Water Absorption of HDPE/Al_2O_3,TiO_2 Composites

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Abstract

The water absorption of high density polyethylene filled with micro hybrid (titanium dioxide and alumina), alumina and titanium dioxide with weight ratio of 15%, 20%, 25% and 30% , are measured in order to study the effect of these particles on water absorption of this polymer. The result shows that the increase of content of filler particles increasing water absorption, because of filler particles which have a higher water absorption percentage than the matrix material, and the filler will take up the free volume within the polymer matrix and create a tortuous path for the water permeating through the sample.

Key word: water absorption, HDPE, composites, biomaterial

امتصاصية الماء لمتراكبات HDPE/Al_2O_3,TiO_2

الخلاصة

تم في هذا البحث دراسة الامتصاصية لعينات من متراكب البولي إيثيلين عالي الكثافة المدعم بثنائي أوكسيد التيتانيوم و الالومينا الهجينة والالومينا و أوكسيد التيتانيوم وبنسب وزنية 15%و20 % و25%و 30%، لغرض دراسة تأثير اضافة ثنائي أوكسيد التيتانيوم والالومينا على قيم الامتصاصية لهذه المتراكب. تشير النتائج الى ان الإمتصاصية تزداد بزيادة نسبة تركيز ثاني اوكسيد التيتانيوم و الالومينا الهجينية والألومينا واوكسيد التيتانيوم، بسبب أن جسيمات حشو لديها نسبة امتصاص الماء أعلى من المادة الاساس، والحشوات سوف تحتل حجم ضمن مصفوفة البوليمر وتخلق مسار متعرج لتخلل الماء خلال العينة.

Aim of the work

1. Study of water absorption for the prepared composite material used as biomaterials in pH like human body (PH= 6.3 like urine and pH =7.4 like plasma solution).
2. Studying the effect of weight fraction of filler on the diffusion coefficient of composites.

INTRODUCTION

A composite material can be defined as macroscopic combination of two or more materials (reinforcing elements, fillers, and composite matrix binder), differing in form, or composition on a macro scale. The constituents retain their identities, that is, they do not dissolve or merge completely into one another although they act in concert. Normally, the components can be physically identified and exhibit an interface between one another. A composite material is created from a

powder (or reinforcement) and an appropriate matrix material in order to maximize specific performance properties [1].

In addition, the constituent phases must be chemically dissimilar and separated by a distinct interface. Thus, most metallic alloys and many ceramics do not fit this definition because their multiple phases are formed as a consequence of natural phenomena. In designing composite materials, scientists and engineers have ingeniously combined various metals, ceramics, and polymers to produce new generation of extraordinary materials. Most composites have been created to improve combinations of mechanical characteristics such as stiffness, toughness, ambient and high - temperature strength [2].

Many composite materials are composed of just two phases: one is termed the matrix, which is continuous and surrounds the other phase, often called the dispersed phase. The properties of composites are a function of the properties of the constituent phases, their relative mounts, and the geometry of the dispersed phase. "Dispersed phase geometry" means the shape of the particles and the particle size, distribution, and orientation [3].

A. Hussein et al.,(2011) studied the water absorption of (high-density polyethylene/egg shell) composites as a function of egg shell(Egg shell is a biomaterial containing 95% by weight of calcium carbonate in the form of calcite and 5% by weight of organic materials, such as (Al2O3 , SiO2 , S, Cl , Cr2O3 , MnO) powder weight content. Polymer composite was fabricated by mixing (HDPE) with (5, 10, 15, 20, 25) Wt.% of egg shell powder to obtain desirable properties. It was found that the addition of egg shell powder to the polymer leads to increases the absorbed amount of water, by increasing the wt.% of egg shell constant exposure time[4].

Hanna et al. (2011), studied the water absorption a particulate composite material used for biomedical applications was prepared by adding ($CaCO_3$, CaO, $MgCO_3$, MgO) ceramic particles with particle size of (< 53 μm) to unsaturated polyester resin with weight fraction of (3, 6, 9, 12, 15) %.The results had revealed that the water absorption percentage increases with increasing weight fraction of all filler [5].

Diffusion

Diffusion can be defined as the process by which matter moves from one position to another in the system because of random molecular motion.

