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Enhancing Some Mechanical Properties (Compression, Impact, Hardness, Young modulus) and Thermal Conductivity, Diffusion Coefficient of Micro Epoxy Composites.

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Abstract

In this research, the study effect of additive titanium dioxide powder (TiO2) as a lone composite (Ep+TiO2) and a mixture of (TiO2) and silicon oxide (SiO2), (Ep+ TiO2+SiO2)as a hybrid composite on the mechanical and physical properties for epoxy coating. Thescompsiteswere prepared by (Hand Lay- the molding) method. The samples were tested for compressive strength, surface hardness, modulus of elasticity, thermal conductivity and diffusion coefficient, from the results obtained showed improvement in mechanical properties after adding ceramic powders, as the alone composite (EP+ TiO_2) had the highest compressive strength (53.738) MPa, the hybrid composite (EP+TiO_2 +SiO_2) had the highest surface hardness (79.65), modulus of elasticity (1166.66) MPa, impact strength (8.48) MPa, thermal conductivity (0.4961)watt/ m.c°. As for the diffusion coefficient in the acidic solution (HCL), the epoxy without adding the highest diffusion coefficient (31.3x 10^{-10}) m^2/ sec while for immersion in ordinary water, the one composite material (Ep+ TiO_2) had the highest value of the diffusion coefficient (7.56x10^{-10})m^2/sec.

keywords: Hardness, Diffusion Coefficient, Compression, Thermal Conductivity.

1. Introduction

thermosets with high resistance to decomposition and low specific weight, give the best mechanical and thermal properties, as these materials are among the best family of polymers. Epoxy resin is one of the best available resins at this time because of its good mechanical properties, and high performance, in addition to its resistance to deterioration, and this gives it importance in its almost exclusive use in the aviation industry. Resins play an important role in shipbuilding because of their high resistance to water degradation when fully treated, in addition to their increased adhesive properties. Ideal for the manufacture of armored vehicles, epoxy resins have many mechanical properties such as toughness, extreme flexibility, high hardness to strength, and high chemical, and electrical resistance. High, high heat resistance. [1].

The inclusion of multiple Small fillings improves the rigidity of the material and may also increase its strength under specific loading conditions. However, it must be remembered that micro-fillings hurt basic qualities, such as resistance to the impact of the material. [2]. The positive and negative effects of micro-fills embedded in a polymeric matrix have been well documented for a variety of phenomena, including energy absorption [3], thermal and electrical conductivity [4].thermaland mechanical behavior [5]. and the dependence of the fracture resistance of the composite on the strength of the particle/matrix bond in particle-filled polyester resins [6]. As a result, the academic focus has turned to nanotechnology and the use of nanometer size fillers to counteract or mitigate the detrimental impacts of polymeric matrix characteristics and micro fillers. [7]. Nanoparticles immersed in a polymer matrix have aroused interest due to the extraordinary mechanical, thermal, optical, electrical and magnetic capabilities exhibited by nanocomposites. The physical and chemical properties of these particles are very different from those of molecular and mass materials due to their nanoscale size. Nanoparticle-reinforced polymers combine the properties of the host polymer matrix and separate nanoparticles synergistically [8]. Dielectric behaviors, thermal stability features, strong wear resistance, mechanical performance and outstanding tribological properties are just a few of the beneficial aspects of nano epoxy composites [9]. Layered nano-silica particles, for example, have been added to epoxy resins to enhance hardness and mechanical strength. [10]. Currently, fiber-reinforced composites are being added to nano-modified epoxy as matrix materials, with promising results in terms of interlamellar fracture toughness and damage tolerance, among others [11].

Abdul-AdheemZuily looked at the physical, mechanical, and image properties of (EP/Al2O3 & EP/TiO2) and hybrid composites, as well as the effects of chemical solutions and UV irradiation on some physical-mechanical properties. When the weight fraction increases, the hardness increases, as he demonstrates [12]. Mu Liang-KL Wong investigates the mechanical and thermal properties of epoxy nano and micro composites. The results demonstrate that both nano and micro composites have superior mechanical qualities, while nanocomposites have better thermal properties than pure epoxy [13].

Zhou et al. investigated two types of TiO2 particle sizes: macro and nanoparticles and found that agglomeration of Nanoparticles reduces mechanical properties[14]. This study aimed to improve the mechanical and physical properties of epoxy composites, both single and hybrid.

