The effects of copper additives on the glass transition temperature and hardness for epoxy resin

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Abstract: The polymeric composites material considered as one of the most isolated materials, but they have a good mechanical flexibility. The main idea of modifying these materials to be one of the applicable materials in environmental aspects. Reducing the temperature inside buildings by coating them with the modified materials will give very good results in decreasing the electrical power used. In this study, polymeric composites material were prepared a by hand- layup technique from epoxy resin (EP) as a matrix and Copper (Cu) powder with average diameter (240.91 nm) as fillers with different weight percentage (5%, 15%,25%, 35%, and 45%) to resin. Glass transition temperature and Hardness testing were investigated. The results show the maximum Glass transition temperature (Tg) of (EP/Cu) composites were the value (58.949°C) at (65%EP + 35%Cu). Increase hardness with Copper concentration increase, and it has maximum values of (83.9) for (55%EP + 45%Cu). This composite can be used in the coating surfaces and floors to match the temperature of our country warm in summer.

Keywords: copper; glass transition temperature; epoxy; hardness.

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1 Introduction

Polymers have good physical and mechanical properties which used in many applications, so that, to produce polymers which have another specification, the Modern technologies are offer many way to combinations of properties (Kakani and Kakani, 2004). Polymers play important role in numerous fields of everyday life due to their advantages over conventional materials (Glushanin et al., 2006; Pelaiz-Barranco and

Marin-Franch, 2005). Engineers and designers today easily turn to polymers since they possess a number of features which are not available in any other materials. Polymers characterises by resistance to corrosion, resilience, colour fastness, transparency, ease of processing**,** lightness …. etc. (Ashby et al., 2009; Crawford, 2002).

The fabrication of polymers has become one of the most developed sciences started to increase. Scientists seek to produce flexible, inexpensive, and multi-use polymers. They are used in housing, electrical equipment, r automobiles and various industrial applications (Kontos et al., 2007).

Polymers have replaced metals in many applications in being chemically inert and erosion resistant. Most polymers are presently fabricated as lightweight, rigid and foam materials. They are used as insulators thermally and electrically with respect to their low conductivity (Dahshan, 2002).

The glass transition temperature (Tg) is important properties for Polymer, and is the temperature where the polymer transitions from a hard, glassy material to a soft material. Many parameters were effect on Tg like the type of polymer, cross-link density for thermosets polymer (Overney et al., 2000).

Polymers are bad to transfer heat and have low thermal conductivity, so that adding metal particle may be improvement thermal conductive. The adding some materials to polymers may be call composites.

Composites are combinations of two or three materials, one of these materials called matrix phase, and the other phase, may be fibre sheets or particles.

Study effect of addition of copper oxide nanoparticle over thermal stability of high density polyethylene (Muthiaha, and Marimuthub, 2015). The HDPE – Copper oxide Nanocomposite are prepared by melt mixing method in twin-screw extruder. It is found that with 2 wt% gives comparatively the best result. SEM Studies are carried out to observe the morphology of reinforcing materials as well as its dispersion in the polymer matrix is investigated. The thermal stability of the composites is measure using thermo gravimetric analysis (TGA) and observed that polymer nanocomposite made with copper oxide nano particle showed higher thermal stability as compared with virgin HDPE.

Improving the thermal conductivity of epoxy resin by the addition of a mixture of graphite nanoplatelets (GNPs) and silicon carbide microparticles (micro-SiCs) (Zhou et al. (2013). They found that thermal conductivity, 26.1 times that of epoxy, was obtained with 7 wt% GNPs + 53 wt% micro-SiCs.

The comparisons of filler particle size of recycled copper that are coarse and fine on mechanical, thermal, physical and mechanical were investigated (Pargi et al., 2015). The recycled copper was collected as a waste from the milling machine and grinded into coarse (300–400 μm) and fine (10 μm) particle sizes. The recycled copper filled epoxy composite was fabricated using mechanical stirrer. The effect of volume fraction of recycled copper of the epoxy composites were also studied based on the flexural properties, coefficient of thermal analysis (CTE), hardness and density. Incorporation of recycled copper has decreased the CTE of the composites. The flexural properties, hardness and density of the composites increased with increasing of volume fraction and filler loading.

The Adding metal particle to polymer may be changes another property, so that, in this research we study effects of Copper Additives on the Glass Transition Temperature and Hardness for Epoxy Resin. Mechanical and thermal properties have been one of the most significant topics to be studied but there is lack of research to look into the effect of additives on the mechanical and thermal properties of the materials (Rammo and Mahdi, 2013).

