SSRG International Journal of Applied Physics
ISSN: 2350 – 0301 /doi:10.14445/23500301/ IJAP-V8I1P101

Volume 8 Issue 1, 1-4, Jan-April 2021

Study of Some Thermal and Dielectric Properties for Hybrid Composite Reinforced with (MgO and ZrO_2) Nanoparticles

Haneen M. Hassan[1], Sabah A. Salman[2,]*

[1]*Student, Department of Physics, College of Science, University of Diyala, Diyala, Iraq*
[2]*Professor, Department of Physics, College of Science, University of Diyala, Diyala, Iraq*

Abstract - *In this research, the additive effect of (Magnesium Oxide (MgO), Zirconium Oxide (ZrO_2)), nanoparticles to epoxy resin as a matrix have been studied, in addition to manufacturing hybrid composites from the same nanoparticles which are (MgO/ZrO_2) to epoxy resin as a matrix too. The hand lay-up method is used to manufacture the composites from the epoxy resin. The nanoparticles with different weight ratios (0, 0.3, 0.6, and 0.9 (wt%)), the thermal and dielectric tests have been done of all prepared composites.*

The effect of the weight ratio of the reinforcement materials on all-polymer composites' thermal properties has also been studied. The practical results have shown that all polymer composites' thermal conductivity coefficient behaves irregularly compared with pure epoxy by increasing the weight ratio of reinforcement materials.

The effect of the weight ratio of the reinforcement materials on all-polymer composites' dielectric properties has been studied. The practical results have shown a decrease in dielectric constant with an increase in the frequency for all weight ratios of reinforcement materials and increasing the dielectric constant with increasing the weight ratio of the reinforcement materials at the same frequency.

Keywords - *(EP) Epoxy Resin, Hybrid Composite, Nanoparticles, Thermal Properties, Dielectric Properties.*

I. INTRODUCTION - Generally, the use of most polymers was limited to the manufacture of cheap products that were used for simple purposes. However, the speedy technical development has required replacing some materials being used in the industry with others having better specifications. Consequently, polymers have replaced Aluminum and Iron for some purposes that do not require stress and high temperature [1]. Later, the development of polymer science has started to increase by leaps and bounds. Nowadays, scientists seek to produce cheap, flexible, and multi-purpose polymers. They are used in housing, automobiles, and they can be used for different industrial applications.

Plastics are the most versatile materials used in different industries, such as aircraft, packaging, electrical equipment, and electrical insulators. They have increasingly important roles in the manufacture of satellites, space research, and thermal barriers [2].

Plastics have replaced metals in many applications. They have superseded steel and many other metals in being erosion resistant and chemically inert. Having higher temperature extension and specific heat than metals, plastics have been used for constructing and lining reactors, absorption towers, and the manufacture of pipes and valves.

Most plastics are currently manufactured as light, rigid and foamy materials and used as insulators due to their low thermal and electrical conductivity. Plastics have almost no free electrons, but recent scientific and technical break-throughs have succeeded in making some modifications on regular plastics and brought into existence a new generation of plastics that combine the conductive electrical features of semi-conductive materials, the mechanical and chemical features of plastics [3].

II. Materials Used

1- **Matrix:** Epoxy polymer matrix is prepared by mixing [3:1] parts by volume of epoxy resin (Nitofill, EPLV with hardener (amine) supplied by a company Fosroc Jordan. Epoxy resin contains epoxide groups that serve as cross-linking points. The resin reacts with the hardener to form long chains of the cross-linked polymer.
2- **Filler:** In this paper, two types of nanomaterials were used to prepare composites and hybrid composites (MgO with particle size (30-40 nm) supplied by a company Nanjing Nano Technology of purity (99.9%), ZrO_2 with particle size (40-50 nm) supplied by a company Hongwu Nanometer of purity (99.9%)), with weight ratios ((0.3, 0.6, 0.9) wt%).

III. Experimental Part

The nanoparticles (Magnesium Oxide (MgO), Zirconium Oxide (ZrO_2)) are weighted according to equations below and added to the epoxy resin firstly with different weight ratios ((0.3, 0.6, 0.9) wt%), this step was happened in the hood to reduce the interaction between nanoparticles and air to reduce the pollution with the environment this is because of this interaction increase the agglomeration of the nanoparticles and decrease the polymer matrix chain of nanoparticles with epoxy.

$$W_p = \frac{w_p}{w_c} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$W_m = \frac{w_m}{w_c} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:

W_p, W_m: The weight fraction of the reinforcement material and matrix material, respectively.

w_p, w_m, w_c: The weight of the reinforcement material, the matrix material, and the composite material, respectively.

