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Heat Transfer Properties of PMMA / $MgTiO_3$ Nanocomposites

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Abstract: ***In this research, thermal analysis properties (Heat Transfer Coefficient) have been studied for PMMA- polymer, reinforced with [n-$MgTiO_3$]$_x$ where x is (0wt%, 1wt%, 2wt%, , 3wt%, 4wt% and 5wt%). Ultrasonic dispersion technique used to prepare the Nanocomposites specimens follow with cold casting technique using flash Teflon molds standard conditions. C-Therm-Sensor (TC i) Technique was used to measure heat transfer such as; (Thermal conductivity, Thermal effusivity, Thermal diffusion and Heat capacity). Results show that values of conductivity, effusively and diffusion increase by succession of weight percentage of fillers. While a Heat capacity results show that values decreases progressively by succession of weight percentage of fillers. Scanning electron microscopy used was employed to aid interpretation results of thermal analyzer and distribution Nano- powder in base polymer matrix.***

Keyword: PMMA, C-Therm TC i Sensor, Thermal effusivity and Nanocomposites

1. Introduction

Polymer nanocomposites are defined as mixing two or more substances to form three phases. The first phase is called the base. It is the base of the bond. The second phase is called the reinforcement. It is in a variety of forms including granule, fibers, plates, wires or nanotubes. These phases are either in the micro or nano- meter. The third phase is called the interfaces, which is very important, i.e., the greater the distance between the base material and the reinforcement, the smaller the overlapping the composite more durability and hardness, non-defect [1].The polymers in general are characterized by their light weight, ease of formation and low melting point and are of different types, including branches, liner and network, , all of them have large molecular chains so it is advisable to use in the formation of the complexities of the strength of its link to supporting materials (reinforcing materials)[2]. In the absence of a strong bond between the base material of the polymer and the supporting material of various additions, defects and distortions occur in the resulting composites due to the weakness of the interstitial and increasing [3 ,4]. The properties of thermal and electrical materials come through several factors, including the abundance of transport charges, crystalline arrangement, high density, the material's ability to react strongly as well as the nature of the material that is insulating or conductive or semi-conductive. Therefore, polymers are considered as insulating and poor materials for transport charges. This has a low thermal conductivity ranging from 0.2 - 0.8 (W/m.K).This low thermal conductivity comes via motion or the phononic vibration resulting from the acoustic part as well as from the characteristic vibrations resulting from the optical part of the movement or the pulse of the polymer side chains at temperatures above 100 ° C[5]. The importance of studying the thermal properties of conductivity, diffusion, flow, thermal capacity, thermal resistance of the behavior of polymer-based industrial dental materials is essential in determining their performance and their suitability to withstand different temperatures (extreme heat and cold)[6].

We mentioned earlier that polymers have low thermal properties. When using these materials, we must improve the heat exchange between them and the outer environment (mouth). Therefore, they are reinforced and improved by reinforcing them with ceramic or metal materials that can withstand different temperatures such as (SiO_2, ZnO, TiO_2, Al_2O_3, CaO, ZrO_2)[7]. Insulation materials have a high thermal storage capacity due to low thermal conductivity, low dispersion and dissipation. Therefore, the reinforced materials that have high conductivity properties and low thermal capacity are adopted to maintain the thermal balance and not to damage the polymer materials [8]. Polymer-based nanocomposites with thermal properties suitable for thermal conductivity applications can be developed by improving and ordering molecular chains to obtain crystalline-like structures Sonam Grawal in (2011)[9]., The thermodynamic flow method was used to measure the thermal conductivity of the insulating materials by reinforcing the epoxy of titanium dioxide to improve thermal conductivity[10]. Khalid et al in (2007) used Ultrasonic technology for the distribution of n-TiO_2 powder with a weight of (1-5) wt% in the acrylic matrix PMMA. It obtained the best distribution at low rates to improve thermal properties used in dental applications [11]. Lieutenant and *et.al* in (2013), The biochemistry system ($SiTiO_4$) was studied in the reinforcement of the acrylic (PMMA) used to improve the mechanical and thermal properties and heat transfer as well as stability in different temperatures [12].

