Study of the Thermal Properties for Polymer Matrix Composite Reinforced by Toner Carbon Nanoparticles (TCNP)

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ABSTRACT

This work focuson study thermal conductivity for polymers and their nano-composites usingtoner carbonnano-particles(TCNP)with particles sizeof (89.77nm) asanano-particles, with different weight percentages(2, 4 and6) % to unsaturated polyester (UPE) and epoxy (EP) resins as a matrix to prepare nano-compsites. Molding method was used to prepare polymers and their nano-composites sheets.

The results show (UPE) has highest value than(EP). Adding nano-particle to (UPE) and (EP) will increase thermal conductivity for nano-composites. The values of thermal conductivity for two types of resins UPE and EP without any additions are (0.181W/m.^{o}c and 0.154W/m.^{o}c) respectively. At the weight fraction(2%) the value for (UPE/TCNP) samples is (0.355W/m.^{o}c),while the value for EP/TCNP samples is (0.405W/m.^{o}c), and the values of the thermal conductivity begin increasing with the increasing ofthe weight fraction which used in this research, were the highest value for (EP/TCNP) samples is (0.429W/m.^{o}c)at weight fraction(6%).

Keywords: -Thermal Conductive,Toner Carbon Nano particles,Unsaturated Polyester Resin, Epoxy Resin andNanoComposites.

دراسة الخواص الحرارية لمادة متراكبة ذات اساس بوليمري مدعمة بدقائق احبار الكاربون النانوية

الخلاصة

هذا البحث يركز على دراسة معامل التوصيل الحراريللبوليمرات ومتراكباتها باستخدام دقائق احبار الكاربون النانوية و بحجم حبيبي (89.77 nm)وبكسور وزنية مختلفة%(2,4 and 6) الى راتنجات البولي استر والايبوكسي كمادة رابطة لتحضير متراكبات نانوية. استخدمت طريقة القولبة اليدوية في تحضير عينات البوليمرات وعينات المواد المتراكبة النانوية. اظهرت النتائج ان قيم التوصيل الحراري لراتنج البولي استر اعلى من قيم راتنجالايبوكسي. عند اضافة هذه الدقائق الى راتنجات البولي استر والايبوكسي سوف تزداد قيم التوصيل الحراري للمتراكبات النانوية. قيمة معامل التوصيل الحراري لراتنجات البولي استر والايبوكسي النقية كانت (0.181W/m.^{o}c, 0.154W/m.^{o}c) على التوالي. عند نسبة الاضافة (2%) كانت قيمة معامل التوصيل الحراري(0.355 W/m.^{o}c)لعينات متراكبات البولي استر و(0.405W /m.^{o}c) لعينات متراكبات الايبوكسي. استمرت الزيادة في قيمة معامل التوصيل الحراري للمتراكبات مع زيادة نسبة الاضافة للدقائق وكانت اعلى قيمة لعينات متراكب الايبوكسي هي (0.429W /m^{o}c) عند نسبة الاضافة (6%).

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INTRODUCTION

Recently, nanotechnology has gained much attention to develop materials with unique properties. Nanotechnology can be broadly defined as: the creation, processing, characterization and use of materials, devices and systems with dimensions on the order of (0.1-100) nm, exhibiting novel or significantly enhanced physical, chemical, biological properties, functions, phenomena, and processes due to their nanoscalesize. Nanocomposites, i.e. composites containing dispersed particles is in the nanometer range, are a significant part of nanotechnology and one of the fastest growing areas in materials science and engineering.

Polymer based nanocomposites can be obtained by the addition ofnanoscale particles which are classified into three categories depending on their dimensions: nanoparticles, nanotubes and nanolayers. The interest in applying nanoscaled fillers into polymer matrices is the attainment of potentially unique properties by use of the nanoscopic dimensions and inherent extreme aspect ratios of the nanofillers [1].