2 Methodology

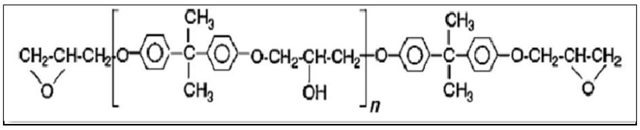
2.1 Matrix material

The matrix material that was utilised is epoxy resin (EP Euxit50). It has a trademark (EP Euxit 50) production of Swisschem is a liquid of low viscosity resin, and it is converted to solid state by adding hardener (Euxit 50 KII) at ratio of (5 : 2), which were supplied by Egyptian Swiss chemical industries company. The properties of epoxy resin used in this work shown in Table 1. According to the properties of Product Company ASTM D-543 and ASTM C-881-87. The chemical structure of epoxy resin is show in Figure 1.

Table 1 Show the properties of epoxy material

Density at 20°C (gm/cm^3)	1.05
Viscosity at 20°C	300
Colour	Colourless
Glass temperature °C	57
Flexural strength (MPa)	63
Modulus of elasticity(MPa)	2800
Bending property (N/mm^2)	45

Figure 1 Epoxy structure



Source: ASTM (2003)

2.2 Copper powder

In this research, Copper powder (Density 8.9 g/cm^3 and purity 99.5), was produced by the Company Central Drug House (P) Ltd, Vardaan House, New Delhi-10002, INDIA. The powder was adding to epoxy with weight percentage (0%, 15%, 25%, 35%, and 45%).

2.3 Composite fabrication

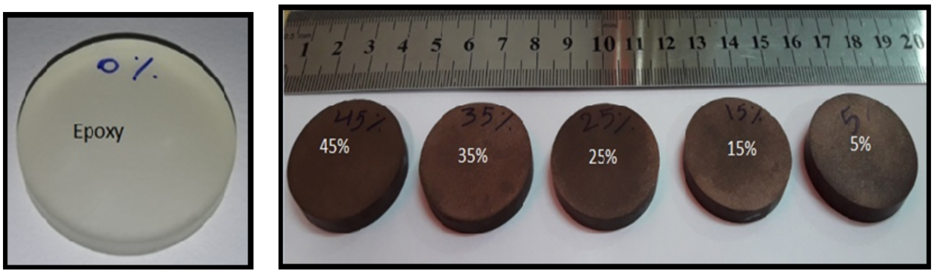
A hand lay-up method was used to prepare all the specimens in this work. Samples composed of epoxy resin with Copper powder at different weight percentage (5%, 15%, 25%, 0.35%, and 45%), and the ratio of Epoxy to hardener is (5 : 2).To get good homogeneity between epoxy resin and Copper powder, homogeniser device at 700 rpm with 10 min to have good distribution for particles in epoxy resin. Vacuum system was used to remove the bubble before cast the composites in earlier prepared mould, blend and then poured into the mould, then we will allowed to cure through a day (24 h) at room temperature (26 ± 2)°C.

2.4 Hardness test

Shore D was utilised to calculating the hardness of the composites. The samples were prepared with (4 mm) thickness and (30 mm) diameter (Figure 2), according to ASTM standard D-2240 (ASTM, 2003). The shore D device consists of needle with vertical direction over the specimen. This needle is going to register the average of three values measured from various sites of each specimen is estimated.

Shore D Hardness tester TH210 made by Time Group INC. Used to measure the hardness of the material, the indenter was attached to a digital scale that is graduated from 0 to 100 unit, the specimens were tested by pressing the indenter of the instrument, which is a needle of a sharp head (Length 2.54 mm) into the specimen surface so that the result was appeared on the digital screen attached with the instrument.

Figure 2 Photograph of shore D hardness test specimens for pure epoxy and epoxy/Copper composites (see online version for colours)



2.5 Glass transition temperature

Differential Scanning Calorimetry (DSC131 EVO)was utilised to calculating the glass transition temperature (Tg) of the composites as a function of temperature.Measurements were performed over a temperature range of (25–200)°C at a heating rate of (10°C/min).

3 Results

3.1 Copper powder

Scanning electron microscope (SEM) with magnifying force (10 µm), is shown in Figure 3.

AFM images and it result are shown in Table 2 and Figure 4.

3.2 Hardness test

Figure 5 and Table 3 shows the variation values for Shore D Hardness of Epoxy resin and its composites.

