

PAPER • OPEN ACCESS

The Effects of micro Aluminum fillers In Epoxy resin on the thermal conductivity

To cite this article: Kareem A Jasim and Rihab N Fadhil 2018 *J. Phys.: Conf. Ser.* **1003** 012082

View the [article online](#) for updates and enhancements.

Related content

- [Research on Preparation and Performance of Epoxy Resin-Boron Nitride Thermal-Conductive Composite](#)
Xiangnan Wu, Zhi Wang, Jiuchuan chen et al.
- [Comparative study regarding friction coefficient for three epoxy resins](#)
G MiHu, I Mihalache, I Graur et al.
- [Degradation of strength properties of epoxy resin filled with natural-based particles](#)
Petr Valášek, Karolína Habrová and Miroslav Müller



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

The Effects of micro Aluminum fillers In Epoxy resin on the thermal conductivity

Kareem A Jasim^{*} , Rihab N Fadhil^{}**

Department of Physics, College of Education for pure science, University of Baghdad, Baghdad, Iraq.

*kareem.a.j@ihcoedu.uobaghdad.edu.iq, **rahb_naser@yahoo.com

Abstract. A hand lay-up molding method was used to prepare Epoxy/ Aluminum composites. As a matrix used Epoxy resin (EP) with reinforced by Aluminum particles. The preparation technique includes preparing carousel mold with different weight percentage of fillers (0, 0.05, 0.15, 0.25, 0.35, and 0.45). Standard specimens (in 30 mm diameter) were prepared to the thermal conductivity tests. The result of experimental thermal conductivity (k), for EP/ Aluminum composites show that , k increase with increasing Aluminums percentage and it have maximum values of (1.4595 W/m .K).

Keywords: Epoxy/ Aluminum composites, thermal conductivity, Epoxy resin, Aluminum.

1. Introduction

The defined of composite material as: “A substance consisting of two or more of two materials, insoluble in one another, which are joint to form a useful engineering material possessing certain properties not possessed by the constituents” [1].

Such materials offer advantages over conventional isotropic structural materials such as aluminum, and other sorts of metal .These advantages involve high strength, low weight, and good fatigue strength and corrosion resistance [2].

Polymer composite materials, based on a polymer matrix and inorganic micro particle fillers, have dragged great attention among researchers, due to improvements in different properties including thermal, electrical, optical and mechanical properties [3]. The polymer composite collects the advantages of polymer (e.g., ductility, dielectric, flexibility, and process ability) and the advantages of the filler materials (e.g., hardness and the stability thermal). Epoxy resins are used to generate structural adhesives helpful to large portions requisitions. Epoxy built adhesives will security an extensive variety about substrates includes composites, metals, pottery and elastic. They might be figured should confer heat and compound safety What's more will show hole filling Furthermore different obliged properties. Adhesives in light of Epoxy resins would skilled about accomplishing precise highshear qualities and would utilize extensively clinched alongside structural holding provisions in the air ship industry [4].



2. Thermal conductivity

Thermal conductivity is the capacity of a material to heat conducting. This quantity represents the rate of heat flow per unit time in a homogenous material under steady conditions, per unit area, per unit temperature gradient in a direction perpendicular to area [5]. Polymers are often utilized as thermal insulators because of their low thermal conductivities. For these materials, the transfer of energy is accomplished by the rotation and vibration of the molecules chain [6].

Imply that free bath and the temperature gradient in (equ.1) are because of the random nature of the thermal conductivity procedures into the expression for the thermal flux [7]. The heat transfer method depends upon several factors, consisting of sort of material, temperature and case of the thermal material. Specifically there are two mechanisms for heat transfer through a solid substance [8].

- Free electrons and lattice vibration in solid conductors are the dominant mechanism of temperature transfer.
- The phonons in solid insulator substances are the unique mechanism.

Consistent with the first clear assertion proposed via Fourier, heat flow through a substance is proportional to the temperature gradient, as the following Equation:

$$q = -k \frac{dT}{dx} \quad (1)$$

Where q : the thermal energy flux transmitted across a unit area per unit time. k is the coefficient of thermal conductivity, and (dT/dx) is the gradient of temperature. The unit of q is W/m^2 and the unit of k is $W/m \cdot K$ [9]. Most conveniently in describe term for Thermal conduction is the scattering of phonons, via other phonons, or by using electrons [10].