2. **Material**

Epoxy resin type in a liquid state (Sikadur – 52 Australia Pty Limited) is used as a matrix material in the preparation of composites micro particles composites, epoxy becomes into the solid state via additives the hardener which has low viscosity and density properties. The hardener was added to the epoxy at a ratio 2:1 with continuous mixing.

The composites were prepared using TiO_2 (1.5)µm purity(99.9) , SiO_2 (1-350)µm, purity(99.9%).

3. Preparation of Composites

Epoxy micro composites were prepared using a glass mold by dimension [20x20x1] cm. The micro particles' oxides were mixed with epoxy using the magnetic vibrator for (10) minutes. After the mixture was completed, the mold was prepared, cleaned, and dried and the surface of the mold was covered with Fablon paper to prevent the casting from sticking to the surface of the mold after that the mixture was poured into the mold quite quietly to avoid the formation of bubbles. The casting was left for 48 hours for hardener, the casting was placed in the oven at a temperature of 50C◦ for (3) hours for solidification. after extracting the casting, they were cut according to the standard dimensions for each test [15].

4. Experimental Test

4-1:Compressive test

The compressive strength is the maximum applied stress that the material can withstand solid under vertical pressure. Compressive resistance can be set from a relationship (1).
C.S=P/A(1)
Where:
C.S: compressive strength (MPa).
P: maximum shed load (N.)
A: cross-sectional area (mm^2).
The composite material has been tested for compressive strength using a piston Hydraulic type (Ley Bold Harris No.36110) and sheds the load gradually on the sample until it fails and the change in length is determined by deflection. The maximum load that the sample can bear (when failure) is the maximum. A value for its compressive strength and was calculated according to equation (1), and from the graph between the applied stress and the strain, the young modulus calculate.

4-2: Impact Test

For performance impact testing on the prepared samples, Charpy impact experiment equipment manufactured by testing machines in Amityville, New York, was employed. The pendulum and the energy normal gauge are the two main components of the instrument. The Charpy impact test consists of a conventional test part that is fractured in one flow of the hammer swinging. The instrument's performance is achieved by elevating the hammer to its highest position and securing it in place, then inserting the samples. Swing action converts potential energy to kinetic energy, but the amount of it in broken samples is missed. As a result, the quantity of broken energy will be displayed on an indication scale, and the sample impact strength will be determined using the relation(2) [16].
$\mathrm{I}.S = \mathrm{U}/\mathrm{A}\ (\mathrm{J}/\mathrm{m}^2)(2)$
Where:
I.S, the impact strength
U, the energy fracture (joule)
A , the cross section area (m^2)

4-3: Hardness Test

The specimens were prepared at room temperature and the hardness test was recorded using a Shore hardness instrument by ASTM D2240.

4-4:Young's Modulus Test

Change in polymer dimensions as a function of stress is one of the properties

Mechanical.When stress is applied to a polymer sample at a constant speed, and measured deformation in which a change in length or change in area or volume can be recognized as behaviorpolymer under the influence of stress.
from (the stress-strain curve)several properties can be obtained strength, durability, flexibility, maximum stress that the model can withstand and maximum elongation may occur in the model in addition to a lot of very important engineering information.
stress usually means the force applied to the unit cross-sectional area of the model and is symbolized by the symbol (σ) [17].

$$\sigma = F / A \quad (1)$$

while strain (ε) represents the amount of elongation of the model as a result of exposure to stress relative to the original length of the model.[17]

$$\varepsilon = \Delta L / Lo \quad (2)$$

compression test obtained relation between from the
stress and strain of epoxy before and after reinforcement with micro oxides, where it was possible to determine the value of the modulus of elasticity (E)
From the slope of the curve, which represents the ratio between stress and strain, according to the following relationship:[17]

$$E = \sigma / \varepsilon \quad (3)$$

4-5:Diffusiontesting

The process of diffusion defines the process you perform in the material that moves from one place to another in the system. To spread physically, because of natural, because the particles are in the gaseous or liquid state in a state of continuous motion through the fields moving from one location to another. This behavior is called the first law of diffusion (Fick's Law of Diffusion) [18].

$$F_x = -D\frac{dc}{dx} \quad (4)$$

F_X : The number of particles scattered downward in the direction of the concentration gradient per second per unit area is called the flow of particles

D: diffusion Coefficient (m^2/ sec).

$$D = \pi([k_t d / 4 M_\infty]) \quad (5)$$

K_t: slope It is the linear part of the mass gain curve with the square root of time(g/sec^{½})

M_∞: The highest value i.e. saturated state (the highest gain value in the mass) (g).
d: Thickness (mm).