By using the hand lay-up method, we prepare the polymer composites and hybrid polymer composites. Careful mixing of epoxy with nanoparticles in a beaker using an ultrasonic processor at (30 minutes) to minimize voids and clustering of particles. The mixture was left to cool down at room temperature; after that, we added the hardener to the mixture and mixed them mechanically for (10 minutes) to obtain homogeneity. Finally, they have cast the mixture in molds, and the samples were cutting depend on the tests.

In general, the samples used in the tests and examinations were prepared according to the standard system specifications, as follows:

a- Thermal conductivity coefficient test: Diameter (40 mm).

b- Dielectric constant test: Diameter (20 mm).

and for thermal and dielectric tests:

- **For thermal conductivity coefficient test:** Using a **(**Lees Disc) of **(**Griffen&George).
- **For** the **constant dielectric test**: Using an (Agilent Impedance Analyze 4294A) of (Taiwan).

IV. Results and Discussion

A. Thermal test

a. Thermal conductivity coefficient test (k): The coefficient of thermal conductivity (k) was calculated using Lee's Disc Method for epoxy before and after reinforcement with nanoparticles (MgO, ZrO_2) with different weight ratios ((0, 0.3, 0.6, 0.9) wt%). Figure (1) shows the effect of the weight ratio of the reinforcement on the thermal conductivity coefficient of pure epoxy and reinforced with nanoparticles, Where we notice that the value of the coefficient of thermal conductivity of pure epoxy is (0.21825 (W/m.K)) and when reinforcement the epoxy with all nanoparticles, we notice a change in the value of the coefficient of thermal conductivity as it behaves an irregular behavior, Where we notice that all the values of the coefficient of thermal conductivity of epoxy reinforced with all nanoparticles (at all weight ratios of reinforcement) are less than the value of the coefficient of thermal conductivity of pure epoxy because the nanoparticles are porous and contain voids. Hence, their thermal conductivity becomes less [4]. Except for the composite EP-ZrO_2 at the weight ratio (0.3 wt%) for reinforcement and the EP-MgO/ZrO_2 hybrid composite at the weight ratio (0.6 wt%) for reinforcement, they have values for the thermal conductivity coefficient greater than the value of the thermal conductivity coefficient of pure epoxy because the presence of these nanoparticles in the base material makes the reduces the degree of entanglement between the molecular chains, which gives them greater freedom of movement and thus increases their ability to vibrational movement, which leads to an increase in the value of the coefficient of thermal conductivity in the composite, in addition, these nanoparticles make the stack the components of the composite materials and reduce the number of voids that can be formed during the composite fabrication process, thus increasing the value of the coefficient of thermal conductivity [5]. The metal is a good conductor of heat, as metals depend on free electrons for heat transfer, as for ceramics, the heat transfer depends on the vibrations of lattice phonons because phonons represent the vibrations of the lattice and are responsible for the heat transfer in the insulating solids [4]. The irregularity of the value of the coefficient of thermal conductivity may be due to the heterogeneity between the base material and the reinforcement materials due to the large surface area of the reinforcement materials [6]. In other words, this may be due to the lack of uniform distribution of the nanoparticles inside the base material because the nanoparticles tend to agglomerate due to their large surface area [7]. Through figure (1), we also notice that the composite EP-MgO has fewer values of the thermal conductivity coefficient than other composites. Table (1) shows the values of the coefficient of thermal conductivity of all the prepared composites.

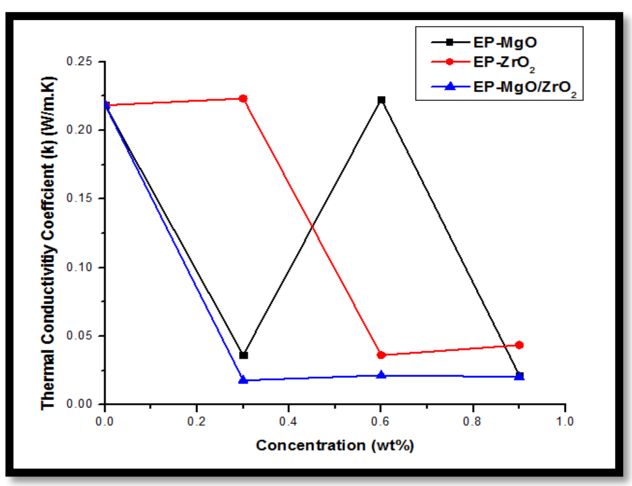

Figure (1): Thermal conductivity coefficient of pure epoxy and reinforced with nanoparticles (MgO, ZrO_2) with different weight ratios.