Through the 'figure 1', the substance S was contained between two copper discs B and C , and the heater between B and a third copper disc A . The temperatures of all the copper discs were measured with a thermometer. When the discs had were assembled they were varnished to give them the same emissivity, and the whole apparatus was suspended in an enclosure of constant temperature. In the theory given below, the following symbols are used [11]:

IV: rate of supply of energy to the heater, after the steady state has been reached.

e : heat loss per second per sq.cm for each 1° increase of discs temperature, over that of enclosure.

T : excess of temperature over that of the enclosure.

d : thickness of disc, r : radius of disc.

The heat received per second by disc A and given up to air is:

$$(\pi r^2 + 2\pi r dA) e TA \quad (2)$$

The heat received per second by S and given up to air from its exposed surface or passed on to A is

$$e TA(\pi r^2 + 2\pi r dA) + 2\pi r ds (1/2)(TA + TB) \quad (3)$$

In terms of IV can be obtained, since the total heat supplied must be equal to that given up by the various surfaces:

$$H = I.V = \pi r^2 e (TA + TB) + 2\pi r e [(1/2) dS (TA + TB) + dATA + dBTB + dCTC] \quad (4)$$

So, thermal conductivity becomes:

$$KT ((TB - TA)/dS) = e [TA + (2/r) (dA + (1/4) dS) TA + (1/2r)dS TB] \quad (5)$$

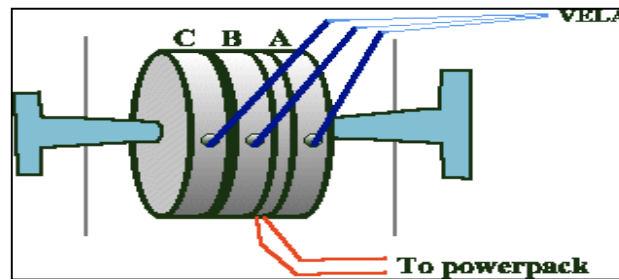


Figure 1: Schematic diagram of Lee's disc.

3. Thermal Conductivity in Composites

So as to attain material with desired thermal, electric, physical, and mechanical residences, polymers combined with different types of fillers are used as matrix materials. The thermal conductivity of composite materials, which can be represented as multiphase substance, depends upon thermal conductivity, proportion, and the distribution of the phase [12]. The distribution of the phase consists of its shape, size, volume fraction, orientation, weight percent, and conductivity relative to the heat flow direction path [8, 10, and 12]. Agari et al. (1990), studied thermal conductivity of a polymer (PS and PS composite), filled with particles (quartz or Al_2O_3) for extensive variety from volume concentration. The results showed that thermal conductivity increased from low to super-high of filler concentration will get materials with wanted thermal, mechanical, electrical and physical properties, polymers mixed with different kinds of fillers (particles or fibers) are used as matrix material. The thermal conductivity of composite materials depends upon proportion, and the distribution of the phase [12]. In 1995 studied Torquato and Rintoul the impact of interface on the characteristic of composite media for metallic particles in epoxy matrices for different volume fraction they developed rigorous bounds on the thermal conductivity effective of dispersion. [6]. Tavaman (2002) studied the thermal conductivity effective of composites filled with particles. His results were compared with experimental data of micro sized Al_2O_3 particles filled with HDPE composites [13].

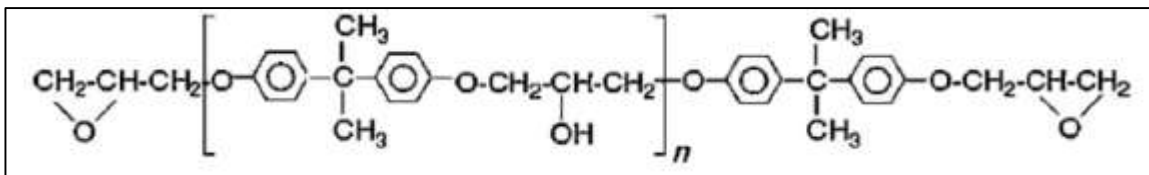
Asmaa, Harith and Ekram (2010), studied The Effect of metals as Additives on Thermal conductivity of Epoxy Resin. They obtained results show increase thermal conductivity with increasing weight percentage for Epoxy/Aluminum and Epoxy/Copper composites. While thermal conductivity for Ep/Fe composite show slight increase [14] Those primary destinations of the research will be with get ready and test tests about particulate composite, which comprises for epoxy resin as a matrix, with metal powder (Aluminum) about different weight percentage (0, 0.05, 0.15, 0.25, 0.35, and 0.45) as fillers. Those Examine expects with examine the impact for filler weight percentage and its sort on the thermal conductivity of the composite.

