Open Access

Baghdad Science Journal **Vol.12(3)2015**

The Effect of nano particles of TiO_2-Al_2O_3 on the Mechanical properties of epoxy Hybrid nanocomposites

Khalid R. Al-Rawi ***Sarah Kh. Taha***

Physics department, College of Science for Women, University of Baghdad.
E-mail: alrawikad@csw.uobaghdad.edu.iq

Received 10, September, 2014
Accepted 2, November, 2014

Abstract:

Preparation of epoxy/ TiO_2 and epoxy/ Al_2O_3 nanocomposites is studed and investigated in this paper. The nano composites are processed by different nano fillers concentrations (0, 0.01, 0.02 ,0.03, 0.04 ,0.05 ,0.07 and 0.1 wt%). The particles sized of TiO_2,Al_2O_3 are about 20–50 nm.Epoxy resin and nano composites containing different shape nano fillers of (TiO_2:Al_2O_3 composites),are shear mixing with ratio 1 to 1,with different nano hybrid fillers concentrations(0.025 ,0.0 5 ,0.15 ,0.2, and 0.25 wt%) to Preparation of epoxy/ TiO_2- Al_2O_3 hybrid composites. The mechanical properties of nanocomposites such as bending ,wearing, and fatigue are investigated as mechanical properties.

Key words: Nanocomposite, Hybrid Epoxy/ TiO_2 - Al_2O_3, bending, wearing, fatigue.

Introduction:

The epoxy is one of the extensively used thermoset resins due to its ease of handling, molding and curing [1]. In composites technology, particulate organic and inorganic fillers are added into the polymers, may provide a good method to improve their physical, mechanical properties and reduce costs[2].For a long time that nanoparticles are used as fillers in polymer composite to improve the mechanical and physical properties of the polymer, such as nanoceramic (ZrO_2,Al_2O_3,TiO_2,SiO_2) [3].The epoxy resins are used in a variety of engineering applications since their properties, such as thermal stability, good mechanical response, low density and electrical insulator, can be varied considerably [4]. The Particles smaller than tens of nanometers in primary particle diameter (nanoparticles) are of interest for the synthesis of new materials because of their low melting point, special optical properties, high catalytic activity, and opaque mechanical properties compared with their bulk material counterpart interest in the development of nanocomposites consisting of organic polymers and (TiO_2) or (Al_2O_3) nanoparticles are growing[5].Organic-inorganic hybrid materials, especially polymer matrix composites with inorganic nanoscale building blocks, have drawn the widespread attention of researchers owing to the promise of combining the superior mechanical and thermal properties of inorganic phases with the flexibility and processibility of organic polymers [6]. The comprehensive performances of the nano composites depended on many factors, such as the intrinsic properties type of the polymers, the processing technology of the composites, the dispersion and concentration of the nanoparticles in the polymer matrix,size of nano particles and the interfacial compatibility between nanoparticles and the polymer matrix. The recent investigation has shown that the epoxy/nanocomposites improved both mechanical and dielectric properties compared with in case of pure resin system and epoxy with micrometer-size fillers at a lower loading concentration less than 9 wt%) [7].Both SiO_2 - Al_2O_3 and TiO_2 - Al_2O_3 nano fillers are used in many application nano fillers hybrid composites Epoxy resins modified with inorganic particles such as TiO_2, SiO_2, Al_2O_3, clay and so on have shown improved performances [8]. For inorganic/organic composites, the size of particles and the interfacial adhesion have great effect on the properties of the resin matrix. The well dispersed inorganic fillers in polymer matrices and compatibility between inorganic and organic phases are important to achieve an overall good performance[9,10]. The aim of this work is to prepar a new type of inorganic-polymer materials of epoxy nano composites with new mechanical properties

Materials and Methods:

Matrix Material

The material system used is a low viscosity epoxy resin type (conbextra EP-10),At room temperature curing and (Metaphenylene Diamine) hardener both supply by Fosrac Jordan company.

The filler that have been used are Titanium dioxide (TiO_2) and alumina (Al_2O_3)

Filler has been added to epoxy resin and it was mixed by ultrasonic device for two hour and then we put the mixture on pyromagnestir device for two hour too ,then hardner added to mixture and mix then cast the mixturein to the template.