To find the percentage change in the mass of the models immersed in water and solutions, we use the following law:

Weight gain% = $(M_2 - M_1 / M_1) \times 100\%$ (6)

M1: mass of the sample before immersion (g).

M2: mass of the sample after immersion (g)

4-6: Thermal Conductivity

We can compute the factor thermal conductivity of total samples for this research used method Disk Lee, depending on the equations.
Q = - KdT/dx(7)
dT/dx : heat grade in (° C/ m) , negative symbol mean the heat movements first great temperature range to the smaller temperature range.
Thermal conductivity amount we can compute in the following equations.

$$k[T_B - T_A/d_s] = e[T_A + 2/r(d_A + 1/4d_s)T_A + 1/2rd_sT_B] \quad (8)$$

$$IV = \pi r^2 e(T_A + T_B) + 2\pi re[d_AT_A + d_s(T_A + T_B/2) + d_BT_B + d_cT_c] \quad (9)$$

When[e] represents the amount of heat energy transient in disc material space the unit per second, unit ($w/m^{2\circ}C$).
I, a current pass through a convector coil.
(T_A, T_B, T_C,) , heat for disc A, B, C. (°C)
(d_s), the thickness for samples(mm).

5. Results and Discussion

5-a: Compressive

Under normal conditions, the results of the compressibility test showed that the addition of Powders SiO_2, TiO2 and hybrid (TiO2 + ZnO) to an epoxy resin, as a filling agent (Filar) it improves the compressive strength of the composite material, where has the lone composite material (Ep + TiO2) highest compressive strength showed(53.73) MPa. The explanation of this is that the ceramic powders have high durability and can withstand the largest part of the applied stress, Residual stress distribution center on the main project, that the consolidation In minutes it is symmetric the same on all servers, and small the size of the particles makes the inter-spaces small, and this hinders the growth of cracks [19].
Figure(1) shows the results of the compressibility test.

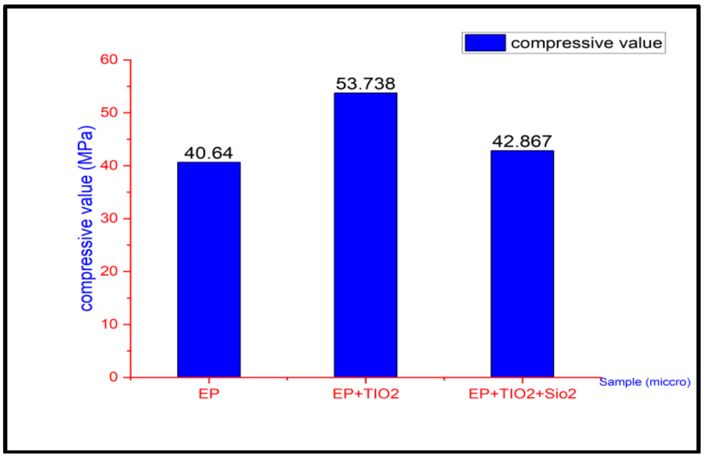

Figure 1. Represents the compressive value before and after reinforcement by ceramic oxides

5-b:**Impact**

The basis of the impact test work depends on the absorption of the initial kinetic energy in the hammer by the test sample before the fracture occurs, and the amount of energy absorbed depends on the internal components of the composite material. It also depends on the resistance of the sample to the external stresses imposed on it. **Figure (2)** shows the value of the impact resistance before and after the reinforcement with ceramic oxides, as it is clear from the results that the value of the impact resistance increased after the reinforcement with ceramic oxides for each of the lone and hybrid composite materials compared to pure epoxy, where the hybrid composite material (EP+TiO_2 +SiO_2) reached (8.48)KJ/ m^2 and the lone composite material (7.89) KJ/ m^2 and the reason for the increase in impact resistance can be attributed to the fact that the powders act as buffers for fracture growth, which leads to an increase in the strength of the composite material [20].