Figure 3 SEM images of the copper powder

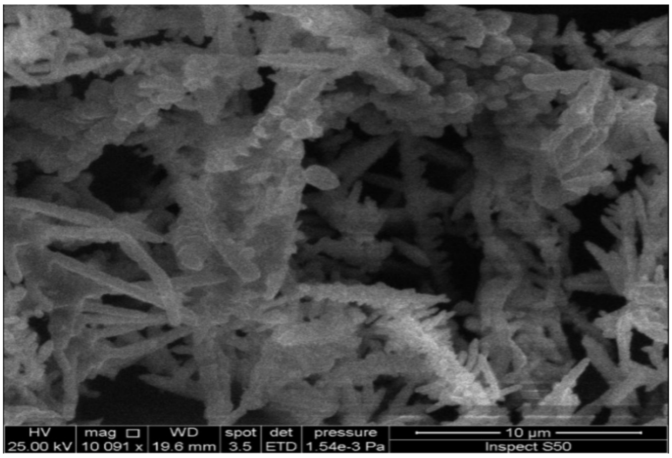


Table 2 Granularity distribution for copper powder and average diameter (D)

Avg. (D):240.91 nm		*<=10% (D):160.00 nm*
<=50% (D):220.00 nm		*<=90% (D):320.00 nm*
Diameter (nm)	*Volume (%)*	*Cumulation (%)*
160	4.35	4.35
180	9.42	13.77
200	14.49	28.26
220	17.39	45.65
240	13.04	58.70
260	6.52	65.22
280	12.32	77.54
300	6.52	84.06
320	3.62	87.68
340	3.62	91.30
360	3.62	94.93
380	2.17	97.10
400	1.45	98.55
420	0.72	99.28
480	0.72	100.00

3.3 Glass transition temperature

Glass-transition Temperature (Tg) of Epoxy resin and EP/Cu composites are shown in the Figure 6.

Figure 4 AFM image of cu powder (see online version for colours) (see online version for colours)

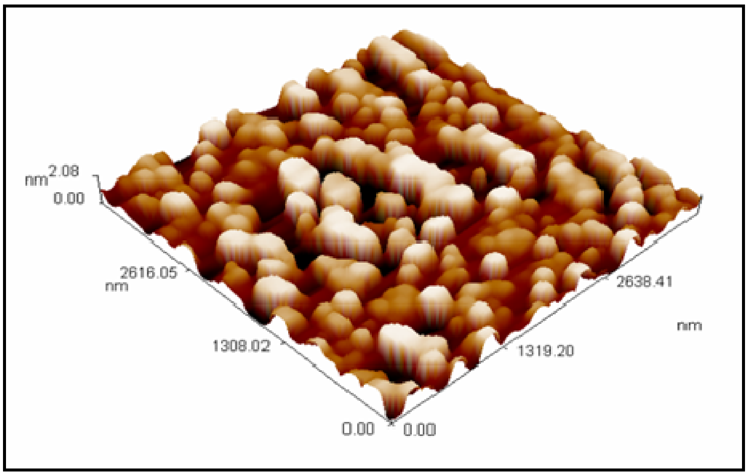


Figure 5 Hardness V.s cu weight percentage for Ep/Cu composites (see online version for colours)

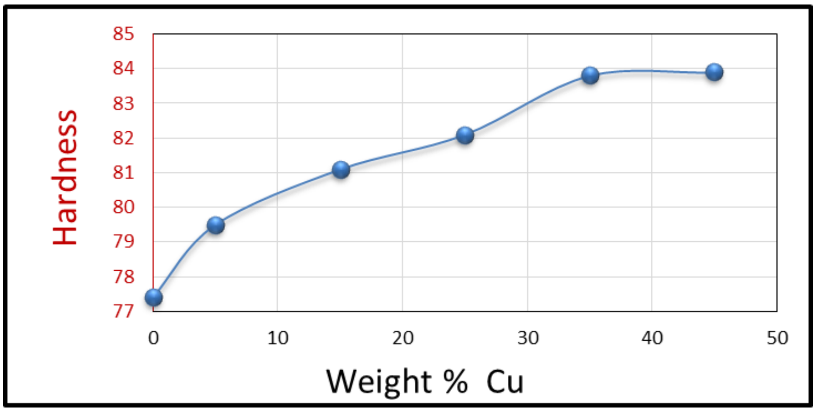
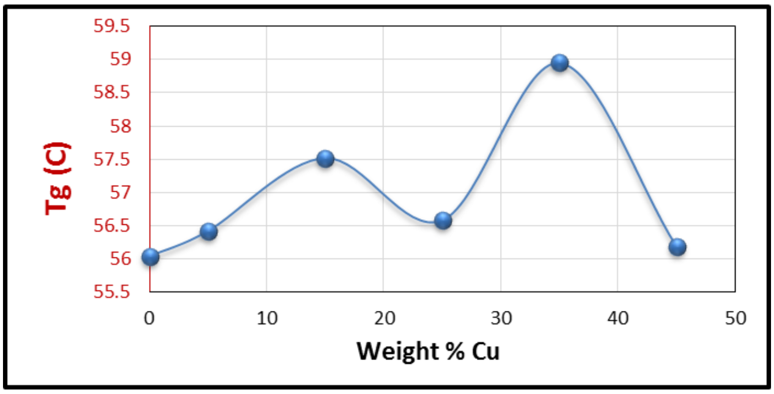