Table (1): Thermal conductivity coefficient values of pure epoxy and reinforced with nanoparticles (MgO, ZrO_2) with different weight ratios.

Weight Ratio (wt %) of Nanoparticles	Thermal Conductivity Coefficient (k) (W/m.K)		
	EP-MgO	EP-ZrO_2	EP-MgO/ZrO_2
EP	0.21825	0.21825	0.21825
0.3 %	0.01790	0.22326	0.03635
0.6 %	0.02159	0.03621	0.22274
0.9 %	0.02055	0.04362	0.02164

B. Dielectric test

a. Dielectric constant: The dielectric constant of epoxy was recorded before and after the reinforcement with nanoparticles (MgO, ZrO_2) with different weight ratios ((0, 0.3, 0.6, 0.9) wt%) and with a range of frequencies (50Hz-5MHz) at room temperature and as shown in the figures from (2) to (4), where we notice that the dielectric constant decreases with increasing the frequency for all composites, and this behavior is known for electrically insulating materials [8], the effect of polarization is the reason for this because the dielectric constant depends mainly on the mechanism of polarization of its different types (electronic polarization, ion polarization, directional polarization and the polarization which reduce from the interface surface) [9]. In the low frequencies region, all types of polarization occur, so we see the dielectric constant values as the largest possible. However, these high values of the constant dielectric result from the interface polarization due to its large value relative to other polarization types. In the low frequencies region, the effect of polarization is more important because the molecules of the dielectric materials have sufficient relaxation time to direct them in the direction of the applied electric field when the voltage is applied. After that, the polarization effect becomes insignificant at the high frequencies region because the particles do not have sufficient relaxation time to direct themselves in the applied alternating electric field. The dielectric constant is not dependent on the frequency only, but also on the weight ratio of the reinforcement, Since we notice that the dielectric constant increases with the increase in the weight ratio of the reinforcement at the same frequency for all the composites due to the increase in polarity [10], but at the hybrid composite EP-MgO/ZrO_2, we notice that the dielectric constant increases at the weight ratio (0.3 wt%) of the reinforcement at the same frequency and then the dielectric constant decreases with the increase in the weight ratio of the reinforcement at the same frequency so that the values of the dielectric constant become less than the dielectric constant values of pure epoxy at the same frequency, and the reason for this decrease in the dielectric constant may be due to the heterogeneous distribution of the reinforcement materials within the matrix, or perhaps due to the increase in the molecular weight of the polymeric chains as a result of their association with the reinforcement materials, which causes difficulty in rotating these polymeric chains with the applied electric field, this leads to a decrease in the polarity of the material and consequently to a decrease in the dielectric constant [11].

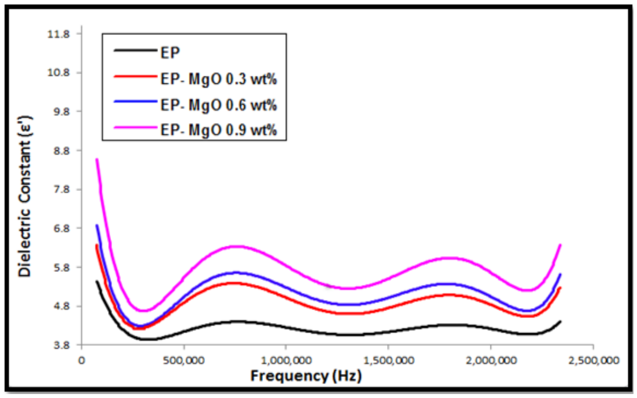

Figure (2): Dielectric constant as a function of frequency for composite (EP-MgO) with different weight ratios.

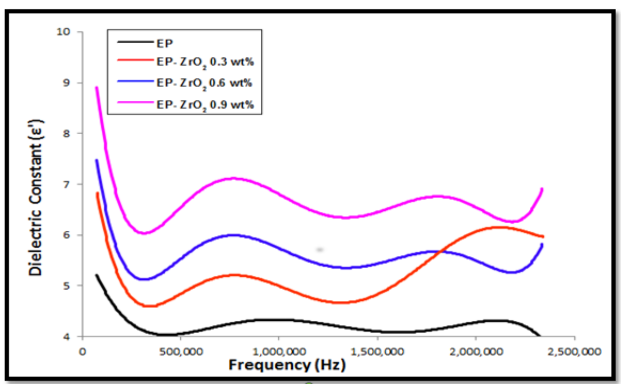

Figure (3): Dielectric constant as a function of frequency for composite (EP-ZrO_2) with different weight ratios.

