Global Journal of Science Frontier Research: B
Chemistry
Volume 14 Issue 6 Version 1.0 Year 2014
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Physical Properties of Polymer Filled with Inorganic (Granite) Filler

By Aseel. A. Kareem
University of Baghdad, Iraq

Abstract- In this study the physical properties such as the thermal conductivity, thermal diffusivity, porosity and density of the epoxy composites were characterized as a function of weight fraction of granite.

According to the test results, addition of granite increases the thermal properties of the composites. This is due to the smaller interfacial thermal barrier at the interface between the particles and the matrix, and the easy pathway among particles, and we can say decrease of apparent porosity and increase in density because of the highest density of granite comparable with density of epoxy.

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GJSFR-B Classification : *FOR Code: 030299*

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I. Introduction

Polymer composites filled with inorganic filler are of interest for many fields of engineering. There is a constant demand for materials engineers to develop better mechanical, thermal and electrical insulation systems that can operate at higher temperatures and greater electrical stress and that can be made for significantly lower cost and higher efficiency[1]. Epoxy composites have been widely used in both the power industry and the microelecronics industry because of their generally superior electrical, mechanical and thermal properties along with their economical and convenient processability. Polymers have low thermal conductivity compared with metal and many inorganic materials, to resist transfer of heat by conduction[2]. The properties of these epoxy/inorganic filler composites depend on the nature of the inorganic filler such as its chemical and physical composition, size, shape and dispersion in the epoxy matrix etc [3].The thermal conductivity of composite materials which are represented as a multiphase substance depends upon the thermal conductivity of each face, the proportion of each phase, and the distribution of the phase [4]. It is well known that the interface in a composite has a significant role in influencingthe properties of electrical insulation materials - especially the thermal conductivity[5]. The random nature of the thermal conductivity process brings the temperature gradient and a mean free bath into the expression for the thermal flux[6]. It is know that the transport of heat in nonmetals occurs by phonons or lattice vibration. The thermal resistance is caused by various types of phonon scattering processes: phonon-phonon scattering, boundary scattering and defect or impurity scattering[7]. in order to maximize the thermal conductivity these phonon scattering process must be minimized. The scattering of phonons in composite materials is mainly due to the interfacial thermal barriers[8].

Thermal conductivity and diffusivity are discussed together because they differ only in that the former is descriptive of equilibrium or steady state conditions and the latter describes non equilibrium or transient conditions. Under steady state conditions, the amount of heat transferred is a function of the temperature difference across the material. For transient conditions, however, the amount of the heat the material can store as internal energy must also be considered [9]. Yet Mehmet dogan study the effect of polymer additives on the physical properties of bitumen based composites the results shows decrease in porosity and thermal conductivity with increase in polymer content [10].

II. Expermentals

a) Experimental Materials

The polymer used in this work is epoxy which is commercial adhesive grade at room temperature curable araldite Euxit50 resin K (Epoxy) supplied by the Egyptian swiss chemical industrials Co., with formulated amine hardener in ratio 3:1 for curing. The epoxy resin is a liquid with low viscosity and transparent in color, the specific gravity of it at 20 °C is 1.05 g/cm3. Granite powder was obtained from a locally available granite industry. Granite's composition shows feldspars and quartz minerals and the particle size of the granite powder ranged from 1 to 100 micrometers, granite has a density of 2.6 g/cm3.

b) Processing of composite

To prepare the composite samples, a mould of size 150×150×1 mm3 was made from glass. Glass silicon was used for joining frames, and then plastic sheet was placed in the bottom of the mould. The composites were prepared with hand lay-up technique. The epoxy/granite composites were prepared with 5, 10,15 and 20 wt. % filler content. The epoxies consist of two parts, resin and hardener which need to be mixed in 3:1 volumes to forms the epoxy polymer. For preparing composite samples, granite powder was first washed thoroughly with water and then dried at 100 ^{o}C for 2-3 h

Author: University of Baghdad. e-mail: aseelalobaedy@yahoo.com

before using it for preparation of composites then a weighted quantity of granite powder was first thoroughly mixed with a measured volume of epoxy resin. Then a half volume of hardener was added and the result mixture was well mixed so as to obtain a uniform. The mixture was poured into the mould. Then it was covered by plastic sheet. The curing time was around 24 hr. at room temperature 23°C. The composite was taken out of the mould in the form of a plate and was cut and machined to produce samples conforming to the thermal conductivity test samples were cut with 85mm of diameter and 1-2 mm of thickness. For thermal test lee,s disc method was used.

III. Mesurements

a) Thermal conductivity

Thermal conductivity is defined as the rate at which heat is transferred by conduction through a unit cross sectional area of material when temperature gradient exists perpendicular to the area. The coefficient of thermal conductivity is expressed as the quantity of heat passes through a unit cube of the substance in a given unit of time when the difference in temperature of the two faces is 1 °C. The quantity of heat flow depends upon the thermal conductivity of the material and upon the distance that the heat must flow. This relationship is expressed as:

$$Q = K/X$$

where Q is the quantity of heat flow, K is the thermal conductivity, X is the distance the heat must flow [11]. Thermal conductivity is also related to the specific heat capacity Cp .This relationship expressed as:

$$\alpha = (k)/(Cp.\ \rho)$$

where α is thermal diffusivity, k is the thermal conductivity, Cp is the heat capacity and ρ is the density[12].

b) Apparent Porosity

Porosity originates from the voids, which are created within the bulk. These pores are of two kinds; open and closed pores. The open or otherwise known as apparent porosity measures the fraction of void volume to the material volume. The open pores are usually interconnected so that they provide passages through which gases can pass [13]. The following procedure was used in determining the porosity. The samples were kept in the oven at 1100C for 3h to obtain constant weight W1. The samples was then suspended in distilled water and boiled on a hot plate for 30 minutes. After boiling while still in hot water, the water was displaced with cold water, the weight W2 was measured on a digital balance hinged on the tripod stand. The test sample was removed from the water and extra water wiped off from the surface by lightly blotting the sample with wet towel and the weight W3 of the soaked sample suspended in air was measured. The apparent porosity of the sample was determined from the relationship [13].

$$Pa = (W3-W1)/(W3-W2) \times 100\%$$

Where;

Pa = apparent porosity

W1 = Weight of the sample

W2 = Weight in cold water.