Table 3 Values of the shore D hardness for Ep/Cu composites

EP	*Cu*	*Shore D Hardness*
100%	0%	77.4
95%	5%	79.5
85%	15%	81.1
75%	25%	82.1
65%	35%	83.8
55%	45%	83.9

Figure 6 Tg vs. Cu weight percentage for Ep/Cu composites (see online version for colours)



4 Discussion

4.1 Copper powder

The powder was adding to epoxy with weight percentage (0%, 15%, 25%, 35%, and 45%). The images showed scanning electron microscope (SEM) with magnifying force (10 μm), with differences in particle sizes for Copper powder, Where it is observed that there are clusters of particles and that the form of particles dendritic structure. However, the measurement of particle size for each grouping was difficult. As shown in Figure 2, therefore, the particle size and the percentage of its presence in the sample were measured through a test (AFM). It was performed to measure the average diameter for Copper powder. Table 2 and Figure 3 showed the results for Copper powder with average diameter (240.91 nm).

4.2 Hardness test

Figure 5 and Table 3 shows the variation values for Shore D Hardness of Epoxy resin and its composites. It has been found that the hardness values increase with the increasing of Copper powder ratio in the Epoxy composites, as from this figure it was observed that there was an increasing in hardness values as Copper particles increase in Epoxy matrix. To explain this behaviour, the particles of Copper will distribute between the chains for epoxy, so that the indenter of device will touch the surface of specimen, which contain deferent and small sizes of particles beside of epoxy. The increase Cu powder, the Cu particles will line and clustered in all the volume of specimen, so that the indenter of device will touch the surface of clustered Cu at the surface and the values of hardness will increase. We have noticed that the hardness increases with increase the reinforcement rate. This test gave us a good picture of the strength of the material and the mass cohesion of the material. Thus, we can say that we obtained a composite that bears environmental factors more than pure epoxy.

4.3 Glass transition temperature

Pure epoxy is using in coating surfaces and floors and has a glass-transition temperature of (56.034°C). To improve the glass transition temperature, it has been reinforcement by copper powder with different proportions. We have been succeeded in increasing the value of glass transition, and this can be used in the coating surfaces and floors to match the temperature of our country warm in summer.

Glass-transition Temperature (Tg) of Epoxy resin and EP/Cu composites are shown in the Figure 6, The (Tg) values are increased with increasing weight percentage of copper except the ratios (25%) and (45%), the maximum value (58.949°C) at (35%) Cu of composites as shown in Table 4, to explain this behaviour, the particles of Copper will distribute between the crosslink chains for epoxy, which reduce the mobility of epoxy chains and filling free volume between epoxy chains. Upon heating through the (Tg), the amorphous solid polymer transforms from a rigid to a rubbery state. The value of the (Tg) will depend on molecular weight characteristics that affect chain stiffness. Increasing the molecular weight also tends to raise the (Tg), when the molecular weight is very high, this is due to a decrease in free volume due to a decrease in the movement of the ends of the polymer chains because free volume depends on the concentration of the ends of the chains. Where the number of chain ends movement decreases with the molecular weight of the polymer increases. Also, the glass transition temperature increases with increasing polymer polarity and increasing the density of the cohesive energy. The decrease in the degree of glass transition temperature, due to the increased degree of branching in polymers and this is because the increase in the degree of branching leads to Increase the number of chains ends and increase free volume. These behaviours agree with reference (Singha and Thomas, 2005).

Table 4 Values of the Tg (^{o} C) for EP/Cu composites

EP	*Cu*	*Tg (^{o}C)*
100%	0%	56.034
95%	5%	56.419
85%	15%	57.518
75%	25%	56.58
65%	35%	58.949
55%	45%	56.184

5 Conclusions

In this work, polymeric composites material were prepared a by hand- layup technique from epoxy resin (EP) as a matrix and Copper (Cu) powder with average diameter (240.91 nm) as fillers with different weight percentage (5%, 15%,25%, 35%, and 45%) to resin. Vacuum system was used to remove the bubble before cast the composites in earlier prepared mould, blend and then poured into the mould, then we will allowed to cure through a day (24 h) at room temperature (26 ± 2)°C. Added copper powder with different proportions to the pure epoxy to increase hardness of epoxy. The hardness of epoxy increases with increase Copper concentration, and it has maximum values of (83.9) for 45% Copper powder concentration, which increased by 8.4% compared with hardness of pure epoxy. The maximum glass transition temperature (Tg) of EP/Cu composites were the value (58.949°C) at 35% Cu, Which increased by 5.2% compared with glass transition temperature of pure epoxy. Then this composite can be used in the coating surfaces and floors to match the temperature of our country warm in summer. The images of SEM with magnifying force (10 μm), Showed differences in particle sizes for Copper powder, Where it is observed that there are clusters of particles and that the form of particles dendritic structure. The results of average diameter for Copper powder by the using the (AFM) test, show that the average diameter was (240.91 nm).

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