Diffusion occurs in all fluids, since their atoms are moving continuously, so these atoms change their positions continuously [6].

The weight change percentage of the diffusivity samples after each period of immersion is calculated from the relationship [7]

$$\text{Weight gain \%} = \frac{W2-w1}{w1} \times 100 \quad \ldots\ldots (1)$$

Where:

W_2: weight of immersed specimen.

W_1: weight of dry specimen.

The diffusion coefficient (D) is calculated from the equation (Fick 's second law):

$$D = \pi (Kt/4M_m)^2 \quad \ldots\ldots (2)$$

Where:

K: the slope of straight line of the curves, which represent the relationship between the weight gain percentage and square root of time (time) $^{0.5}$
t: the thickness of the specimen.
M_m :the apparent maximum water content.

Experimental part

Material Used

High density polyethylene as polymer matrix, the materials used as filler Titanium dioxide (TiO_2) and Aluminum oxide (Al_2O_3) with particle size 53 µm and 100 µm respectively.

Samples Preparation

Hot press technique was used to make homogenized polymer. A weight amount of the polymer HDPE was mixed with TiO_2 and Al_2O_3 powders in different percentages to obtain 3gm of the total weight for polymer and filler at 150°C and 100 bar until homogenized mixture attained. The List of samples prepared with different composition are shown in Tables (1), (2) and (3) and Fig. (1), (2) and (3).

Table (1): HDPE/Al_2O_3 Composites

Sample	HDPE	Al_2O_3
1	85%	15%
2	80%	20%
3	75%	25%
4	70%	30%

Table (2) :HDPE /TiO_2 Composites

Sample	HDPE	TiO_2
1	85%	15%
2	80%	20%
3	75%	25%
4	70%	30%

Table (3) :HDPE /Al_2O_3 /TiO_2 hybrid Composites

Sample	HDPE	Al_2O_3	TiO_2
1	85%	5%	10%
2	80%	10%	10%
3	75%	15%	10%
4	70%	20%	10%

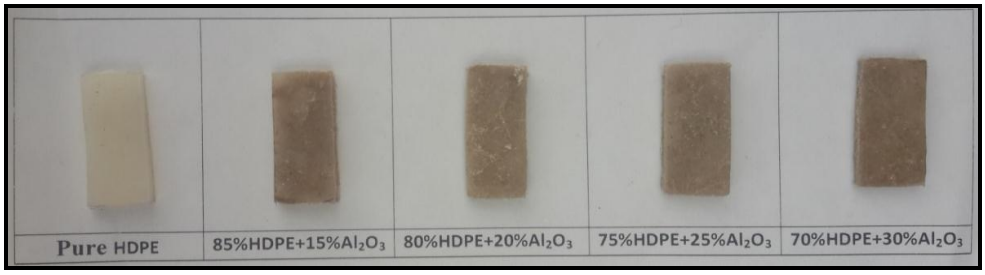
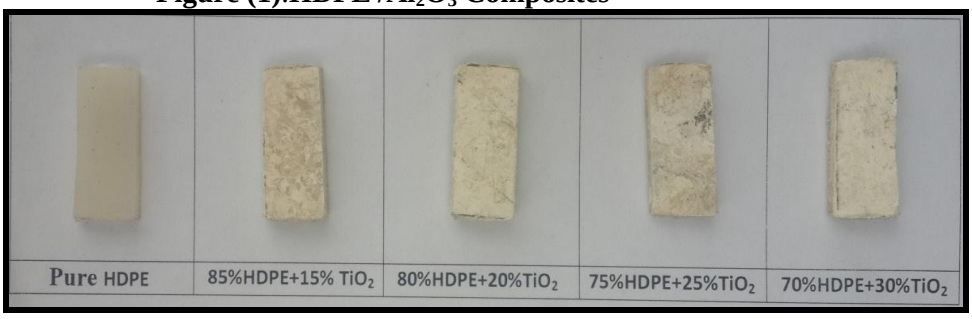