2. Theoretical Part

The thermal conductivity of polymer nanocomposite is not significantly high [13]. Thermal conductivity can be calculated:

$$\frac{dH}{dt} = K.A.\frac{dT}{dX} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where:
H = Heat (J)
t = Time (sec)
K = Thermal Conductivity (W/K. m)

T = Temperature (K)
x = Height of test specimen (m)
A = Cross sectional area of test specimen (m^2)
The heat capacity C is expressed as follows:

$$C = \frac{dQ}{dT} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

The thermal diffusion equation (mm^2/ s) [14]:

$$Ɗ = K\,\frac{1}{c.\rho} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

The Eiffuisivity measured by ($Ws^{½}$ / m^2. k) is [15]:

$$\Sigma = (K.C.\rho)½ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

3. Experimental and Materials Used

The bio-ceramic powder was prepared from Mixtures of MgO and TiO_2 powders at a molar ratio MgO:TiO_2 = 2:1 were mechanically activated in a high energy planetary ball mill. The milling process of MT system was performed in air for 120 minutes. Ball to powder mixture mass ratio was 20:1. Samples were denoted as MT-120 according to the milling time. The binder-free powders were compacted in an 8 mm diameter tool under 392 MPa pressure. Compacts were placed in an alumna boat and heated in a tube furnace. MT compact was sintered isothermally at 1000 ^{0}Cto 1300 ^{0}C for 2h. The heating rate was 10 ^{0}C/min. The morphology of obtained powders before and after heating was characterized by scanning electron microscopy. The ceramic powder was then mixed with white acrylic powder with the chlorophromic solvent using an ultrasound device to obtain the Nanocomposies which was formed with a 20 mm and 3 mm Teflon mold for the laboratory tests of thermal transfer properties using the thermal sensor.

4. Result and discussion

In this work the effect of the addition of bio-ceramic powder to improve the efficiency of the base material for the purpose of carrying the direct and indirect thermal stresses while using it as a toothpaste for natural damaged teeth as a result of caries or erosion. Standard samples for the purpose of laboratory tests were fabricated using the thermal sensor device type Therm TCi. The results of the test showed that the prepared Nanocomposites gradual improvement in the percentages of enhanced bio-ceramics, with the highest values for the conductivity, diffusion and thermal effusivity at the value of 5%. In contrast, a rapid decline in the values of thermal capacity, where it was reduced from 1369.9 to for pure (PMMA) to 980.9% at 5% Nanocmposites. This means that the thermal energy will be quickly dispersed because of its low value. This is the value of the speed of thermal diffusion propagation at 5%. The value of thermal diffusion propagation speed around 0.398, this is consistent with the source [16]. Table (1) and figures (1, 2, 3, 4 and 5) show the test results for all samples.

Table 1: Heat Transfer Properties of Neat and Nanocomposites.

NO. Samples	K(W/K. m)	Σ($Ws^{½}$ / m^2. k)	$Ɗ$(mm^2 / s)	ρ(kg / m^3)	C_p(J/kg. k)
0% $MgTiO_3$	0.26	640	0.165	1150	1369.9
1% $MgTiO_3$	0.30	666.5	0.202	1263	1172.39
2% $MgTiO_3$	0.31	681.3	0.207	1355	1123.13
3% $MgTiO_3$	0.34	741.8	0.210	1441	1105.03
4% $MgTiO_3$	0.40	777.7	0.264	1532	986.9
5% $MgTiO_3$	0.63	998.1	0.398	1612	980.9

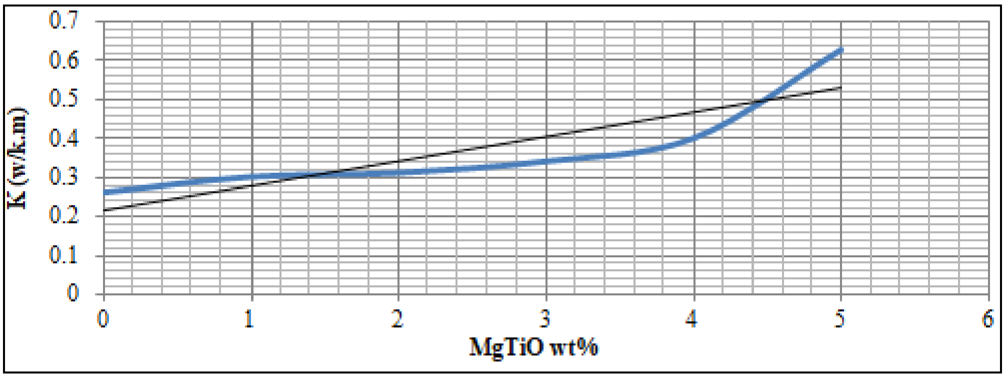

Figure 1: Thermal Conductivity Values of Neat and Nanocomposites.