4. Experimental

For thermal tests, the procedures of preparing EP/Al composites with different additive weight percentage (0, 0.05, 0.15, 0.25, 0.35, and 0.45) percentage) were almost similar. The materials used to prepare the test samples were epoxy resin (EP Euxit 50) production of Swisschem with the hardener (Euxit 50 KII) as a matrix and metal particle Al has average diameter of (7.1228 μm) of purity (99.0) as fillers. (Table 1) summarizes the materials and some of their properties. The chemical structure of epoxy resin is shown in 'figure 2'.

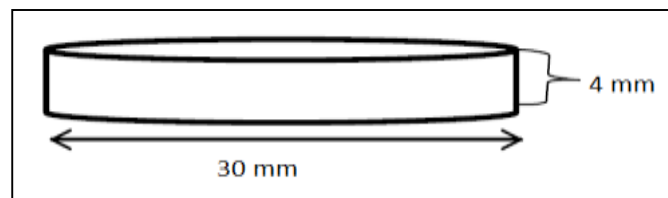
Table1. Some of properties of the used material

Material	Sample	Density (g/cm ³)	Thermal conductivity (W/m. K)
Epoxy	EP	1.05	-----
Aluminum	Al	2.7	247(9)

**Figure 2:** Epoxy structure [15].

A hand lay-up method was used to prepare all the specimens in this work. Samples composed of epoxy resin with Aluminum powder at different weight percentage (0%, 5%, 15%, 25%, 35%, and 45%), and the ratio of Epoxy to hardener is (5:2). To get good homogeneity between epoxy resin and Aluminum powder, homogenizer device at 700 rpm with 10 minutes to have good distribution for particles in epoxy resin. Vacuum system was used to remove the bubble before cast the composites in earlier prepared mold, blend was then poured into the mould, allowed to cure for 24 hours at room temperature (26 ± 2) °C.

Lee's disc was used to calculate the thermal conductivity. the prepared samples have a diameter 30 mm as shown in 'Figure 3' and 'Figure 4', the temperatures were measured by thermometers to calculate Heat current (H) and thermal conductivity (K) were calculated by using 'equation (4) and 'equation (5)' [16]. The experimental values for epoxy (0.671688 W/m. K)

**Figure 3.** Dimension of thermal conductivity Test Specimens.**Figure 4:** Photograph of Thermal conductivity Test Specimens for Epoxy and Epoxy/ Aluminum composites.

5. Results and Discussion

A Scanning Electron Microscope (SEM) with a magnifying force $5\mu\text{m}$ was used to calculate the average diameter partical for Al ($7.1228\mu\text{m}$) as shown in 'figure 5'.