Table (1-1) Materials properties

Materials	Density (g/cm$^{3)}$	Diameter (nm)	Surface area (m^2/g)	Purity %
Epoxy (EPLV)	1.04	-------------	-------------	-------
TiO_2		40-65	233	99.99
Al_2o_3		45-75	90-350	99.98

Flexural test

The flexural test adopted in this work was the three-point test in accordance with ASTM D-790 standard. The load was applied at a rate of 2 mm/min until a rupture occurred .A direct plot of load-deflection curve for each specimen tested was obtained on the x-y recorder. In similar manner to that followed in tensile test.. Flexural strength can be calculated from below eq.

$$F.S = \sigma_{\max} = \frac{3PS}{2B^2D}$$

Where :p the applied load (N) S: span (m) B: width (m) D: thickness (m)

In addition, Young modulus can be calculated from following eq.

$$E = \frac{PS^3}{4\delta BD^3}$$

Wearing test

The diameter of 40mm was used in all the tests. However, each test was run on a fresh track, a normal load of 7 newton and a sliding velocity of 0.98 m/s. A transducer attached to the dry wear tests of the epoxy composites were carried out on a pin-on-disc machine. As illustrated in Fig. 1, two composite pins were held against a rotating constant speed steel disc. A fixed track specimen holder recorded the tangential force. The volumetric wear was measured by the weight loss of a specimen using an analytical balance of resolution 0.01mg.The wearing characteristic was assessed by the weight loss, *W*, which was calculated by the following equation

$W = W_1 - W_2$

Where W_1 and W_2 are respectively the weight of a sample before and after its test.

Fatigue test

Interlaminar fatigue tests were performed according to ASTM-D3479 specimens using an HI-TECH LIMITED Model No.:HSM 19, SER. No. E280 computer controlled loading frame.The applied load was sinusoidal with a frequency of 2 Hz, with 2 mm deflection a maximal load of (*P*max) 9 N and a stress factor of (*R*) 0.2. specimens were tested from the composite and the and reinforced hybrid composite on room temperature . All fatigue specimens were tested using the same machine. The machine cycles the specimens to failure and the number of cycles-to-failure was recorded by computer data acquisition system.

Results:

Flexural test

The results in this test as shown in fig(2) & (3) reinforcing specimens give a high bending strength and high elasticity as compare with pure epoxy in case of reinforcing with TiO2 and Al_2O_3 but hybrid nanocomposite give low bending strength and low elasticity as compare with pure epoxy.TiO2 nanocomposite give a high bending strength at(0.04wt%) and high modulus of elasticity at(0.07wt%) ,and then return to decrease but Al_2O_3 nanocomposite give a high bending strength at(0.03wt%) and high modulus of elasticity at(0.05wt%) and then return to decrease on the other hand hybrid nanocomposite give a low bending strength and low modulus of elasticity per ratio as compare with pure epoxy . As the rigidity of nano filler particles is greater than that of epoxy resin, it can be expected that nano filler particles will assist in improving the mechanical properties of the composites. Small sand particle relative with larger surface area achieve better wetting which leads to better reinforcing ability and stiffer nano composite [11,12]

Wearing test :-

In this test reinforcing specimens give high wear resistance as compare with pure epoxy as shown in fig(4).TiO_2 nanocomposite give a high wear resistance at(0.07%) and then return to decrease but Al_2O_3 nanocomposite give a high wear resistance at(0.05%) ,on the other hand hybrid nanocomposite give a high wear resistance at(0.025%). This is probably due to the fact that epoxy can easily remove at sliding surfaces (contact area) but in the composite case the ceramic Nano particles act as a rough surface relative to the counterface against which they slide.