Figure (1):HDPE /Al_2O_3 Composites



Figure(2): HDPE/ TiO_2 Composites

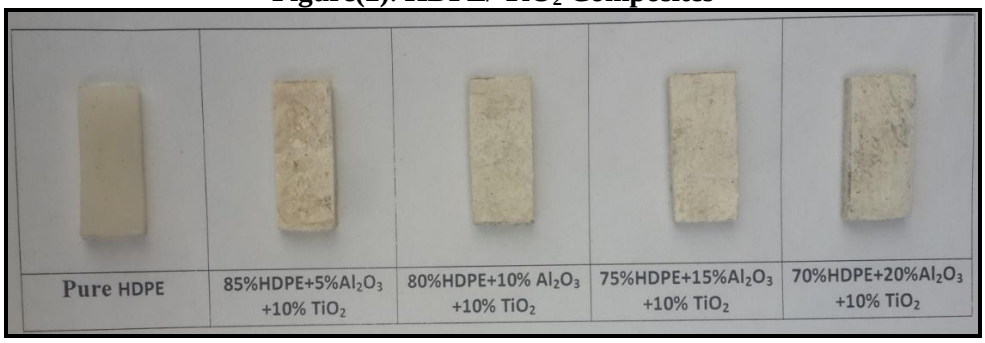


Figure (3):HDPE/Al_2O_3/TiO_2 Composites.

Water Absorption Test

In order to determine the coefficient of absorption, This test is performed according to (ASTM D 570-98) standard, The weight of all specimens was determined before they were immersed. Then all the specimens were immersed, in beakers containing two types of water with different pH (6.3 and 7.4) at 37^{o}C for 48 hour, the data were recorded every four hours to evaluate the weight gain for the immersed samples. Then by using equation (1), the variation in weight gain w_2 as a percentage of the original dried specimens were determined. Then from Fick's second law, diffusion coefficient can be determined by using equation (2) [7].

Results and discussion

All polymers absorb moisture in humid atmospheres and when immersed in water. Absorption processes often follow the predictions of Fick's law; the mass of water absorbed increases linearly with the square root of time, and then gradually slows until an equilibrium plateau is reached [8].

The transport of small molecules through a polymer membrane occurs due to random molecular motion of individual molecules. The driving force behind the transport process which involves sorption, diffusion and permeation are the

concentration difference between the two phases. The transport process slowly tries to equalize the concentration difference or the chemical potential of the penetrant in the phases separated by the membrane [9]. From the figures (4), (5), (6), (7), (10), (11), (12) and (13) which show the relation between the weight gain with the square root of time for immersion of unfilled HDPE and filled with Al_2O_3, TiO_2 and Hybrid (Al_2O_3 and TiO_2) fillers. Water absorption of HDPE is little because it's non polar. In case of composites, the higher absorption was due to the addition of (Al_2O_3) and (TiO_2) particles due to hydrophilic nature of these fillers which accelerates the penetration of water [10,11].

From the figure (8) ,(9), (14),(15) it is seen that the increases weight gain absorption and diffusion with increasing weight fraction, this increasing may be due to Al_2O_3 and TiO_2 particles which have a higher water absorption percentage than the matrix material [12], additionally, the porous structure of inorganic filler which increase with increasing in the weight percentage of the fillers ,this will take up the free volume within the polymer matrix and create a tortuous path for the permeating molecules, this increase in water absorption [13]. The diffusion of composites immersed in pH 6.3 is higher than pH 7.4 than because of the penetration of water through composites works to break down of linkages between the fillers and the polymer, these regions are centers permeate water within composites, especially when reduce pH and because Al_2O_3 can withstand acidic solutions [14].

The water absorption for HDPE/Al_2O_3 composites is higher than HDPE/TiO_2 and HDPE/Al_2O_3/TiO_2 composites because water absorption percentage of Al_2O_3 (0.08%), while TiO_2 (0.04%) [15] and because Al_2O_3 represented an acidic refractories [7].

