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The effect of TiO_2 addition on the thermal conductivity of Polymethylmetha acrylate, Polycarbonate and Polystyrene Polymers

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Abstract

Thermal conductivity measurement was done for specimens of Polystyrene/ titanium dioxide, Polycarbonate/ titanium dioxide and Polymethylmetha acrylate/ titanium dioxide composites for weight ratio of 1.9/ 0.1 and 1.8/ 0.2 wt% for different thickness of the samples. The experimental results show that the thermal conductivity is increased with the increasing of thickness of layers and with the weight ratio of TiO_2.

Keywords
Titanium dioxide
Thermal conductivity

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تأثير اضافة اوكسيد التيتانيوم على التوصيلية الحرارية لبوليمرات البولي مثيل ميثا اكريليت, البولي كاربونيت و البولي ستايرين

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الخلاصة:

تم في هذا البحث دراسة التوصيلية الحرارية لعينات من متراكبات البولي ستايرين / ثاني اوكسيد التيتانيوم, البولي كاربونيت / ثاني اوكسيد التيتانيوم و البولي مثيل ميثا اكريليت / ثاني اوكسيد التيتانيوم وبنسب وزنية 1.9/0.1و 1.8/0.2من ثاني اوكسيد التيتانيوم .تشير النتائج الى ان التوصيلية الحرارية تزداد بزيادة كل من سمك طبقة المتراكب ونسبة تركيز ثاني اوكسيد التيتانيوم .

Introduction

Polymers belong to the substances which are poor conductors of heat, their coefficient of heat transfer not generally exceeding (0.5 W/m.k.), and in the case orientated samples, (10 W/m.k.). The description of heat transfer in polymers requires different theories depending on whether the polymer is amorphous, or with percent degree of crystallinity and on the range of temperature studied. In the interpretation of the relationship between the coefficient of heat transfer of the crystalline phase and temperature use, is made of phononic theory of heat transfer in a crystalline phase. Description of heat transfer in the amorphous phase uses the theory of solid bodies, taking into account the vibration of combined structural elements and phenomenon of phonon scattering, or the phenomenon of heat transfer by chemical bonds. The first of these is used of low temperatures, where the wavelength of the vibrations is much lower than the distances between the structural elements; the second is used at higher temperatures[1].

The enhancement of thermal conductivity in polymers can be achieved by blending thermally conductive fillers into the polymers at high loading. The thermal conductivity improvement is largely related to the volume fraction of filler and its thermal conductivity. The type of thermally conducting filler, including its size, shape and dispersion, determines the thermal conductivity of the mixture [2].

Thermal conductivity systems containing high volume fractions of particles are "attached" systems in which particles interact with each other and affect the position of particles in composite. Therefore, it is considered that the powdery properties of particles (the ease of forming an aggregate of particles, limit of packing, etc.) greatly affect the thermal conductivity of the composite [3].

We understand by heat conduction in solids the heat flow from hotter regions of a solid to colder regions, as a result of which the temperatures become stabilized. Let us consider a long thin rod. Suppose that the temperatures at the ends of this rod are T_1 and T_2, and the length of the rod is x; then a temperature gradient develops in the rod which results in the appearance of a heat flow along the rod. The basic law of thermal conductivity is Fourier's law [4]:

$$q = -x \text{ grad } T \text{ --------------- (1)}$$

Where q is the hear flux density vector (which is numerically equal to the energy transferred through the cross-section area of the specimen per unit time); and x is the thermal conductivity, usually in W/m.k.

Heat conduction is an energy-transfer process. Like other energy-transfer processes, heat conduction is relaxational by its nature. Indeed, if the temperature in an element of a solid is changed in some way, the presence of a temperature gradient will lead to the generation of a heat flux which will exist until the temperature gradient becomes equal to zero as a result of the transfer of energy from sites with a higher temperature to lower temperature. If a constant temperature gradient is maintained artificially, a stationary, or steady-state, heat flux, constant in time, will develop in the solid [1].

Experimental part:

Materials:

Three polymers were used polystyrene, polycarbonate and polymethy methacrylate polymers.

Fillers:

The material used as fillers throughout this study is Titanium dioxide (TiO_2), with thermal conductivity (8.7864 W/m.k), density (4250 Kg/m^3) [5] and purity (99.999%).

Samples preparation:

Hand lay-up technique was used to make homogenized polymers. A weight amount of the polymer was then mixed with TiO2 powder in different percentages (1.9/0.1) , (1.8/0.2)wt%. To obtain 2gm of the total weight for polymers and filler until homogenized mixture attained. The prepared samples were left at room temperature for 24 hours.

The samples were disc like shape of a diameter about 30mm and thickness of exactly (0.2 mm).