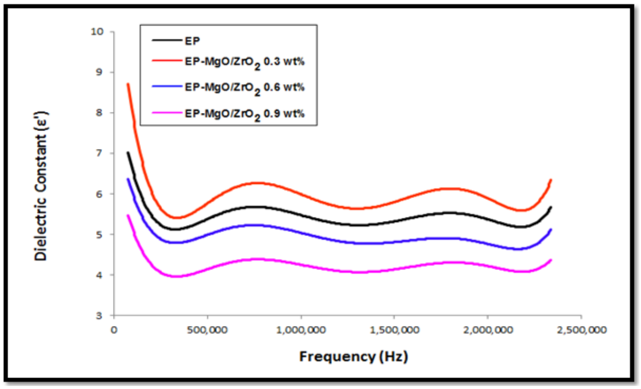

Figure (4): Dielectric constant as a function of frequency for the hybrid composite (EP-MgO/ZrO_2) with different weight ratios.

V. CONCLUSIONS

1. The thermal conductivity coefficient of all polymeric compositions after reinforcement with nanoparticles with different weight ratios has an irregular behavior compared to pure epoxy, and it is found that the thermal conductivity coefficient of these polymeric compositions is very small, and that is why these polymeric compositions can be used as a heat shield.
2. Increasing the dielectric constant with increasing the weight ratio of the reinforcement with nanoparticles at the same frequency for some polymeric composites, and the dielectric constant decreases with increasing the frequency for all polymeric composites and all weight ratios of the reinforcement, in the high frequencies region, these dielectric properties do not depend on the frequency and stay constant, indicating the possibility of applying these polymeric composites in devices that require stability in the dielectric properties at high frequencies.

REFERENCES

[1] G. A. Kontos, A. L. Soulintzis, P. K. Karahaliou, G. C. Psarras, S. N. Georga, C. A. Krontiras, and M. N. Pisanias, Electrical Relaxation Dynamics in TiO_2-Polymer Matrix Composites. Express Polymer Letters (1) (2007), 781-789.

[2] S. Mustafa, Engineering Chemistry, Library of Arab society for publication and distribution, Jordan, (2008).

[3] M. Dahshan, Introduction to Material Science and Engineering, 2nd Ed, King Saud University Press, (2002).

[4] H. H. Thanon Albyate and A. A. Mohammed Al jaboury, Effect of Nano Silica Nano Alumina and Short Carbon Fibers Addition on Mechanical and Physical Properties of Blend Epoxy – Polyester, Iraqi Academic Journals 14(4) (2019), 273-293.

[5] H. H. Thanoun and N. A. Hussein, Mechanical and Physical Properties of Composites of Epoxy and Polyester Unsaturated are Reinforced with Glass fibers and Nano Alumina Powder, Journal of Education and Science, 28(1) (1997), 300-325.

[6] V. Kovacevic, M. Leskovac and S. Blagojevic, Morphology and Failure in Nanocomposites. Part ll: Surface Investigation, Journal of Adhesion Science and Technology, 16 (2002) 1915-1921.

[7] Z. Han and A. Fina, Thermal Conductivity of Carbon Nanotubes and Their Polymer Nanocomposites, Progress in Polymer Science, 36(7) (2011), 914-944.

[8] R. S. Mahmood, S. A. Salman, and N. A. Bakr, The Electrical and Mechanical Properties of Cadmium Chloride Reinforced PVA: PVP Blend Films, PAPERS IN PHYSICS, 12 ,120006-1200013, (2020).

[9] E. M. Abdelrazek, I. S. Elashmawi, A. El-Khodary, and A. Yassin, Structural, Optical, Thermal, and Electrical Studies PVA/PVP Blends Filled with Lithium Bromide, Current Applied Physics, 10(2) (2010), 607-613.

[10] G. C. Psarras, K. G. Gatos, P. K. Karahaliou, S. N. Georga, C. A. Krontiras and J. Karge, Relaxation Phenomena in Rubber/Layered Silicate Nanocomposites, Express Polymer Letters, 1 (2007) 837-845,

[11] S. Basavaraja, Dielectric Properties of PMMA and its Composites with ZrO_2, Physics Procedia, 49 (2013) 15-26.