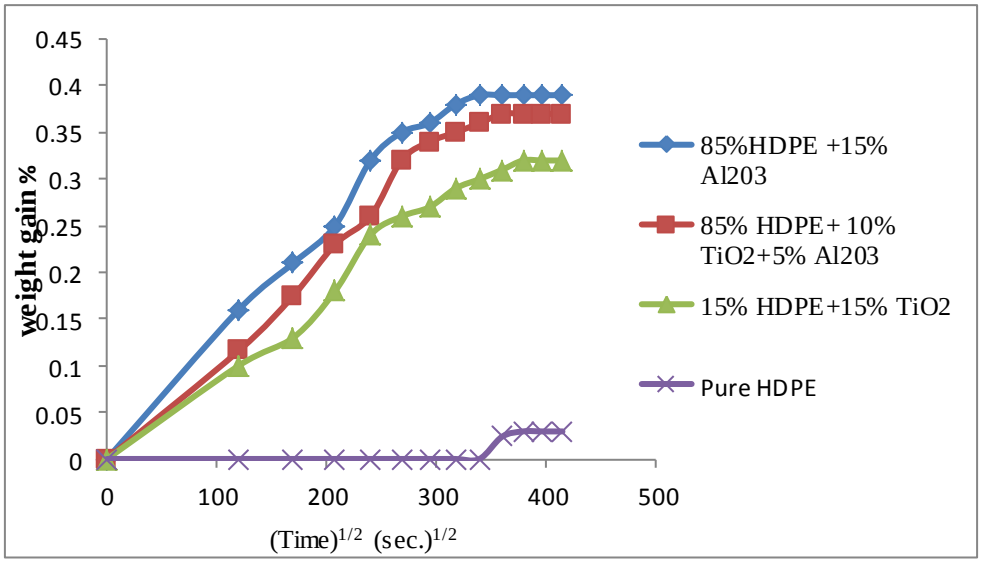


Figure (4): Weight gain vs. time of immersion at pH 6.3

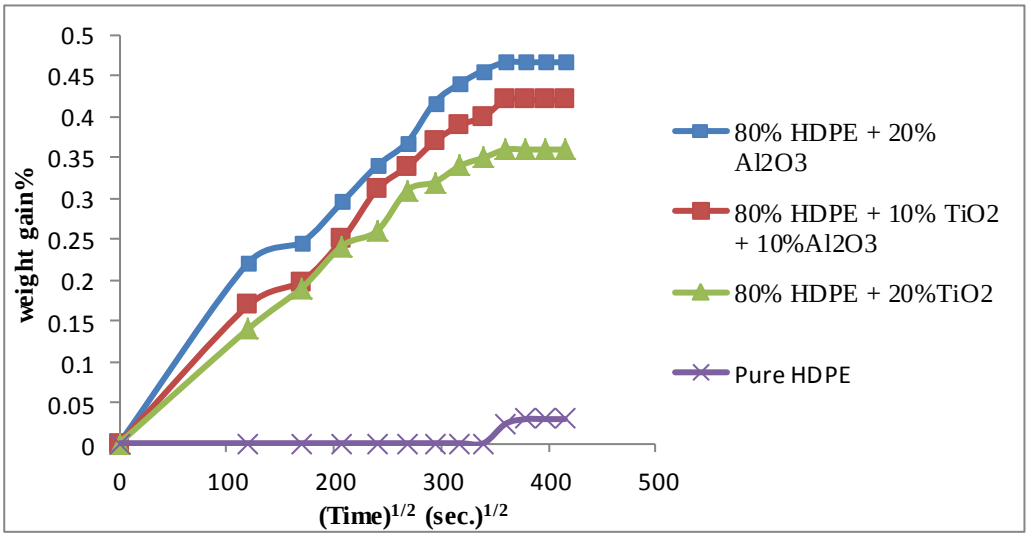


Figure (5): Weight gain vs. time of immersion at pH 6.3

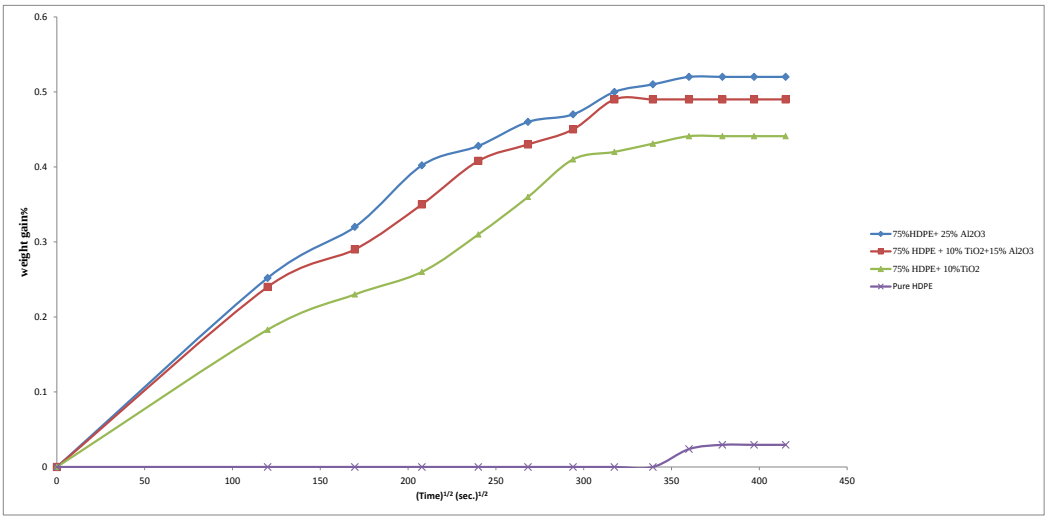


Figure (6): Weight gain vs. time of immersion at pH 6.3