Fatigue test :-

In this test reinforcing specimens give high number of cycles as compare with pure epoxy as shown in fig(5).TiO_2 nanocomposite give a high number of cycles at(0.04wt%) but Al_2O_3 nanocomposite give a high number of cycles at(0.07%) and then return to decrease,on the other hand hybrid nanocomposite give a high number of cycles at(0.2wt%). It is observed that when fatigue tests are performed at high and low number of cycles, the repaired specimens can be affected by void rich regions created during repair. These voids are responsible for delaminations but, due to the low loads, the composite did not present catastrophic fracture but can most likely be affected by debonding. The debonding occurred randomly in the specimen before the rupture, but parallel to the fatigue loading direction.

When this kind of debonding propagation occurs, fatigue damage can be concentrated in one particular region of the specimen. As a consequence, that region will become weaker and critical[13]. Fig.6 show Atomic Force Microscopy (AFM) observation uniformity and three-dimensional surface profile of 0.03 TiO2 nanospheres in the nanocomposite . Fig.7 show Atomic Force Microscopy (AFM) observation uniformity and three-dimensional surface profile of 0.07 Al_2O_3 nanospheres in the nanocomposite .

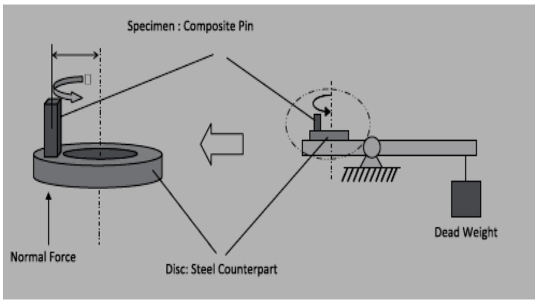

Fig.1 : The pin-on-disc wear test.

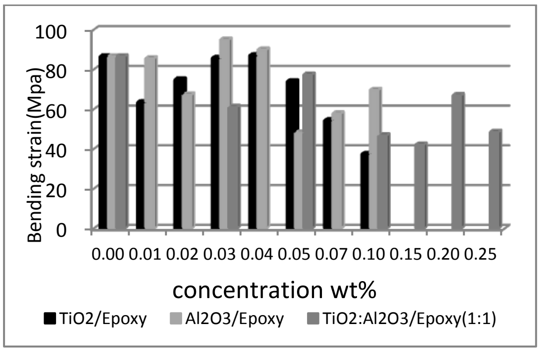

Fig.2 : The relation between Bending strain and concentration

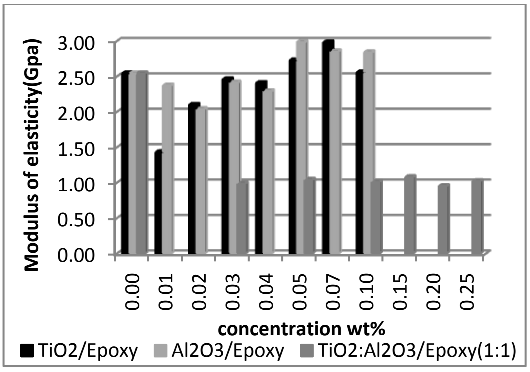

Fig.3 : The relation between modulus strain and concentration

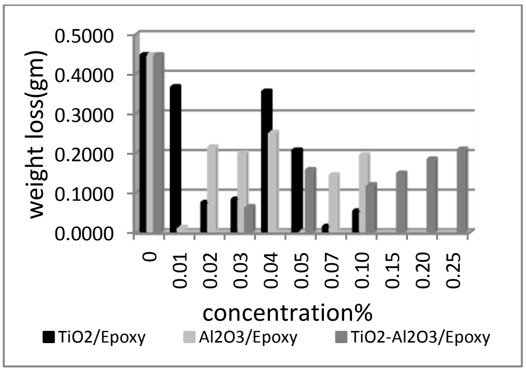

Fig4: The relation between weight loss and concentration.

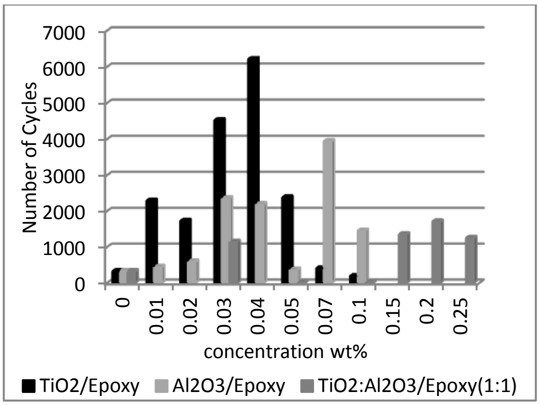

Fig.5 : The relation between Number of Cycles and concentration.