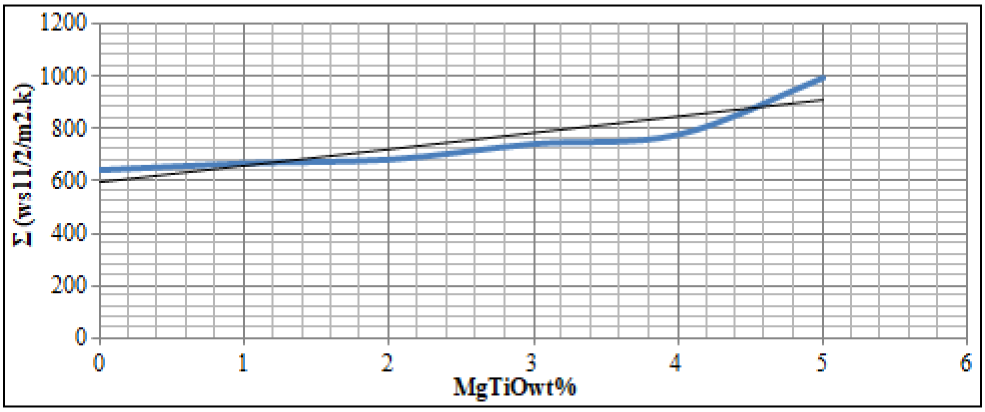

Figure 2: Thermal Eiffusivity Values of Neat and Nanocomposites.