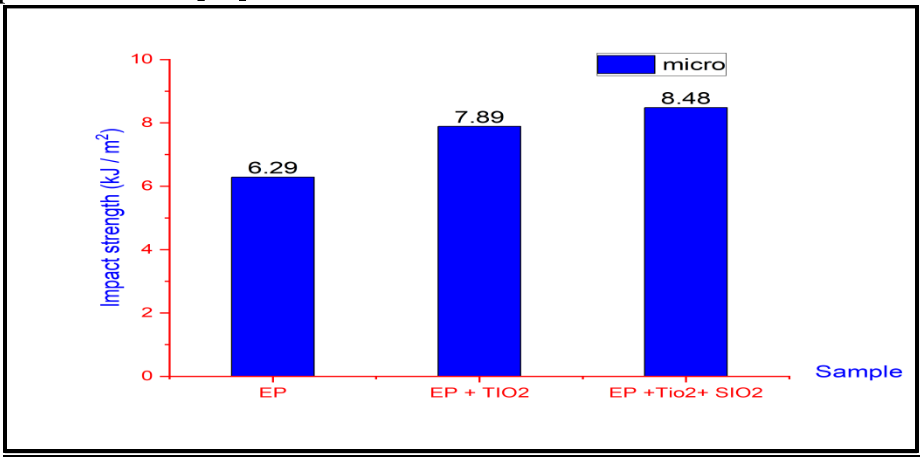

Figure2.Represents the impact value before and after reinforcement by ceramics oxides

5-c: Hardness

Hardness can be defined as a measure of a material's resistance to scratching, abrasion, and wear [21]. **Figure (3)** shows the relationship of hardness to epoxy and its composites, from this figure, it can be seen that the hardness value of both alone and hybrid composite materials increased compared its value for pure epoxy, where the hybrid composite material (EP+TiO_2 +SiO_2) had the highest value of hardness (79.65). The reason can be explained that the materials The additives of (TiO_2, SiO_2) are characterized by high hardness as they are ceramic materials. As the particles diffuse through the polymer and work to fill the voids arising from the manufacturing process and the spaces between them, which leads to an increase in the stacking and the strength of the bond between them and the base material and thus increases the hardness.[22,23].

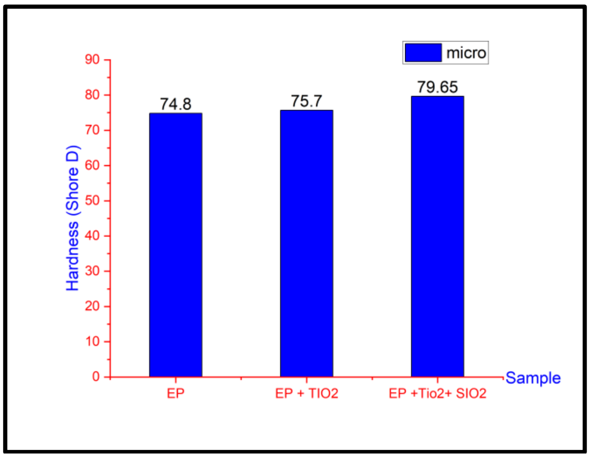

Figure 3.Represents the hardness value before and after reinforcement by ceramics oxides[40].

5-e: Young modulus

The **Figure (4)** shows the stress-strain curve for epoxy and for both the alone and hybrid composite materials, where from this figure the values of the modulus of elasticity were obtained for epoxy and its composites, and we can see the owned hybrid composite material (EP+TiO_2 +SiO_2) high value of young modulus(1166.66) MPa compared than a lone composite and pure epoxy the modulus of elasticity increase because that the ceramic particles become in contact with matrix, and also their small sizes and spread in the material lead to restriction of the movement of the polymer chains, which makes the relaxation process more difficult and thus increases the modulus of elasticity [24]. **Figure** (5) represents the compressive young modulus of epoxy and alone and hybrid composites materials.