Heat transfer involves the transport of energy from one place to another by energy carriers. In gas phase, gas molecules carry energy either by random molecular motion (diffusion) or by an overall drift of the molecules in a certain direction (advection). In liquids, energy can be transported by diffusion and advection of molecules. In solids, energy is transported by phonons, electrons or photons. Phonons, quantized modes of vibration occurring in a rigid crystal lattice, are the primary mechanism of heat conduction in most polymers since free movement of electrons is not possible [2].

The heat transfer through material achieved by impaction operation between molecules or atoms which formed the material, these phenomena is known as thermal conductivity. When direct touching of bodies. According to this will transfer from hot side to cold side through material boundaries which isolated both sides. Thus chemical construction of molecules & atoms act as an important rule to achieve heat transfer or isolating [3].

Due to the fact that most polymers exhibit low thermal conductivity, it is of interest to obtain an improvement for some applications. For example, when used as heat sinks in electric or electronic systems, composites with a thermal conductivity approximately from 1 to 30 W/m·K are required. Thermal conductivity of polymers has been traditionally enhanced by the addition of thermally conductive fillers, including graphite, carbon black, carbon fibers, ceramic or metal particles [4].

Polymer nanocomposites have attracted alot of attention in the last few years due to theirenhanced properties at low weight fraction of filler.Carbon nanomaterials are particularly interesting; asconductive fillers they allow the enhancement ofmultiple properties including mechanical, electricaland thermal properties [5].

Conductive polymer composites are used in a widevariety of industrial application such as battery, fuelcell electrodes and corrosion-resistantmaterials. Consider, for example, the utility of carbon black particles, which have been routinely added to polymers over the past quarter, century formain purpose: improved electrical conductivity and mechanical properties [6].

The advantage of nanocarbon was meant largeindustries in tires, cars, printing, pencils, laptops, computers, printers, photocopiers and laboratorytables[7].

The present work focuses on the thermal properties of carbonnanofilledpolymer (epoxy resin and polyester resin) composites.

The aim of this work is to:-

1. Fabrication of (UPE /TCNP, EP/TCNP)nanocomposites.
2. Evaluation of thermal properties of the nanocomposites.
3. Preparing of polymeric composites by mixing the resin with different percentages of tonercarbon nanoparticles so as to increase their thermal conductive.

Materials and Methods:

(A) Raw Materials

The materials used to prepare the nanocomposites are unsaturated polyester (UPE) resintype (A-50) with the hardener MEKP and with acceleratorcobalt naphthenate(having a symbol SIR SIROPOL) which was supplied from Saudi industrial resin,Epoxy resin (type Conbextra EP10) was used in this research; it is a liquid with moderate viscosity and capable to be converted to solid state by adding the solution (MetaphenyleneDiamine, MPDA) as hardener. This hardener is a light liquid with yellowish color, the ratio of this hardener to the epoxy is about (1:3)andtoner carbon nanoparticales(TCNP) with particle size of (89.77 nm) was used in this work as a filler materialas in fig.(1) and fig.(2). The compositions of this material are stated in the table (1).

(B) Cast Mould

The cast mould used for casting the polymeric specimens and composites

1. Glass plates of dimensions (300 ×300 ×6)mm were used as a mould stages.
2. Glass strips of dimensions (200 × 20 × 6) mm were used as boundaries for the cast mould.

Before casting, a glass plates were cleaned with water and soapsolution, after drying in oven, one base of the glass plates was coated with wax, then glass strips were fixed on glass plates and left for one hours todry at room temperature**.**

(C) Composites Preparation

Thenanocomposites were prepared from unsaturated polyester resin (as a matrix) and carbon nanoparticles (as aparticles fillers) with different weight percentages of (2,4 and 6)% , Epoxy resin (as a matrix) and carbon nanoparticles (as aparticles fillers) with different weight percentages of (2,4 and 6)% by molding method which can be summarized by thefollowing steps:

1. Determine the weight of carbon nanoparticles by using a sensitive balance (four digits).
2. Weight of hardener and accelerator were calculated proportional to weight of resin and added to it .
3. Mix the content thoroughly in a clean disposable container by a fan type stirrerbefore casting it as sheets of dimensions (200× 120 ×6) mm by using glass mould.
4. Leave the nanocomposite at room temperature about 24 hours and then for post-curing, the sheets were left for (2 hours) in an oven at temperature (60˚C).
5. The steps (1 to 4) were repeated simultaneously according to number of used resins .