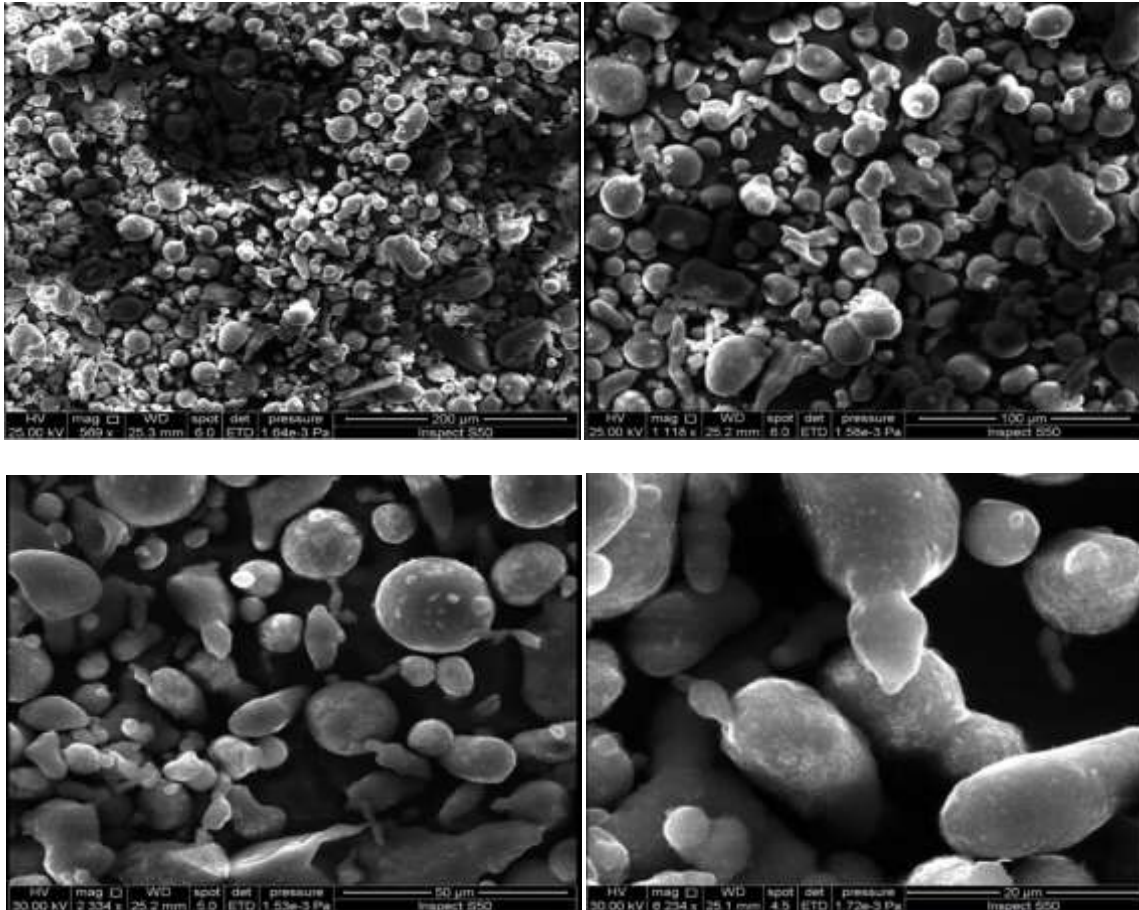


Figure 5. SEM image for Al

The results appear that k values for increase with increasing weight percentage from reinforcement, the maximum value 1.459549 W/m. K at 45% filler weight percentage for EP/Al composite as shown in (table 2). This table includes the type and weight percentage affect thermal conductivity of the composite.

Table 2. Thermal conductivity k for EP/Al composite

Wt%	V%	K (W/m. K)
0%	0	0.671688
5%	2.005731	0.732399
15%	6.422018	0.857353
25%	11.47541	0.976934
35%	17.31449	1.104591
45%	24.13793	1.459549

'Figure 6' shows the obtained results of thermal conductivity for EP/Al composites under study state. It is clear that k for Epoxy/Aluminum composites increase with increasing wt% of filler, this can be due to the well separation of the particles, that there is no interaction between them.

A phonon is a collective excitation in a periodic, elastic arrangement of atoms or molecules in condensed matter, such as solids and some liquids [17].

Aluminum has thermal conductivity and its value (247 W/m. K) [9]. When you add (5%) percentage of Aluminum to epoxy found that there was an increase in thermal conductivity by (0.060711) on thermal conductivity for epoxy.

The reason for this that when you mix epoxy with Al, Aluminum granules will spread in the matrix material at random according to manufacturing process, The presence of these particles plays an important role in the transition process.

When the sample surface bearing its thermal shed will move this energy from the higher temperature zone to the region least heat the heat transfer mechanism in the composite that depend on heat transfer phenomena by phonons and electrons. Upon arrival of a quantity of heat to the polymer chains and molecules made up a bunch of phonons which in turn will travel or absorb by Aluminum granules, transporting energy by electrons to the surrounding area leading to heat transfer from the higher temperature zone to the region least heat. Thermal conductivity for composites increase with increasing wt% of filler, The consequences show that the thermal conductivity increase for all composites .additionally it's affected by the type and weight percentage of additive, this end result is in a good agreement with general theory of the thermal conductivity of composites, which has been predicted that the addition of a second phase with thermal conductivity different than that of the matrix can be effect on the thermal conductivity of the resulting composite [18].