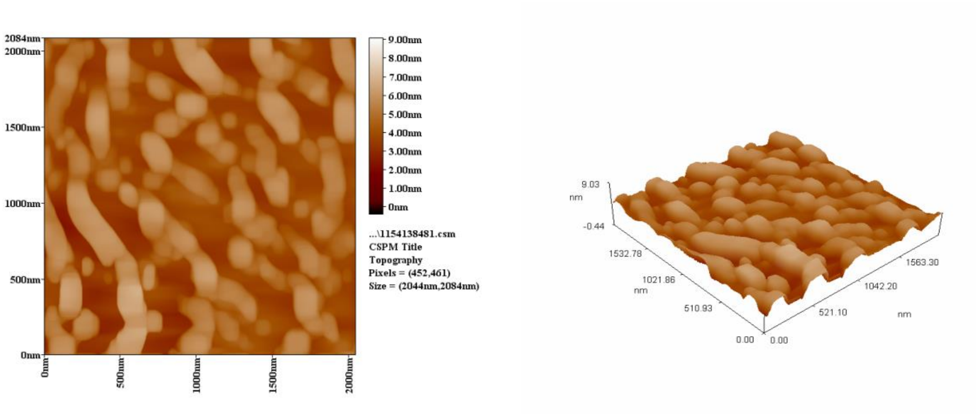

Fig. 6: AFM micrograph showed uniformity and a three-dimensional surface profile of 0.03 TiO2 nanospheres in the epoxy nanocomposite.

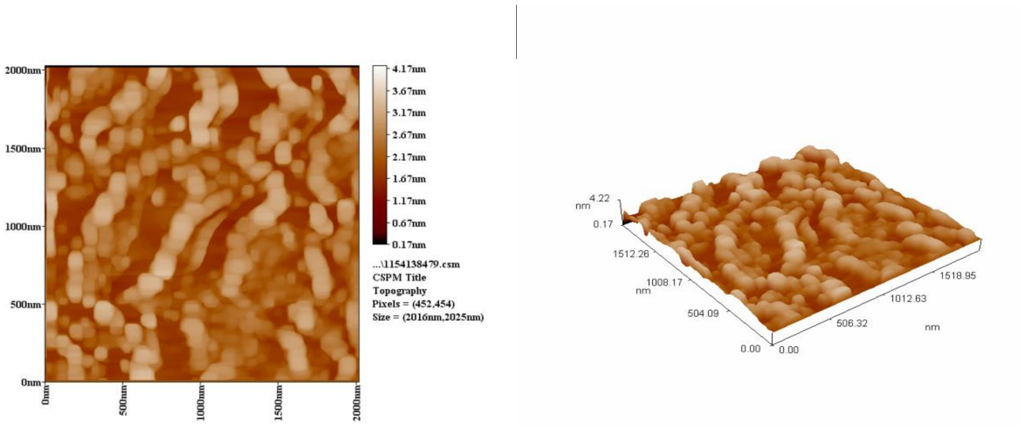

Fig. 7: AFM micrograph showed uniformity and a three-dimensional surface profile of 0.07 Al_2O_3 nanospheres in the epoxy nanocomposite.

Conclusion:

1- High bending strength and high elasticity as compare with pure epoxy in case of reinforcing with TiO2 and Al_2O_3 but hybrid nanocomposite give low bending strength and low elasticity as compare with pure epoxy.

2- hybrid nanocomposite give a high wear resistance at(0.25%).

3- Epoxy/TiO_2 nanocomposite give a high number of cycles at(0.04wt%).

References:

[1] Katz, H. S. and Milewskin, J. V. 1978. Handbook of fillers and reinforcements for Plastics. van Nostrand Reinhold, New York .