(D) Thermal conductivity sample cutting

The sheets of the nanocomposites are cutting into specimens, by using a circular iron saw, pluses from the samples were removed by using the iron rasp, the samples were polished by using abrasive emery papers of grade (400). The shape and dimension of the samples cut for thermal conductive test shown at figure (3) and figure (4).

Thermal Conductivity Calculations

Lee's disc instrument showed in figure (5), manufactured by the Griffen and George Company, was used to calculate the thermal conductivity of the samples under test. The figure belowshows this instrument which consists of three discs of brass (40 diameter by 12.25 thickness) mm and a heater. The sample (S) is placed between the discs (A) and (B), while the heater is placed between (B) and (C). Heater was supplied with voltage (6 volt) and the current value through the apparatus was about (0.25A). The heat transfers from the heater to the near two discs then to the third disc across the sample. The temperature of the three discs (T_A, T_B, and T_C) is measured by using a thermometers placed inside them. After reaching thermal equilibrium, the temperatures were recorded.
The value of thermal conductivity is determined by using the following equation [8]:

$$k\left[\frac{T_B - T_A}{d_S}\right] = e\left[T_A + \frac{2}{r}(dA + \frac{1}{4}d_S)T_A + \frac{1}{2r}d_S T_B\right] \quad \ldots\ldots (1)$$

Where:

K: The thermal conductivity coefficient (W/m. °C).

T_A, T_B, & T_C: Temperature of the metal discs (A, B & C) respectively (°C).

d_A, d_B&d_C: Thickness of the discs (A, B & C) respectively (mm).

d_S: Sample's thickness (mm).

r: disc's radius (mm).

e: The quantity of heat flowing through the cross sectional area of the specimen per unit time (W/m^2. °C) is calculated from the following equation [8]:

$$IV = \pi r^2 (T_A+T_B) + 2\pi re\, [d_A T_A + d_S (1/2) (T_A+T_B) + d_B T_B + d_C T_C] \quad \ldots. (2)$$

Where:

I= Current through the heater (Ampere)

V= Applied voltage (Volt)

Results and Discussion:

The results of this test are shown in fig. (6) and fig. (7), which show the effect of (TCNP) content on the thermal conductivity values of the prepared composites.

Table (2) gives the values for thermal conductivity. It was found that (UPE) has highest value from (EP) because of the structure for chains and the density of crosslink bonds. When the molecules vibration due to thermal heating, the phonon will generated so that, if the chains have degree of freedom to vibrate more phonons will transfer and the thermal conductivity will increase.

Adding toner carbon nano-particles will increase thermal conductivity for nano composites, this due to the composition for toner which has iron so that electron will transfer the thermal energy.

Increase the percentage weight for nano particles will change values of thermal conductivity. This due to distribution and homogeneity of particles which effect on the scatter electrons and phonons.

Conclusion:

Nanotechnology is expected to offer technological advantages in various important areas, such as production, processing, storage, transportation, safety and security. This experimental investigation of thermal conductive of toner carbon nanoparticles as a fillers filled polyester, epoxy nanocomposites leads to the following conclusions:

- The polyester resin and epoxy resin are good adhesive materials which can use as a matrix with toner carbon nanoparticles.
- The above experimental results indicate that these toner carbon nanoparticlesmay be a good filler material forpolymer nanocomposite materials.
- Toner carbon polymer-based as nanocomposites have a great deal of future promise for potential applications as high-performance materials.
- From the experimental results itwas concluded that the high thermal conductivity possessed by the toner carbon nanoparticles and their good dispersion ability contributed to the significant improvement in the effective thermal conductivity.

Table (1): Chemical composition forToner carbon nanoparticales(TCNP).