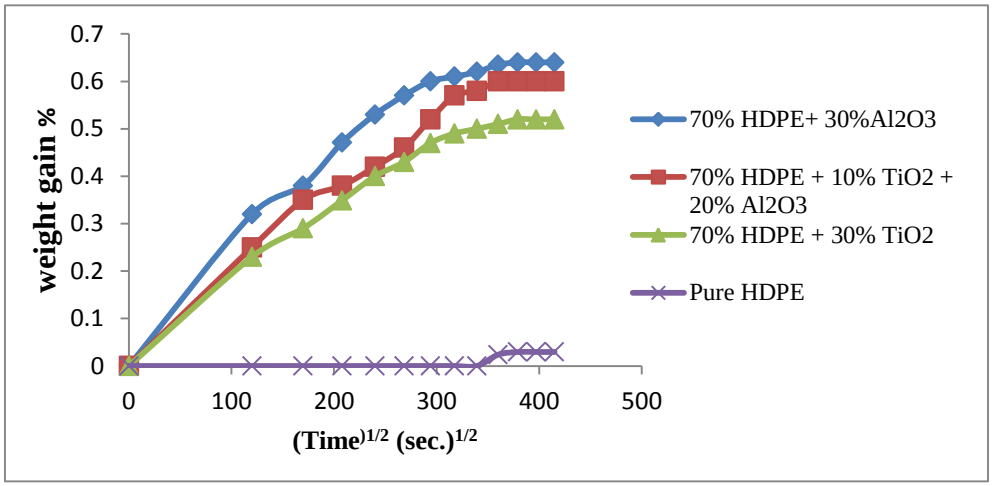


Figure (7): Weight gain vs. time of immersion at pH 6.3

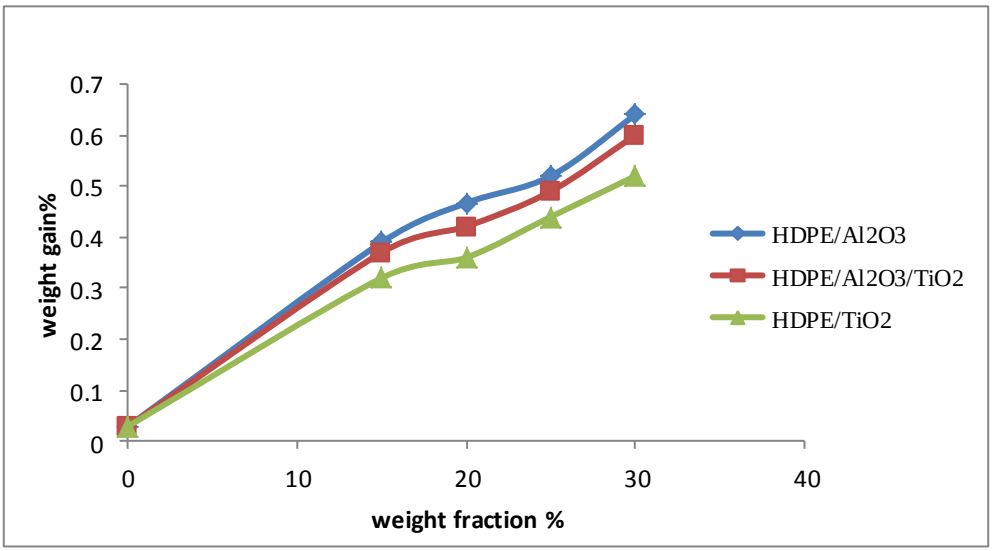


Figure (8) :Weight gain vs. Weight fraction at pH 6.3

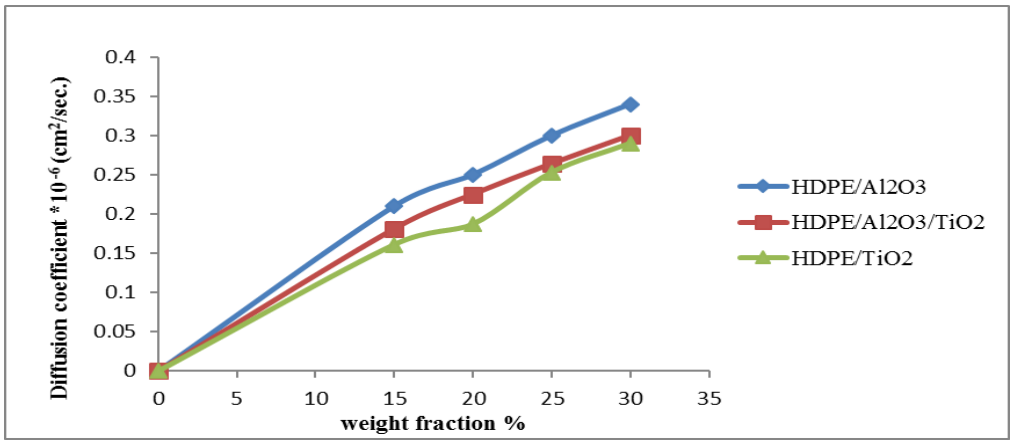


Figure (9): Diffusion coefficient vs. Weight fraction at 6.*3*