W3 = Weight in air

c) Density

The density of the respective samples was determined basically by measuring the mass and the volume by using the beam balance and the measuring cylinder respectively. It is then estimated from the formula given below [14].

Density (g/cm3) = (Mass (gm))/(Volume (c m3))

IV. Results and Discussions

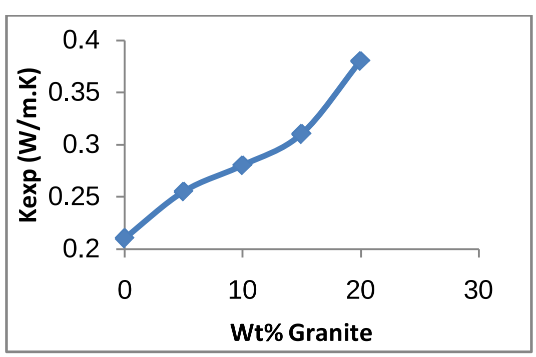

Figure1 : The variation of thermal conductivity Kexp (W/m. K) as a function of granite content

Figure (1) shows that the thermal conductivity increase slightly with increase filler weight fraction .This can be explained because of precipitation of filler particle, which lead to make two layers with more homogenous in distribution, make homogenous media for flowing heat, which make little defect in the material structure lead to gain in energy, and the interface between the matrix and the reinforcement materials was making new path way for heat flow this behavior agree with the obtained results in reference[15].

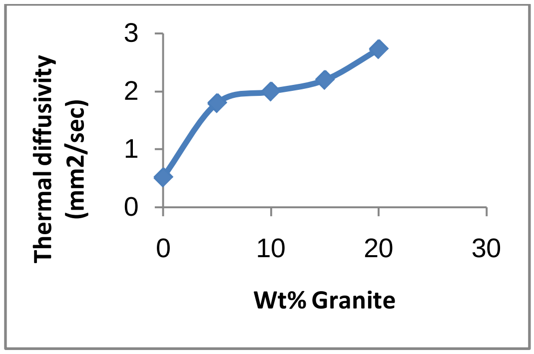

Figure 2 : The variation of thermal diffusivity as a function of granite content

Fig (2) shows that the thermal diffusivity increased with granite content. The increase in granite content cause that the interfacial thermal barriers in composites increase that leads to decrease the phonon scattering and decrease the thermal resistivity that leads to increase the thermal diffusivity This behavior is agreement with[16].

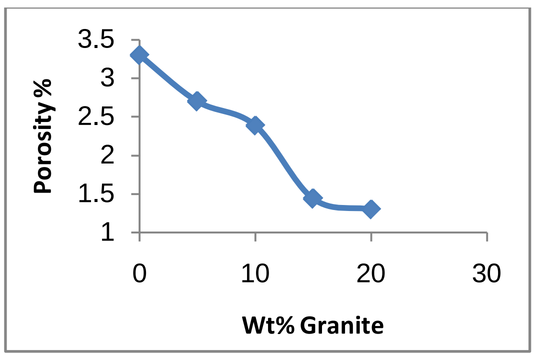

Figure 3 : The variation of apparent porosity as a function of granite content

Voids and air bubbles are a problem in composites. the apparent porosity measures the fraction of void volume to the material volume.

The calculations of porosity give approximate values for void formation during composite preparation. In any case during compression molding of the composites, despite measures taken to reduce air entrapment a small amount of air does get entrapped in the structure.

That reduce void formation leads to decrease the apparent porosity [14, 17].

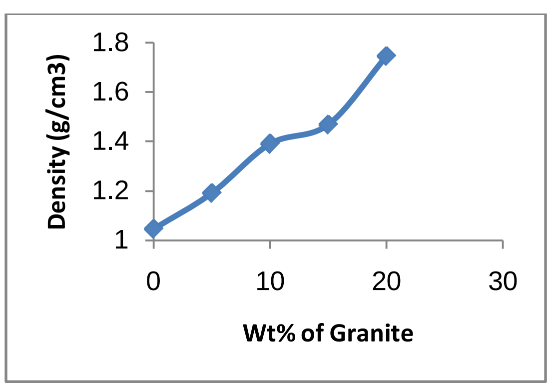

Figure 4 : The variation of density as a function of granite content

Fig (4) shows that the density increase with granite contents this increase in itare normally with the highest density of granite (2.6 gm/cm3) comparable with

Their low density means that they contain fewer atoms per unit volume[17]

V. Conclusions

1. Thermal conductivity and thermal diffusivity increase with increase of granite weight. This is due to the smaller interfacial thermal barrier at the interface between the particles and the matrix, and the easy pathway among particles.
2. The apparent porosity decrease with increase granite content because of low voids became.
3. The density increase with granite contents this increase in it is normally with the highest density of granite comparable with density of epoxy.

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