples. The surfaces of the specimens are mechanically polished to minimize the influence of surface flaws, mainly the porosity. Molds are made from Teflon. The mold smeared by wax before the mixture is casting into the mold after homogeneity. Sensitive electronic balance was used to calculate the weight of blends resin and ZnO.

IV. UNITS

The thermal conductivity of nanocomposites and neat blend was measured by thermal conductivity analyzer. Thermal properties results of nanocomposites samples are summarized in Table I. The samples are placed directly on the wetted sensor, without using an aluminum foil in between. In the present study, where better conducting samples are investigated, it is found that the using of the aluminum disk is superfluous. The results of effusivity were increasing with increase the percentage of nano – ZnO.

Thermal conductivity was improving from 0.21 (W /m.K) for UPE-PMMA blend matrix to 0.3 (W /m.K) for 5 wt % nano – ZnO, this because a good distributions of nanoparticles and a good thermal conductivity for materials reinforced in polymer and this a good agreement with [15]. Thermal diffusivity was increased with increasing percentage of nano – ZnO. The heat capacity is drop from 1318(J/ Kg. K) in UPE-PMMA polymer to 1097.62 (J/ Kg. K) in 5% nano – ZnO, this because low heat capacity of nanoparticles. The thermal resistance was decreased from (0.015) (m².K/W) to (0.011) (m².K/W), this because the thermal resistance is inverse of thermal conductivity and increase nano – ZnO reinforced, decrease heat capacity for nanocomposites. A good evidence of excellent dispersion of ZnO nanoparticles in UPE – PMMA blend matrix can be shown in Fig. 1.

![Image of sample and measurement](a)

![Image of sample and measurement](b)

<table>
<thead>
<tr>
<th>Sample Code</th>
<th>( \lambda ) (W/m.K)</th>
<th>( \varepsilon ) (W²/m².K)</th>
<th>( \delta ) (mm²/s)</th>
<th>( C_p ) (W/m.K)</th>
<th>R (m².K/W)</th>
<th>( \rho ) (Kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neat blend</td>
<td>0.21</td>
<td>568.5</td>
<td>0.136</td>
<td>1318.8</td>
<td>0.0157</td>
<td>1167</td>
</tr>
<tr>
<td>1% nZnO</td>
<td>0.22</td>
<td>578.89</td>
<td>0.144</td>
<td>1248.6</td>
<td>0.015</td>
<td>1220</td>
</tr>
<tr>
<td>2% nZnO</td>
<td>0.24</td>
<td>600.24</td>
<td>0.16</td>
<td>1200.9</td>
<td>0.0138</td>
<td>1250</td>
</tr>
<tr>
<td>3% nZnO</td>
<td>0.288</td>
<td>651.82</td>
<td>1.9</td>
<td>1161.6</td>
<td>0.0148</td>
<td>1270</td>
</tr>
<tr>
<td>4% nZnO</td>
<td>0.29</td>
<td>655.0</td>
<td>0.196</td>
<td>1129.31</td>
<td>0.0113</td>
<td>1310</td>
</tr>
<tr>
<td>5% nZnO</td>
<td>0.30</td>
<td>659.1</td>
<td>0.21</td>
<td>1097.4</td>
<td>0.0110</td>
<td>1320</td>
</tr>
</tbody>
</table>
Fig. 1. SEM images for nanocomposites (a): 1wt% ZnO, (b): 2wt% ZnO, (c): 3wt% ZnO and (d): 5wt% ZnO

V. CONCLUSION

Thermal effusivity, thermal conductivity and thermal diffusivity increase with increase percentage of nano ZnO values. The heat capacity and thermal resistance decrease with increase percentage of nano ZnO values. This work is expected to introduce a new class of polymer nanocomposite that might find thermal applications.

REFERENCES