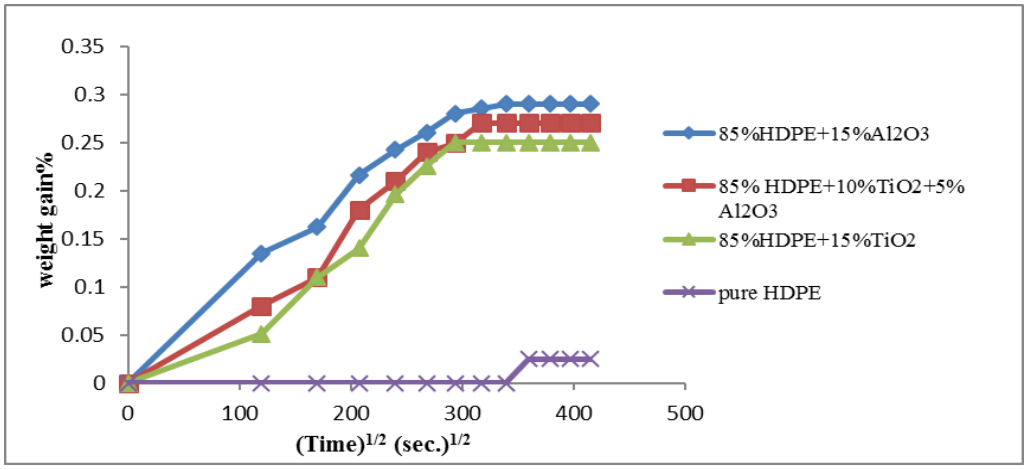


Figure (10) :weight gain vs. time of immersion at 7.4

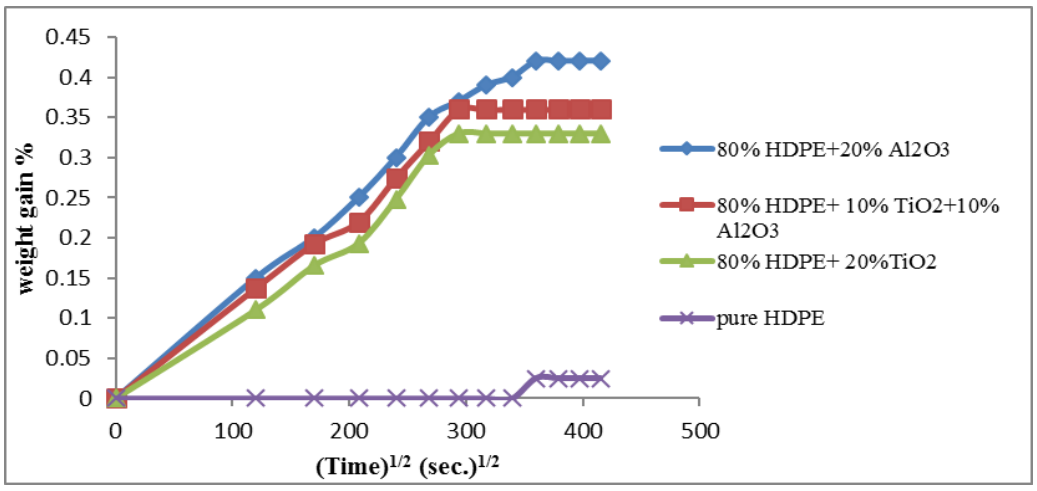


Figure (11) :Weight gain vs. time of immersion at 7.4

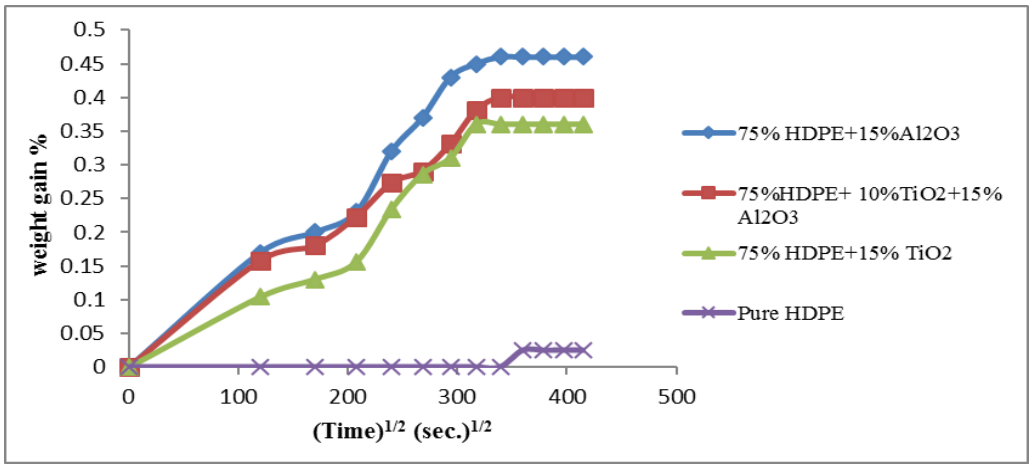


Figure (12): Weight gain vs. time of immersion at 7.*4*

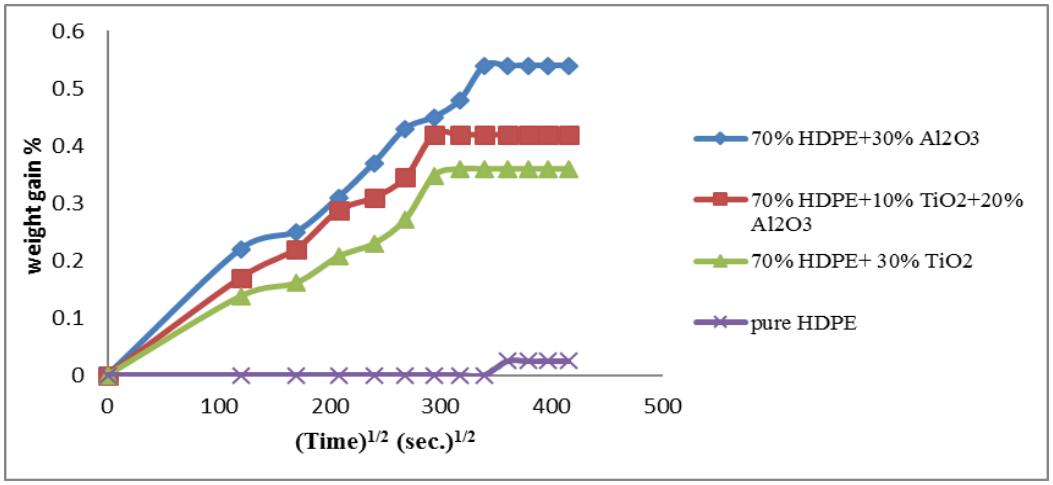