Components	Weight%
C	75.2
Fe	19.72
Mn	0.061
Cu	0.0001

Figure. (1) Photograph shows Toner carbon nanoparticales(TCNP)

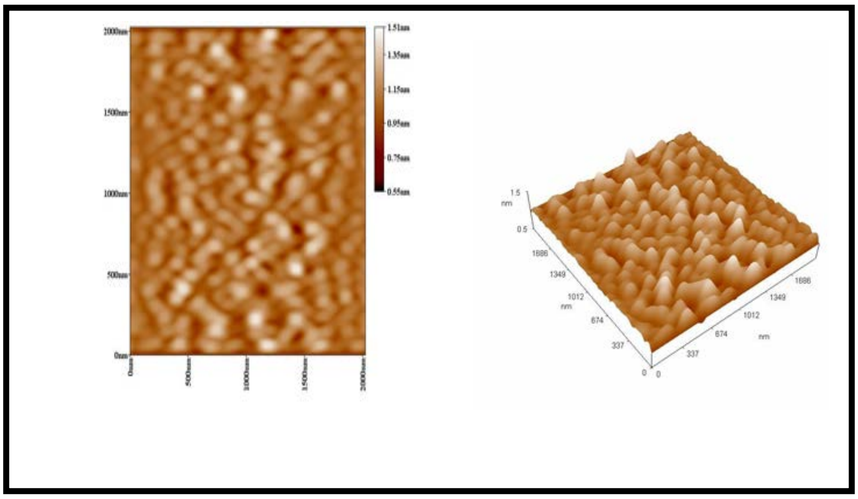

Figure. (2) CSPM Imager Surface Roughness Analysis ofToner carbon nanoparticales(TCNP)

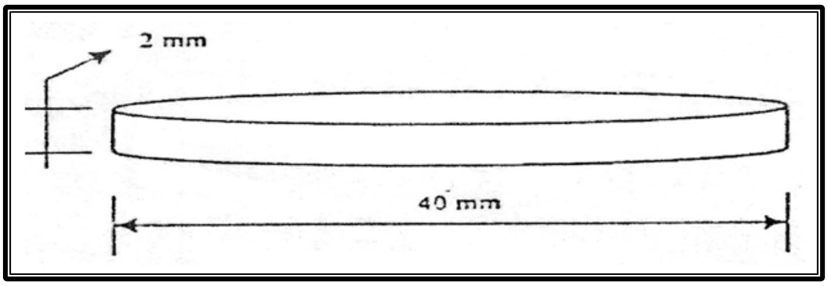

Figure. (3): Dimensions of Thermal Conductive Test Specimens.

(a) (b)

Figure (4): Photograph of thermal conductive test specimens before testing.
(a) Pure polyester and TCNP/polyesternanocompositessamples.
(b) Pureepoxyand TCNP/epoxynanocompositessamples.

Figure (5): Thermal Conductivity Test Instrument

Table(2): The effect of Toner Carbon content (wt. %) on the Thermal Conductive of (UPE/ TCNP and EP/ TCNP) nanocomposites.

Composition	Thermal ConductiveW/m.c°			
	Toner Carbon nanoparticles content (wt. %)			
	0%	2%	4%	6%
UPE/TCNP	0.181	0.355	0.198	0.207
EP/TCNP	0.154	0.405	0.316	0.429