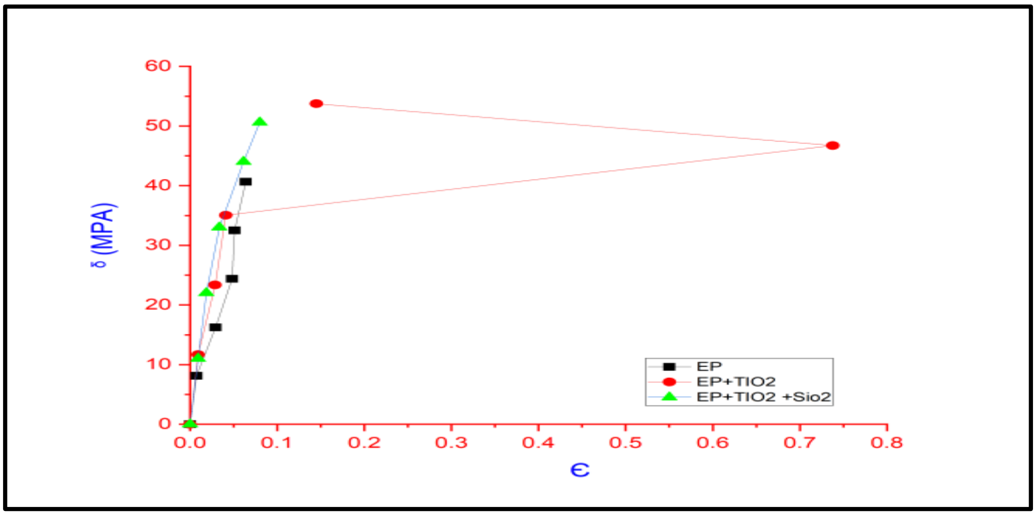

Figure 4. Represents the stress- strain value for epoxy and alone and hybrid composites materials.

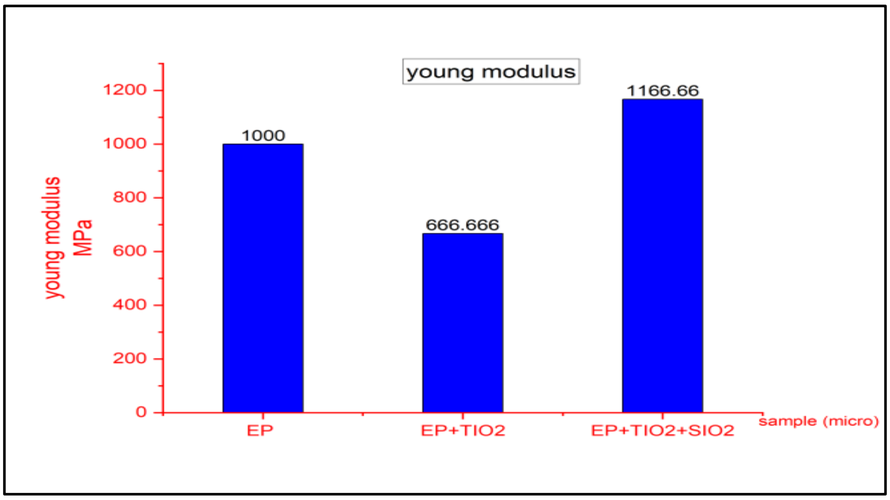

Figure5.Represents the compressive young modulus value for epoxy and alone and hybrid composites materials.

5-d: Thermal conductivity: Figure(6) shows the value of thermal conductivity for epoxy alone and hybrid composites from this fig. we can see high thermal conductivity for the hybrid composite (EP+TiO_2 +SiO_2) , (0.4961)watt/ m.c◦ compared than alone composite and pure epoxy ,this could be due to the increased thermal conductivity of the hybrid composite material compared to the alone composite material and pure epoxy, The addition of ceramic particles to epoxy reduces the degree of crosslinking between the molecular chains, allowing them to move more freely and increase their vibratory ability, resulting in increased thermal conductivity [25- 27].