Figure (13): Weight gain vs. time of immersion at 7.4

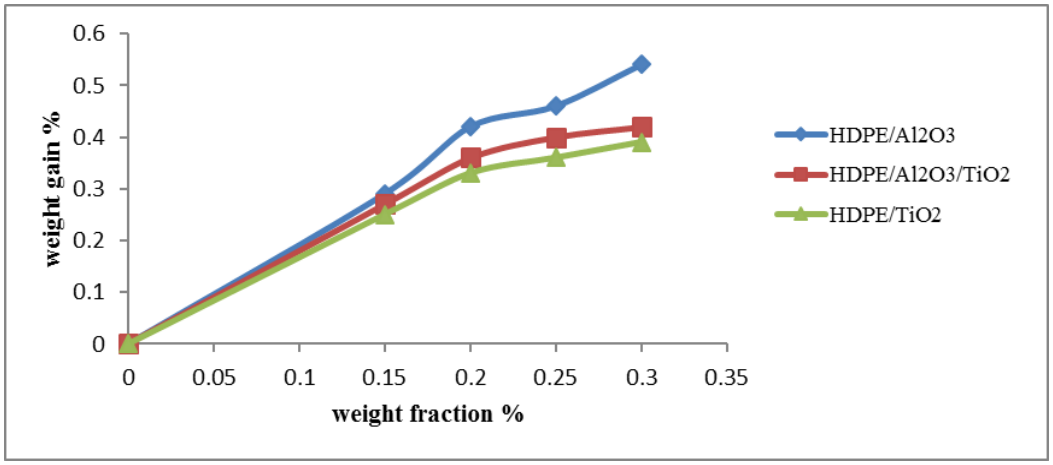


Figure (14): Weight gain vs. Weight fraction at 7.4

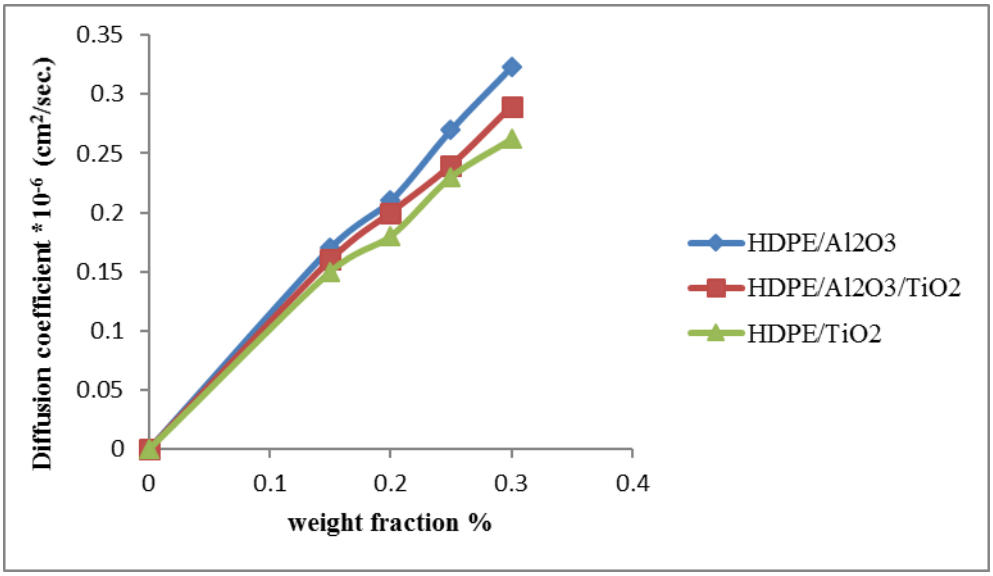


Figure (15):Diffusion coefficient vs. Weight fraction at 7.4.

Conclusions

1. Weight gain percentage increase with increase weight percentage of Al_2O_3 and TiO_2. .
2. Diffusion coefficient increase with increase weight percentage of Al_2O_3 and TiO_2.
3. Weight gain percentage of HDPE/Al_2O_3 composites was the highest compared with other prepared composites.

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