Results and discussion:

Figures (1) and (2) show the effect of different TiO_2 wt% contents on thermal conductivity of polymers $-TiO_2$ composites. it can be seen that the thermal conductivity increased with increasing TiO_2 wt % contents.

For a low ratio of the filler is resided as taken the sample, in this work called "dispersed system" where the heat transfer at low filler content is almost belonging to the polymer matrix due to transfer of energy between monomers via chemical bounds (primary & secondary). These bounds were affected by present of fillers [6].

Another explanation is based on solid state theory deals with the cooperative motion of monomers and the phenomenon a of phonon scattering which limit the region of energies of transfer [7]. According to this theory, the modification may cause reduction in molecular mobility at considerable distance from the filler surface. Since the ends of many chains segments are firmly anchored at the filler surface. The reduced molecular mobility in the boundary layers will influence the intermolecular vibrations. So, the thermal conductivity is increased [8]. In addition, other types of mechanisms, especially radiation, contribute the heat transfer. At high filler concentration, the conduction is the main mechanism of heat transfer as indicated by other researchers [5, 7, 8 and 9].

From figures (1) and (2), it can be observed that the thermal conductivity is increasing with increase the number of layers because the heat flux passing through layers of the medium having non-homogeneous elastic properties in the elastic monochromatic.

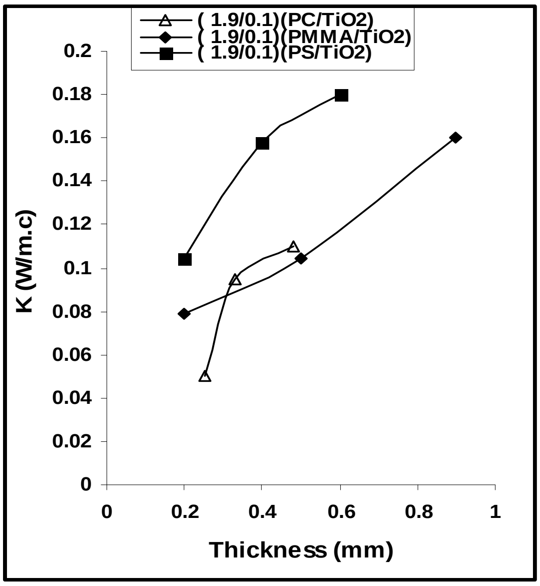

Fig.1: The relation between the thickness of the samples and thermal conductivity for the ratio (1. 9/0.1)

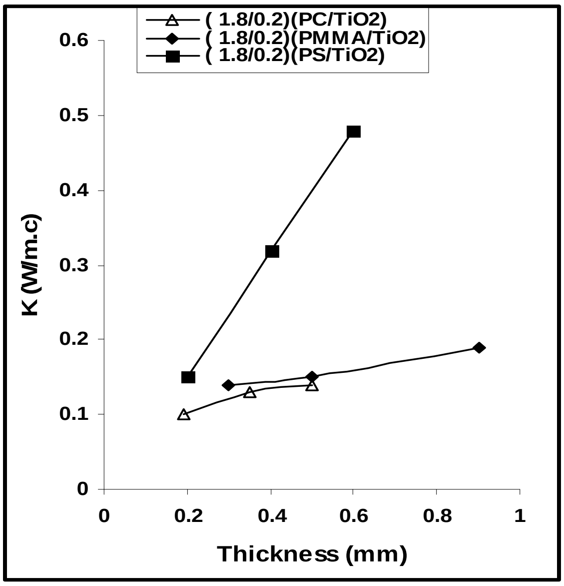

Fig.2: The relation between the thickness of the samples and thermal conductivity for the ratio (1. 8/0.2)

For (1.9/0.1) of (polymer/TiO_2) percentage ratio, the thermal conductivity is increased with the increasing in the no. of layers, the increasing in the thermal conductivity for composites is caused by an increase in the adhesion between the components in the filled polymer produces a decrease in the heat resistance at the component boundaries and an increase in the coefficient of heat transfer of the composites.

The increasing of the weight ratio for TiO_2 i.e.(1.8/0.2) (polymer/TiO_2) increases the thermal conductivity higher than the case of (1.9/0.1), because the highly conductive filler required to a achieve high thermal dissipation and the presence of some crystallinity in specimens enhances the thermal conductivity [8,9].

Conclusion:

The thermal conductivity for (1.8/0.2) is higher than (1.9/0.1) of (polymer/TiO_2). The increasing in the weight ratio of TiO_2 increase the thermal conductivity for polymers, this is attributed to the attached system and separated system. Polycarbonate/TiO_2 is the best heat insulator compared with other used polymers.

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