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The effect of utilization silicon & copper powders at the properties for epoxy resin (mechanical and physical)

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ABSTRACT

In this work the physical and mechanical properties for epoxy resin improvement by addition the particle of Copper(Cu) and Silicon (Si). Copper (Cu) and silicon (Si) powders strengthened epoxy resin was worked to research the action of powders respect to the mechanical properties such as (hardness and impact strength)and physical properties such as (thermal and electrical conductivity) for epoxy resin. Cu and Si powders were inserted to the matrix material as filler with increasing in weight ratio (2%, 4%, 6% &8%). These properties were estimated and compared. The Experimental results show that the hardness enhancement increased gradually with increase weight fraction for the particles silicon until 4%and then begin descend, in other words, should not exceed the proportion of silicon added to the epoxy resin 4% in order to get an improvement in the hardness of epoxy, While increasing the proportion of copper particles added to the epoxy resin more than 4% lead to increased hardness of the resin. The impact resistance increases for epoxy resin to add silicon particles and copper but be better resistance at the rate of 8% Cu, where up to (32.5 J/m^2) while you are adding 8% copper and up to less (14J/m^2). The thermal conductivities increased with increasing of weight ratio for Cu and Si fillers content be for Silicon (24.65 $w/m.c^{-1}$) and the Copper (25 $w/m.c^{-1}$). As well as the electrical conductivity increased with increasing the weight fraction for the Silicon and Copper (σ=0.87 s/m) and (σ=0.967 s/m).

KEYWORDS: Epoxy resin, Cu and Si powders, Mechanical properties, Physical properties.

INTRODUCTION

Composite materials are including of a polymer resin as the matrix, reinforcement as (fibers or particles). These materials are consisting of one or more interrupted phases embedded in a incessant phase. Interrupted phases are generally more difficult and sturdy than the incessant phases and these materials called the strengthening materials, while the incessant phase has less hard and more flexibility called "matrix" [1,2,3]. Reinforcements render to improvement the mechanical properties of matrix in the composite materials. The matrix and the strengthening phase are attached to each other by linkage surface is called interface [4].

The purpose of the composite material is to get the materials characterized by a low density, good toughness, high tensile strength and stiffness, high performance at high temperature and high wear resistance and thermal conductivity, good hardness and resistance to fatigue and corrosion, hence the properties of composite materials depends mainly on the characteristics of each matrix and reinforcing materials as well as the nature of the interface between them so they are used as heat sinks in electronic packaging applications [5,6,7]. The characteristics of resin matrix are effected via the interfacial adhesion & size of particles. The

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excellent dispersed inorganic fillers in polymer matrices and compatibility between interrupted phase &incessant phase are important to produce good performance [8].

polymeric composite materials which are electrically conductivity have many benefits more than that pure metal such as simply manufacturing, low cost, high elasticity, descent weight, corrosion strength, capability of mechanical shock absorption and conductivity control in many engineering fields like electromagnet interference (EMI) shielding, corrosion protection, safety of packaging, control on electrostatic discharge (ESD) and conductive adhesives [9]. The aim of this research was to investigate the effect addition particles (silicon and copper) on hardness, impact resistance, thermal and electrical conductivities) for the epoxy resin with the increment of weight ratio, Results acquired have been disputed and analyzed in experimental part.

Literature Review:

Cu and Al powders strengthened epoxy resin was manufactured by V. K. Srivastava*, Ansul Verma to explore the effect of variation of powders from (1%, 5%, 8% and 10%) weight percentage at the mechanical properties such as (compressive strength, tensile strength, vicker's hardness, wear resistance, fracture behavior and friction coefficient) of epoxy resin. Results have shown that the wear loss and tensile resistance gradually declined with filler content increment. Compressive resistance, coefficient of friction and hardness increased with weight ratio increment of fillers content(Cu and Al)[10].