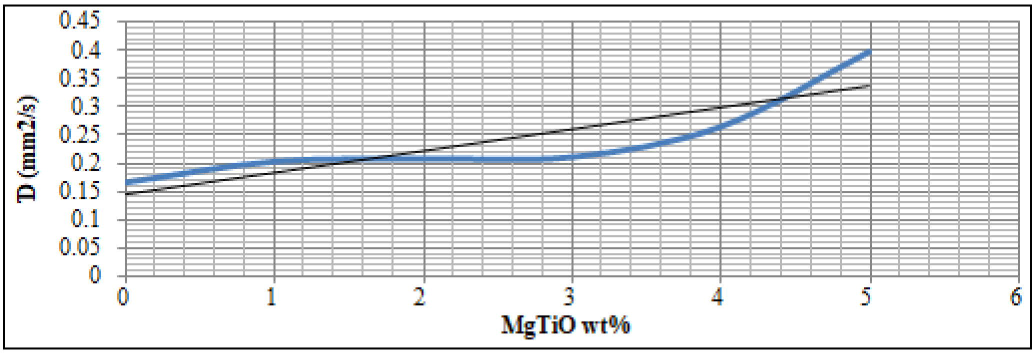

Figure 3: Thermal Diffusion Values of Neat and Nanocomposites

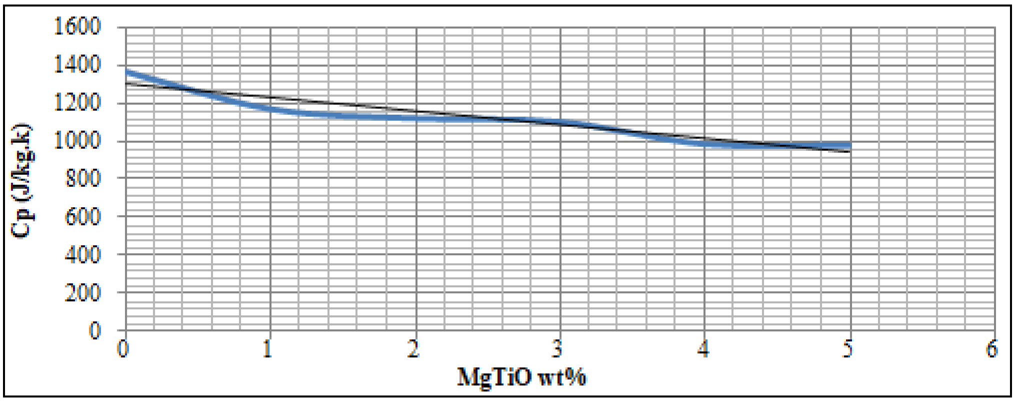

Figure 4: Heat Capacity Values of Neat and Nanocomposites

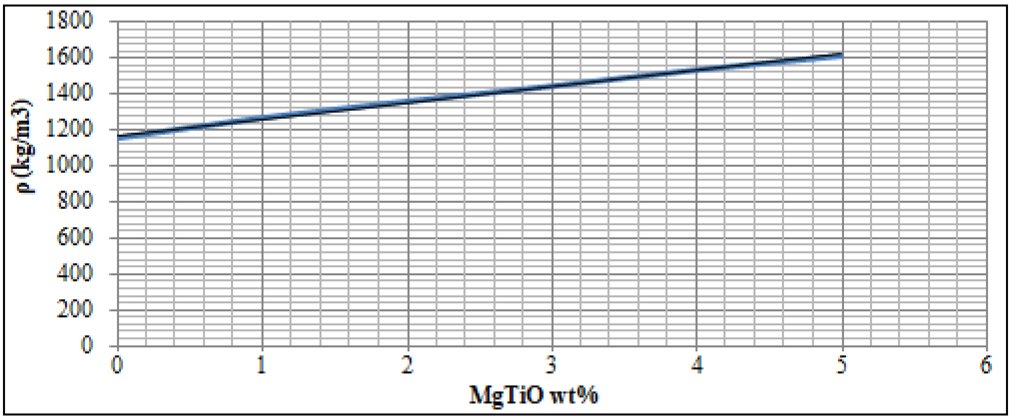

Figure 5: Experimental Density Values of Neat and Nanocomposites

Figure (6) shows images of the scanning electron microscopy technique for the distribution of precipitation of the base material in a uniform and homogeneous manner. This explains the apparent improvement of the thermal transfer properties of the prepared compositions such as dental fillings or damages to damaged natural teeth.