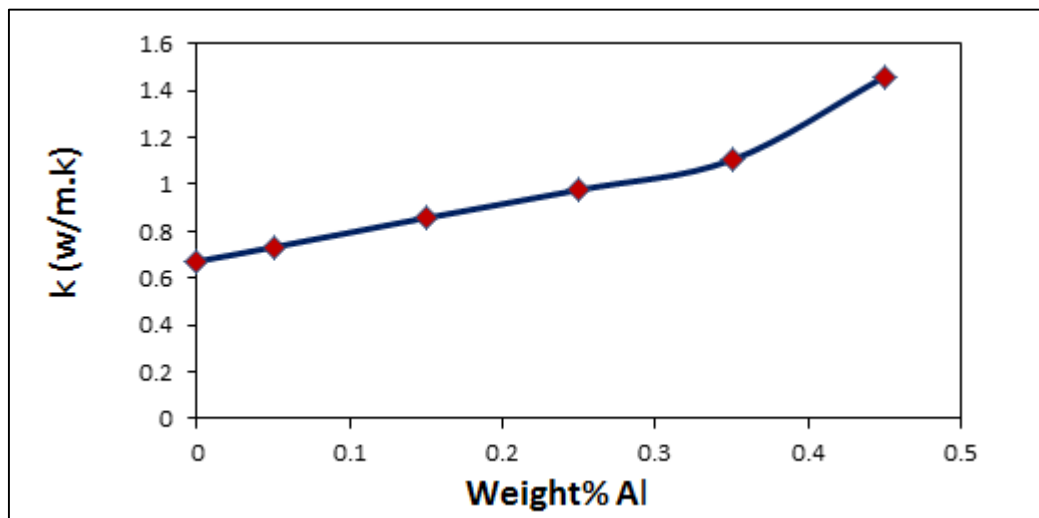


Figure 6. K vs. wt% of EP/ Al composite.

6. Conclusions

Composites were preparation using Epoxy resin as a matrix with metal particles Al which have average diameter (7.1228 μ m) as fillers with different weight percentage of fillers (0, 0.05, 0.15, 0.25, 0.35, and 0.45). Increase thermal conductivity for (EP/Al) composites with increasing addition rates of fillers, where maximum value (1.459549 (W/m. K)) at (45%Al), which increased by (117.3%) compared with epoxy.

References

- [1] William Callister D 2006 Jr *Materials Science and Engineering An Introduction* 7th Edition PP 520-528
- [2] Kullör L P and Spriner 2003 *Mechanics of Composite Structures* (Cambridge University Press Stanford)
- [3] Koo J H 2006 *Polymer Nano composite Processing Characterization and Application* Mc. GrawHill companies USA
- [4] Lubin and George 2013 *Handbook of composites* Springer Science & Business Media
- [5] Harper Charles A 1975 *Handbook of plastics and elastomers*
- [6] Callister W D and David G Rethwisch 2007 *Materials science and engineering an introduction 7* (New York: Wiley)
- [7] P F Intropera and V Dewit 1981 *Fundamental to Heat Transfer* (John Willey and Sons Inc. USA)
- [8] Jaffer H I and Al-Shamri Z R 2002 *Iraqi J. Sci* **43c** 2
- [9] Callister D 2000 *Fundamentals of materials Science and Engineering* Jr August Ch 17 S-254
- [10] Wang W Ga Q and Yan Yang S 2001 *Acta polymerica Sinic a* **1** 1-4
- [11] Kadhim B B 2005 Mechanical and thermal properties and ablation simulation of resole resin composites Ph D Thesis College of Science University of Baghdad.
- [12] Kamoto J O and Ishida H 1999 *J Appl Poly Sci* **72** 1689
- [13] Rondeaus F, Bedy P H and Rey J M 2001 Cryogenic Engineering Conference (John Willy and Sons USA)
- [14] Shawky A H Jafeer and AL Ajaj Ekram 2010 The Effect of metals as Additives on Thermal conductivity of Epoxy Resin *Iraqi Journal of Physics* **8** 12 pp 74 -79
- [15] Jean-Pierre Pascault and Roberto J J Williams 2010 *Epoxy Polymers* (WILEY-VCH Verl GmbH & Co. KGaA, Weinheim)
- [16] Keblinski P and Phillpot S R 2002 *J Heat and Mass Transfer* **45** 4 pp 855-863
- [17] Schwabl Franz 2008 *Advanced Quantum Mechanics* 4th Ed Springer PP 253 ISBN 978 3 540 85062 5.
- [18] Russel L M Johnson L T and Hasselman D P 1987 *J Phys D Appl Phys* **20** 261