The no interactions between the epoxy/MDA in organic phase with Cu obtained by N. H.Mohd Hirmizi, is achieved by FTIR analyses. The epoxy composite reinforced copper (Cu) powder was manufactured by aqueousto organic phase transfer method provided similar electrical conductivity and convenient thermal properties compared with other composites. Results have shown that the thermal stability of Cu-epoxy/MDA composites less than the cured unfilled epoxy/MDA. The composites above 300◦C display the conducting properties similar to Ag-epoxy nanocomposites[11].

K. K. SARAF has found that the thermal conductivity of epoxy resin was improved by the inclusion of copper particles. When a comparison was made between the readings of thermal conductivity from experimental work and those estimated by the use of finite element method, the findings were reasonably similar [12].

Experimental work:

1- Matrix Material:

The matrix material that was utilized is epoxy resin (Bisphenol-A-Diglycidyl-Ether) obtained from Fosroc Corporation and its amine hardener are mixed in a percentage of 3:1.Main properties of these resins are given in Tables 1.

Table 1-1: Main characteristics of epoxy resin

Density (20ºC) [g/cm³]	1.18-1.19
Softening point [ºC]	70-80
Compression Strength (N/mm^2)	77
Flexural Strength (N/mm^2)	91
Tensile Strength (N/mm^2)	29

2 -Copper powder:

In this study Cu powder usedwith weight ratio (2,4,6 and 8%). The copper is used to improve thermal conductivity. Density 8.94 g/cm^3

3-Silicon powder:

Silicon powder (density 2.3 gm/cm^3) used with weight percentage (2,4,6 and 8%).

4-Composite Fabrication:

Samples composed of epoxy resin reinforced Cu and/or Si powder at different weight fraction (2%, 4%, 6% and 8%) & hardener are usedwith ratio (3:1).The blend is mixed via stirrer. The mixture process period is (5-10) minutes to produce the blend approximately homogenized.Blend was then poured into the mould. Allowed to cure for 24 hours at room temperature and then curing is done in an electric oven at 50 ˚C for 4 hours. Specimens were prepared in 5 compositions by varying the copper and silicon content in matrix material. Granular volume has been determined for Cu and Si particles by using laser particle size analyzer. The average particle size of silica powder is 6.99µm and copper powder is 27.44µm.

Physical properties:

1- Thermal conductivity test:

Thermal coefficient meter YBF-3 is utilized for calculating the thermal conductivity of the specimen by placing samples between two plates made of copper and set the temperature to raise to 80°C, when flowing temperature from the upper panel to the lower panel during the specimen is recorded reading of the V1 and it's a remain constant during the test, after that is recorded V2 from the device screen every (120 sec) until it reaches the consistency. After that we remove the sample and allow the two plates to be cooled by air and then record the change in V every (60sec) until it reaches to the value of V2 and then apply the equation of thermal conductivity.

$$\lambda = \frac{M.C.Hb}{\pi.r^2.(V1-V2)} * \frac{2Hp+Rp}{2Rp+2Hp} * \frac{\Delta V}{\Delta T}$$

M = 0.824 Kg

C = 3.805*10² J/Kg.C^{-1}

Hp = 7.01 mm

Rp = 65 mm

r sample = 1.75 mm

Hb sample = 10 mm

4- Electrical conductivity test:

The electrical conductivity was measured by using Keithly electrometer type (616C) . The samples have (3mm) thickness and (15mm) diameter, the volume electrical conductivity (σ) was determined from the equation:-

σ =Error!

Where:-

σ = electrical conductivity, Siemens per meter (S/m)

A = Area of guard electrode effective.

R = volume strength (Ohm).

L = medium thickness of specimen (mm).

Circular area is used of electrodes in this test

A= $D^2\pi/4$ ⟶ D= 5mm

Mechanical properties:

1-Hardness test:

Shore D was uitalized for calculating the hardness of the specimens, thickness of samples at least more than (3mm) which must have smooth surface and not be exposed to mechanical vibrations therefor the prepared sample has (5mm) thickness and (30mm) diameter with reference to ASTM (D 2240). The shore D device involve aneedle that is positioned vertically to the specimen for period about half aminut.To register an accurate reading, the average of three values measured from various sites of each specimen is estimated.