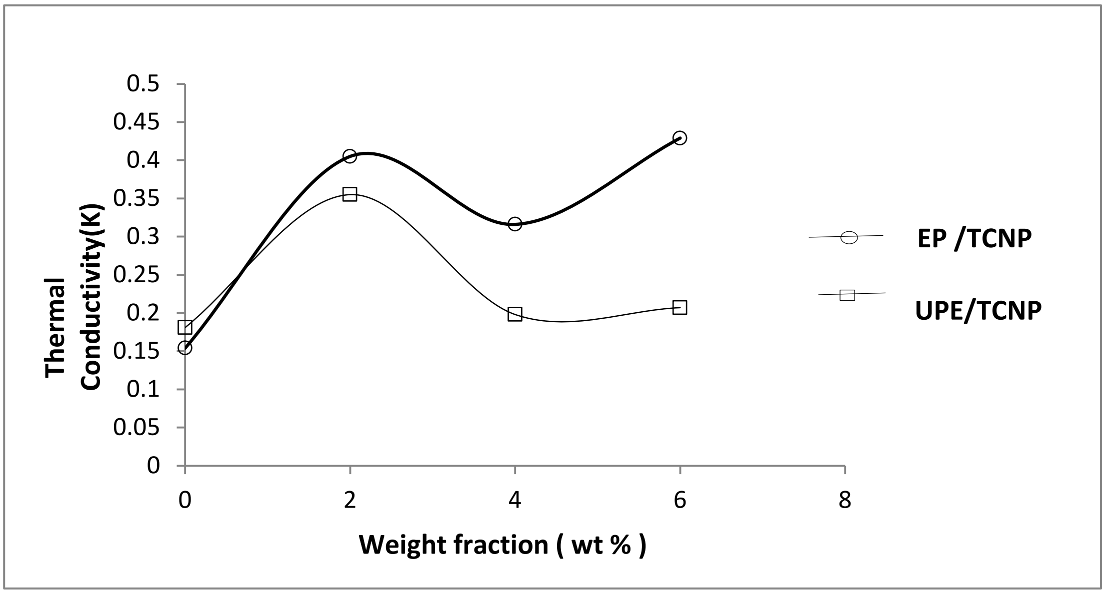

Figure. (6): Thermal Conductivity variation with (TCNP)content in (UPE, EP)resins.

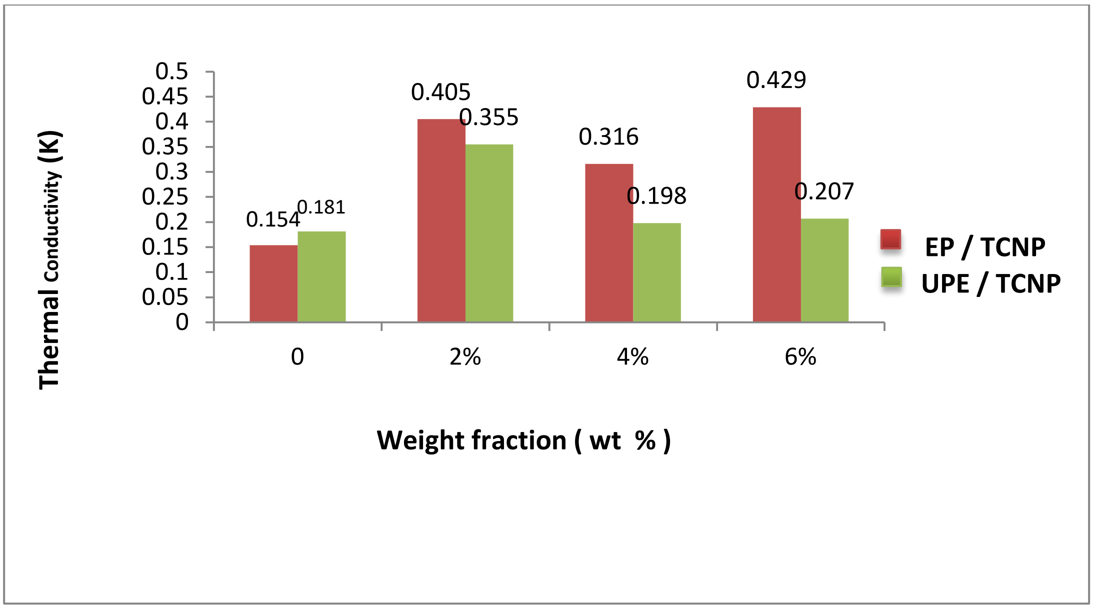

Figure. (7): Thermal Conductivity variation with (TCNP) content in (UPE, EP) resins.

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