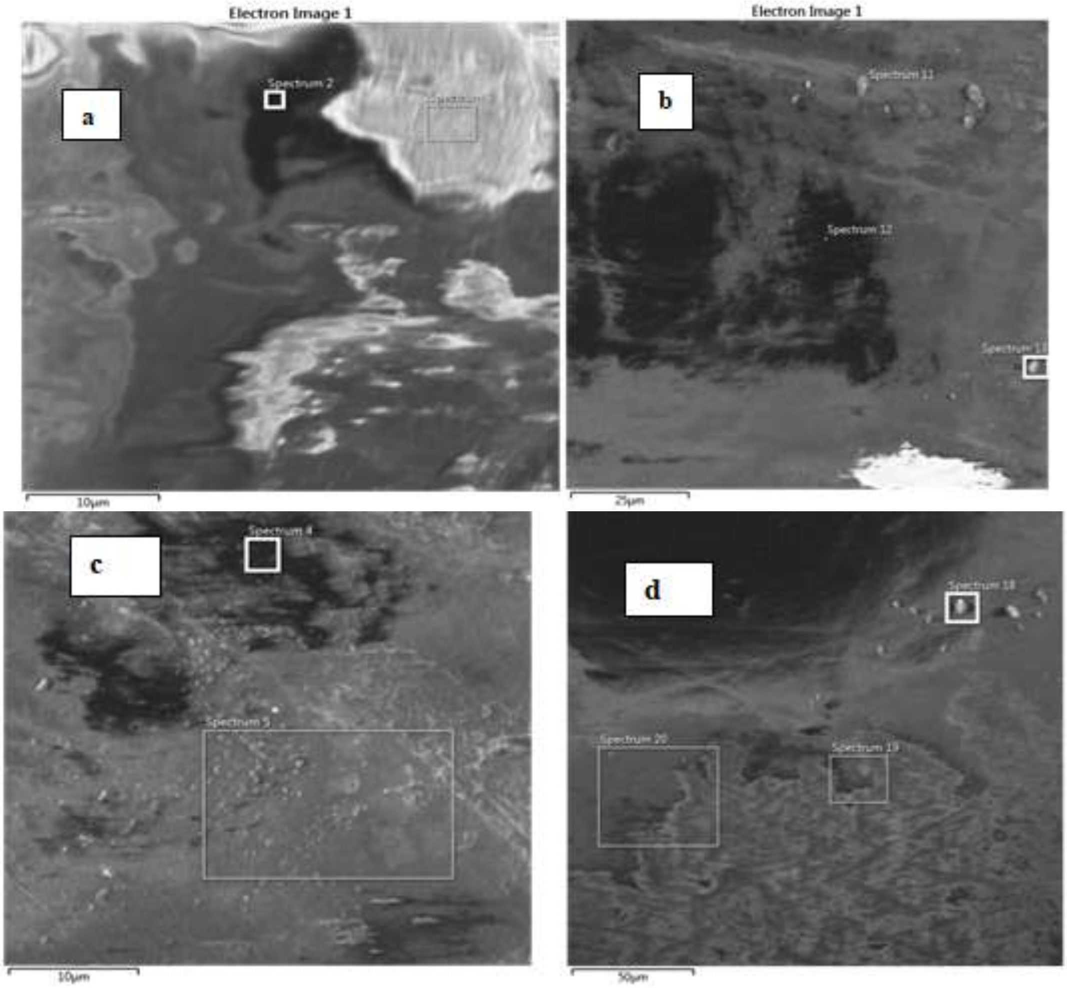

Figure 6: SEM images (a) pure PMMA: (b) 1%$MgTiO_3$:(c)3% $MgTiO_3$:and (d) 5% $MgTiO_3$

5. Conclusions

We can deduce from the research:

1) The prepared Nanocomposites have the ability to withstand sudden thermal stress and all the percentages of the bioceramic powder supported, unlike the dominant sample
2) All thermal transfer properties such as conductivity, flow, thermal diffusion of Nanocomposites are improved compared to base material.
3) The important finding in our current research is the low amount of stored heat energy and the speed of dissipation, which makes these Nanocomposites ready for dental restoration or filling applications.
4) From these above conclusions, it is possible to say that new compositions have been prepared that can be used for thermal applications with low thermal capacity.

References

[1] Powell C. E., Beall G.W**.** Physical properties of polymer/ claynanocomposites. Current Opinion in Solid State and MaterialsScience; 10(2):P73–80. (2006).

[2] Katsikis N., Franz Z., Anne H., Helmut M., Andri V.Thermal stability of PMMA/ Silica nano- and micro composites as investigated by dynamicmechanical experiments. Polymer Degradation and Stability.; 22:P1966-1976. (2007).

[3] Van Krevelen and D.W." *Properties of polymers*", ELSEVIER, (2003).

[4] Zumdahl and Steven S."*Chemical Principles 6th Ed*". Houghton Mifflin Co. (2009).

[5] Powers J.M., and Sakaguchi R.L**.** Craigs *Restorative dental materials.*13th Ed. Philadelphia: Elsevier, P: 163-176., 192- 194 (2012).

[6] Craig R, Power JM**:** restorative dental materials. 11th ed.Mosby Inc, Ch.4: P80-82, 68-109; Ch9:p232-251. (2002).

[7] Ziman, J., "*TheThermal properties of Materials*,". Scientific American, Vol. 217.(2011)

[8] Charles Kittel; Herbert Kroemer. Thermal physics. Freeman. pp. 78. ISBN 0716710889. (2000).

[9] W.J. Parker; R.J. Jenkins; C.P. Butler; G.L. Abbott "Method of Determining Thermal Diffusivity, Heat Capacity and Thermal Conductivity". Journal of Applied Physics. 32 (9): 1679. Bibcode:1961JAP....32.1679P. doi:10.1063/1.1728417, (1961).

[10] Delong R Inter-oral restorative materials wear: rethinking the current approaches:" *how* to measure wear Dental Mate"r. **22,** 702–11, (2006)

[11] Yabe T., Takajo T., Kato S.and Ueki F.: "Lubricant-supplying properties and durability of oil-impregnated polymers, Tribolology Transactions", Vol. 43, pp. 453. (2000).

[12] Oberholze T.G.r, S.R. Grobler, C.H Pameijer, and A. G.Hudson."The effects of light intensity and method of

exposure on the hardness of four restorative materials". International Dent.;Vol.53 PP. 211- 215, (2003).

[13] Antczak, E., Chauchois, A., Defer, D. and Duthoit, B., "Characterization of the thermal Effusivity of a Partially Saturated soil by the Inverse Method in the Frequency Domain", Applied Thermal Engineering, Vol. 23, pp. 1525-1536. (2003).

[14] Charles Kittel; Herbert Kroemer. Thermal physics. Freemanpp. 78. ISBN 0716710889. (2000).

[15] J.Blumm;J. Opfermann *"Improvement of the mathematicamodeling of flash measurements"*. High Temperatures–HighPressures. **34**: 515. doi:10.1068/htjr061(2002).

[16] E1952, "Method for Thermal Conductivity and ThermalDiffusivity by Modulated Temperature Differential Scanning Calorimetric", ASTM International, West Conshohocken.PA.(2013).