[2] Sare, I. R.; Mardel, J. I. and Hill, A. J. 2001. Wear-resistant metallic and elastomeric materials in the mining and mineral processing industries – an overview, Wear, 250,1–10 .

[3] Wang, Q.; Xue, Q.; Liu, W.; Shen, W. and Xu J. , 1996 . The effect of particle size of nanometer ZrO2 on the tribological behavior of PEEK. Wear; 198: 216 – 219.

[4] Thostenson, E. T. and Chou, T. W. 2006. Mechanical and thermal characterization of cooh-functionalized mwcnt inf used epon 862 nanocomposites, Carbon., 44: 3022.

[5] Joseph, J.; Tseng, C-Y.; Pan, C-J.; Chen, H-M.; Lin, C-W.; Pillai, K. C.; Hwang, B-J. 2010. Growing well-defined mono -dispersed silica in polyimide host

membranes using. A surfactant assisted sol-gel process Polymer, **51**, 5663–5669 5668.
[6] Park, J. J.; Kwon, S. S. and Lee, J. Y. 2011. Effect of Nano-silicate on the Mechanical, Electrical and Thermal Properties of Epoxy/Micro-silica Composite. Trans. Electr. Electron. Mater. 12: 135
[7] Singha, S. and Thomas, M. J. 2008. Dielectric properties epoxy nanocomposites. IEEE T. Dielect. El. In,15(1):2-3
[8] Wang*, Q. and Chen, G. 2012. Effect of nanofillers on the dielectric properties of epoxy nanocomposites. AMR, 1(1), 93-107 93.
[9] B. Fiedler, F. H. Gojny, M. H. G. Wichmann, M. C. M. Nolte,K. Schult, 2006. Compos. Sci. Technol., 66, 3115.
[10] Singh, R. P.; Zhang, M.; Chan, D. 2002. Toughening of a brittle thermosetting polymer: effects of reinforcement particle size and volume fraction. J Mater Sci,37:781–8.
[11] Sumita, M.; Ookuma, T.; Miyasaka, K. and Ishikawa, K. 1982. Preparation and Properties of Natural Sand Particles Reinforced Epoxy Composites. J. Mater. Sci., 17,2869.
[12] Li, B.; Zhang, X.; Gao, J. et al., 2010. Epoxy based Nano composites s with fully exfoliated unmodited clay: mechanical and thermal properties. JNN, 10(9):5864-5868.
[13] Roudet, F., Desplanques, Y., Degallaix, S., 2002. Fatigue of Glass/Epoxy Composite in Three-point-bending with Predominant Shering. lgf, 24 : 327-337.

تأثير جسيمات ثنائي اوكسيد التيتانيوم النانوي والالومينا النانوية على الخصائص الميكانيكية للمتراكب النانوي الهجيني

خالد رشاد الراوي **سارة خضير طه**

قسم الفيزياء – كلية العلوم للبنات – جامعة بغداد

الخلاصة :
لقد تم في هذا البحث تحضير ودراسة متراكب ايبوكسي- ثنائي اوكسيد التيتانيوم والايبوكسي – الومينا فقد حضر المتراكب النانوي بتراكيز وزنية مختلفة وهي %(0.1،0.07،0.05،0.04،0.03،0.02،0.01) وكان الحجم الحبيبي لدقائق ثنائي اوكسيد التيتانيوم والالومينا يتراوح بين20-50 نانومتر ،وقد تم خلط ومزج دقائق ثنائي اوكسيد التيتانيوم والالومينا معا مع الايبوكسي بنسبة 1:1 وبتراكيز وزنية مختلفة %(0.25،0.2،0.15،0.1،0.05،0.025) لتحضير المتراكب الهجين ايبوكسي / ثنائي اوكسيد التيتانيوم والالومينا وقد اجريت الاختبارات الميكانيكية للمتراكب النانوي مثل اختبار الانحناء والبلى والكلال للتحقق من الخصائص الميكانيكية

الكلمات المفتاحية : متراكب ايبوكسي- ثنائي اوكسيد التيتانيوم، الايبوكسي – الومينا، اختبار الانحناء، البلى، الكلال، الخصائص الميكانيكية.