2- Impact test:

Charpy impact test involve the use of hammer blow that will be delivered to the sample until reaches to breaking point. The sample is positioned in such away that both of it's ends are fixed in position and the blow is dielvered to the middle part. Samples of impact device has a dimensions of (10*55*10mm)according to ASTM (D4812). The apparatus used in this test is manufactured by (Testing Machines,Inc , Amityville New York). The following equation can be used to calculate the impact strength (I.S.):

I.S. =Uc/A

Uc: the fracture energy (Joule) from Charpy impact device.

A: the area of the samples (m^2) (cross-sectional).

RESULT AND DISCUSSION

Hardness test:

Hardness test was performed using shore D. The effect filler particle on hardness values is shown in fig.(4-1) and table (4-1). Figure (4-1) shows that hardness increase with increasing Cu percentage in epoxy resin. While the hardness of Si filled in epoxy resin increased with the increment of weight ratio of filler until 4% because the fine particle content of Si filler leads to less void content of the composite materials so it will pack the structure. The packed structure will reinforce the composites, thus the hardness value is high. But with further weight ratio increment, agglomeration for Si filler particles could takes place and this agglomeration thereafter may probably decreased the hardness. V. K. Srivastava [10] in their research shown similar trend to increment hardness values until certain filler content.

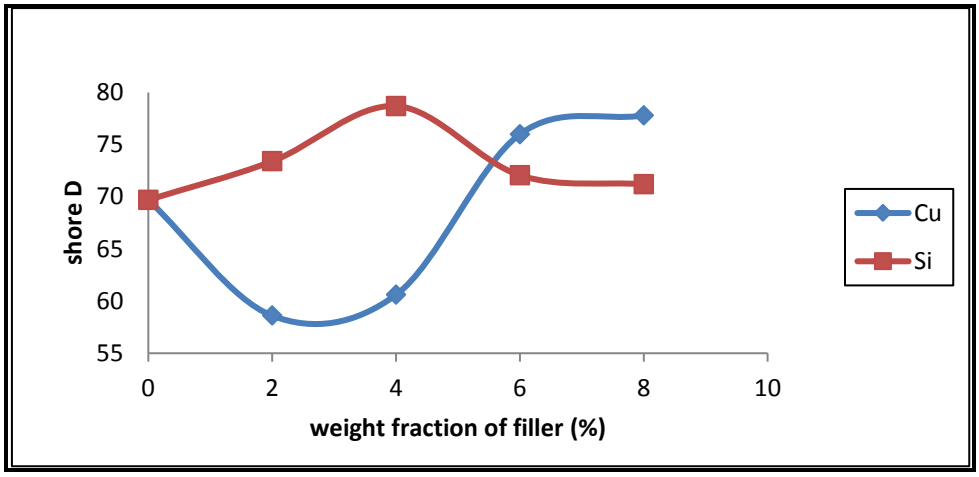

Fig. 1: The effect of Cu and Si weight fraction on the shore D hardness.

Impact test:

Impact test was carried to the samples by charpy method at room temperature. Figure (4-2) and table (4-2) show that the Impact strength for pure epoxy are higher than that for reinforced epoxy with copper powder as a result of less ductility of reinforced epoxy than that for pure epoxy. But for reinforced epoxy with copper powder, it can be noted that any increase in weight fraction leads to an increase in impact strength due to increase the number of copper particles in unit volume which impede crack propagation, (i.e. increase in the absorb energy). While the impact strength for filler Si are higher than that for pure epoxy and increase with increasing Si percentage in epoxy resin because these particles increase the stiffness of the specimen [13].