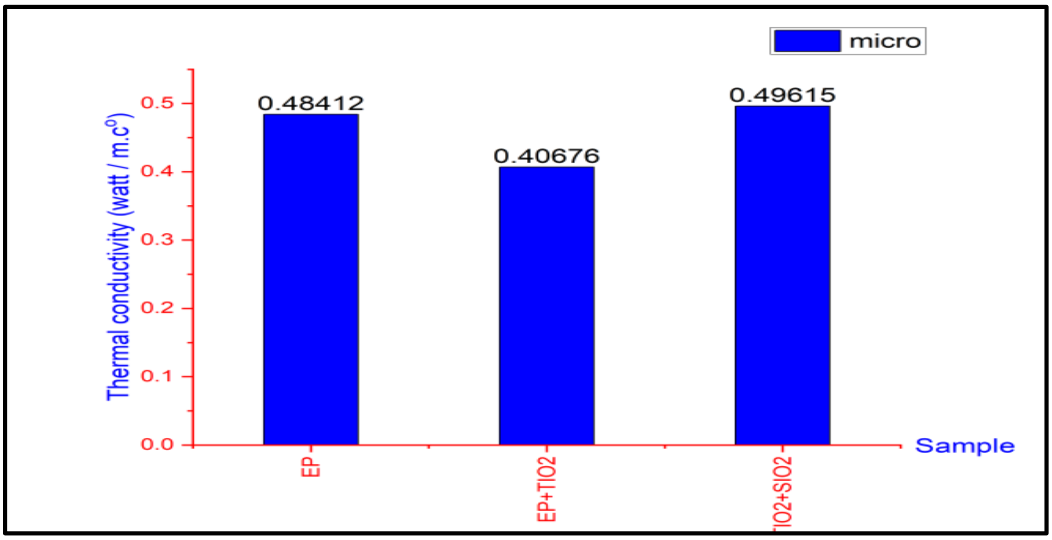

Figure6.Represents the thermal conductivity value for epoxy and alone and hybrid composites materials.

Effect of acid solution (HCL) and water on the physical properties of epoxy before and after reinforced:The goal of investigating polymer decomposition is to figure out how different liquids affect them. The resistance of a polymer is found to be dependent on the polymer's nature as well as the kind and nature of the medium in which it is immersed. When exposed to moisture in the environment or submerged in water or solutions, all types of polymers and composites absorb moisture according to the first law of diffusion (the mass of water or the absorbed solution increases linearly with the square root of time gradually and slowly until a state is reached) [28].

Figures (7,8)show the relationship between the percentage increase in mass and the squared root of time for both immersion in normal water and in alkaline solution (HCL) for epoxy before and after reinforcement by ceramic oxides for both alone and hybrid composite materials, **Figure (7)** shows that the highest diffusion coefficient immersion in (HCL) for pure epoxy, where the owned value of diffusion coefficient ($31.3x10^{-10}$) m^2 / sec, while for immersion in ordinary water **Figure (8)**, the alone composite material (EP+ TiO_2) had the highest value ($7.56x10^{-10}$) m^2 / sec, the reason for the increase in the diffusion of the alone composite material can be attributed to ceramic powders are characterized by containing voids (pores) through which water and solutions escape, lead to the negative effect of immersion in solutions. It can also be said that water and solutions penetrate to the interface region between the powders and the matrix, which leads to weakening the bonding between them and increasing the porosity and thus causing the failure of the material [29]. **Figure** (9) represents the value of diffusion coefficient for epoxy after and before reinforcement when immersion in (HCL) and normal water.

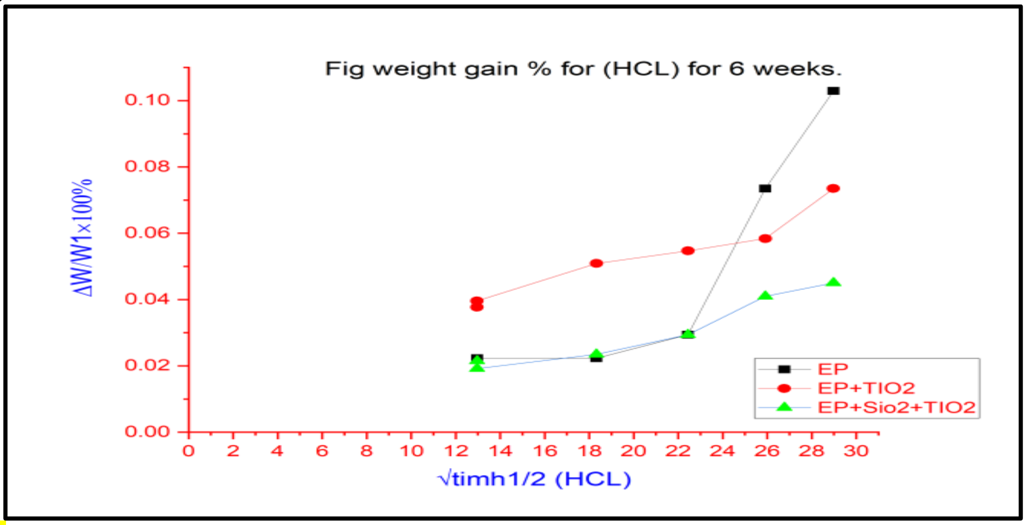

Figure 7. The weight gain % for epoxy and alone and hybrid composites material when immersed in (HCL) for 6 weeks**.**