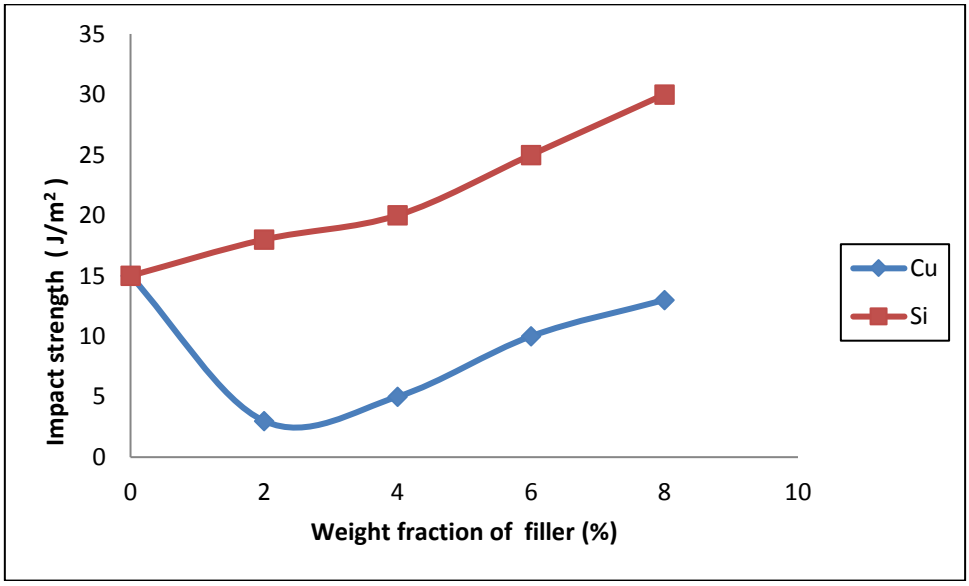

Fig. 2: The effect of Cu and Si weight fraction on impact strength.

4-3-1 Thermal conductivity test results:

By using the thermal coefficient meter device we measured V1 , V2 , ΔV and ΔT and after applied their values in the law we get thermal conductivities for the samples as in the table (4-3) and figure (4-3). Figure (4-3) indicate that the thermal conductivity increase with increasing Cu and Si percentage in epoxy resin because of Cu powder that has high thermal conductivity. The thermal conductivity increment of epoxy/Si composites is expected due to the thermal conductivity for silicon (Si) filler is greater than that for epoxy resin. With the weight content increment of silicon in epoxy resin, the interaction among Si particulates increase and they are more likely to be in contact with one another, leading to easy transmission of thermal energy and subsequent improvement in the thermal conductivity[14].

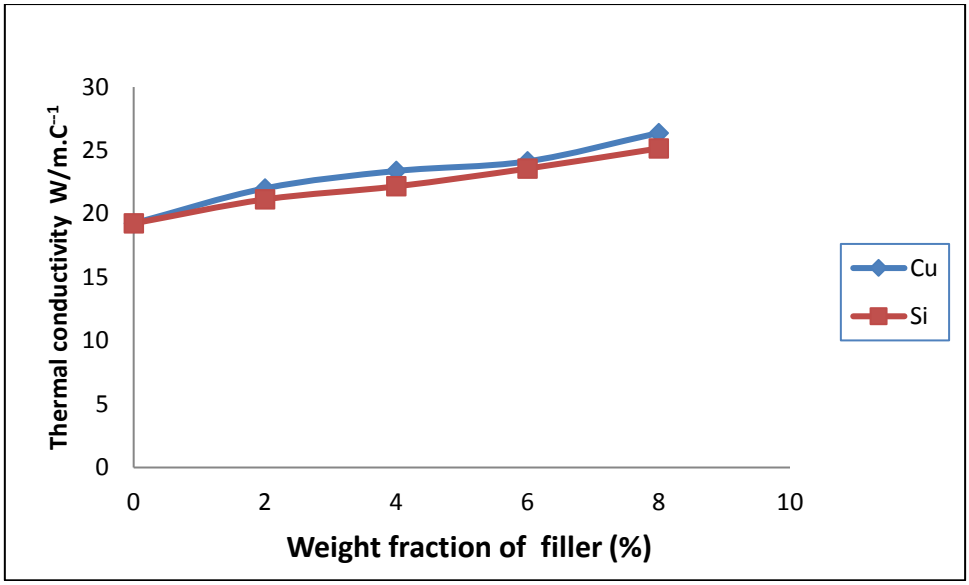

Fig. 3: The effect of Cu and Si weight fraction on thermal conductivity.