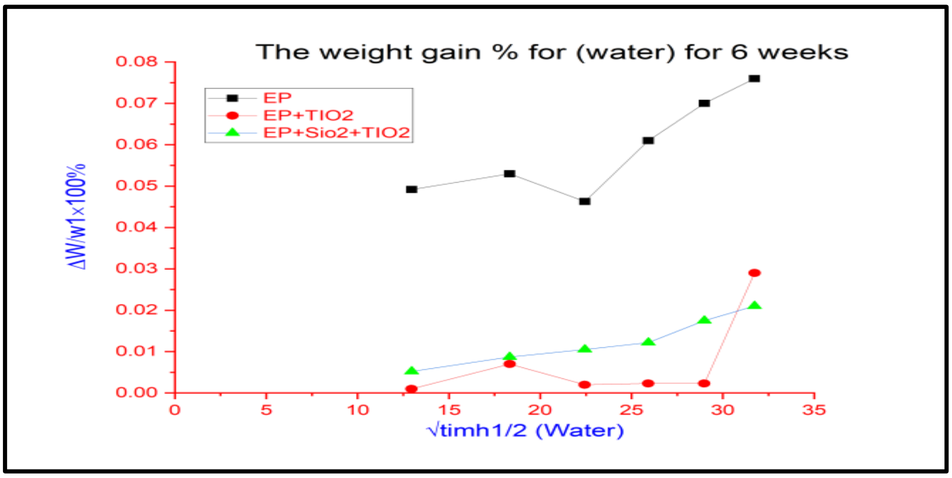

Figure 8. The weight gain % for epoxy and alone and hybrid composites material when immersed in water for 6 weeks

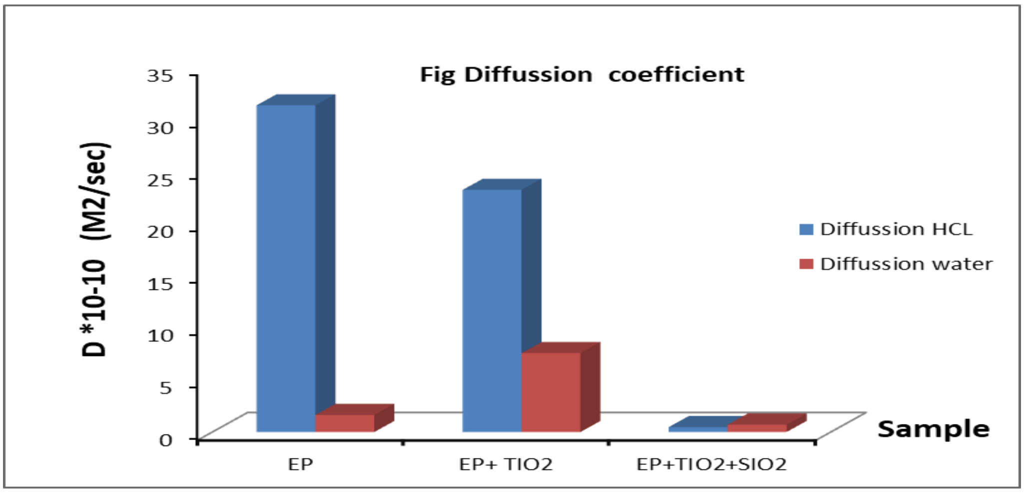

Figure 9. The value of diffusion coefficient for epoxy and alone and hybrid composites material after. immersion in (HCL) and water.

7. Conclusions

Through the search results, the following was found:

1- The addition of ceramic powders to the epoxy resin material improved the mechanical properties, as the alone composite material (EP+ TiO_2) had the highest value for compressive strength, while the highest value for hardness, impact resistance and modulus of elasticity was possessed by the hybrid composite material (EP+ TiO_2+ SiO_2).

2- As for the thermal conductivity, the hybrid composite material (EP+ TiO_2+ SiO_2) had the highest value of thermal conductivity compared to the alone composite material and pure epoxy.

3- For immersion in acid solution and normal water, pure epoxy had the highest diffusion coefficient in acid solution, while for water immersion, the alone composite material (EP+ TiO_2) had the highest diffusion coefficient value.

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