4-3-2 Electrical conductivity test results:

keithley electrometer type (616 c) was utilized to calculate the electrical conductivity for composite samples. Figure (4-4) show that the electrical conductivity increase with increasing Cu and Si percentage in epoxy resin due to changes in amount of filler's surface in contact with other fillers in a conductive system called (contact resistance) and in amount of overlapped electron wave function of fillers called (tunneling resistance) . Increment in the amount of filler raises the chances of contact area among the fillers. More contact area means better conduction path for the electrons [15].

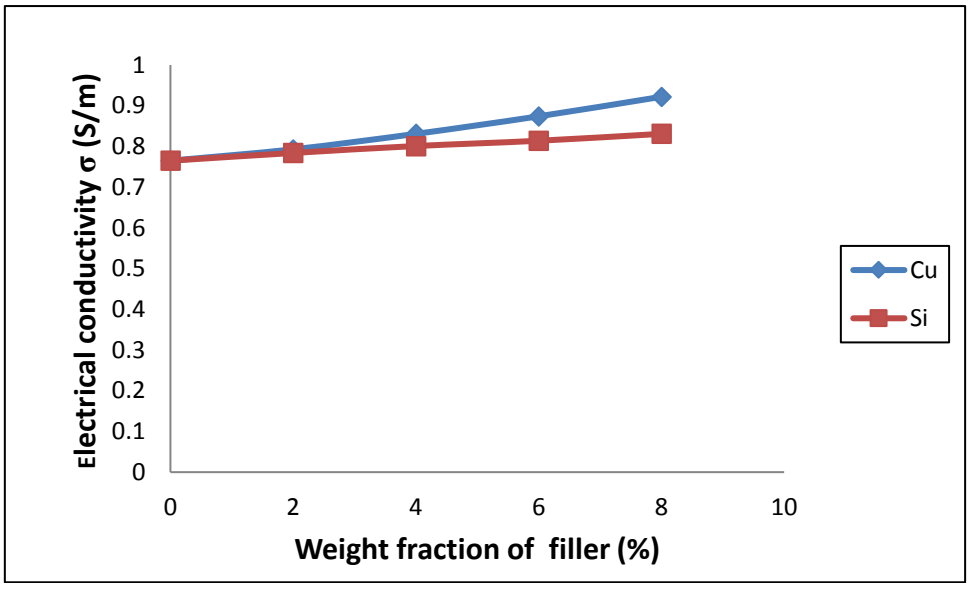

Fig. 4: The effect of Cu and Si weight fraction on electrical conductivity.

Conclusions:

This experimental investigation on mechanical properties (hardness and impact resistance) and thermal properties (thermal conductivity and electrical conductivity) for Cu and Si reinforced epoxy composites led to the specific conclusions:

1- The hardness increment of (Si)reinforced epoxy resin composites with increasing filler content until 4% weight ratio. While the hardness after that decrement for Si filled epoxy resin composites, but showed better results than Cu filled composites. At 4% weight ratio for fillers, hardness tends to increase as compared to pure epoxy resin.

2- Impact strength increase with increasing weight percentage of Cu and Si powder, but Si show better results than Cu filled composites.

3- Incorporation of Cu or Si shows increment the electrical conductivity and thermal conductivity for epoxy resin when addition the weight ratio (8)% of (Cu and Si), the thermal conductivity improves related to pure epoxy resin.

4- These composite for Cu or Si reinforced epoxy resin can be utilized of applications as electronic packages. And from this present work was concluded that the properties of Si filled epoxy resin better than Cu filled epoxy resin in this application.

5- Others fillers can be used to reinforcement epoxy resin such as (Al & Ti) instead of (Si & Cu).

6- Utilized fibers to reinforcement epoxy resin.

7- Carried out other mechanical tests for the same specimen in this research.

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