



## Study the of effect of micro and nanoCadmium Oxide on the hardness test of (epoxy-polyurethane) blend

Ghasaq Talal Suhail\*<sup>1</sup>, Faik Hammad Anter<sup>1</sup>, Ziyad Shihab Al-Sarraj<sup>2</sup>

<sup>1</sup>Department of Physics, College of Sciences, Anbar University, Anbar, Iraq

<sup>2</sup>Department of Materials Research, Ministry of Science and Technology, Baghdad, Iraq

### Abstract

This research includes using epoxy resin and polyurethane resin to form a blend (EP+PU) with different resin ratios (90 – 10)%, (80 – 20)%, (70 – 30)%, and (60 – 40)% to achieve best ratio for impact strength as a function of better toughness; then reinforced with micro and nano (CdO) with weight fraction (0.02, 0.04, 0.06, 0.08). Mechanical properties were studied including hardness before and after exposure to UV irradiation. Results showed that the composite (nano CdO+ blend) had better properties compared with (micro CdO+ blend) composite. Also hardness show increases with increasing the weight fraction for all samples.

**Keywords:** micro, nano, cadmium oxide, hardness test, epoxy, polyurethane.

## دراسة تأثير اوكسيد الكادميوم المايكروي والنانوي على اختبار الصلادة لخليط (الايبوكسي-البولي يوريثين)

غسق طلال سهيل\*<sup>1</sup>، فائق حماد عنتر<sup>1</sup>، زياد شهاب السراج<sup>2</sup>

<sup>1</sup> قسم الفيزياء ، كلية العلوم ، جامعة الانبار ، الانبار ، العراق

<sup>2</sup> قسم بحوث المواد ، وزارة العلوم والتكنولوجيا ، بغداد ، العراق

### الخلاصة

يتضمن هذا البحث استخدام راتنج الإيبوكسي وراتنج البولي يوريثين لتشكيل مزيج (ايبوكسي+بولي يوريثين) مع نسب راتنج مختلفة (90 – 10) % ، (80 – 20) % ، (70 – 30) % ، (60 – 40) % وتم تعيين النسبة الافضل من خلال حساب متانة الصدمة التي هي دالة لمتانة المادة واعتماد هذه النسبة لتدعيمها بمادة اوكسيد الكادميوم الدقائق والنانوي (CdO) بنسب وزنية (0.02 ، 0.04 ، 0.06 ، 0.08). تمت دراسة الصلادة قبل وبعد التعرض للأشعة فوق البنفسجية. أظهرت النتائج أن المركب (نانو CdO + الخليط) له خصائص أفضل مقارنة مع مركب (دقائق CdO + الخليط). كما ان قيم الصلادة تزداد مع زيادة النسب الوزنية لجميع العينات.

### Introduction

The great industries and technological development in the world need to find new materials with good properties which are light weight materials with high mechanical specifications and give the durability and flexibility of material. In addition, resistance to different environmental conditions, economical and suitable in industrial products like airplanes, cars ,and engineering applications and other engineering designs, are manufactured of composite material[1].

\*Email: gasak.talal90@gmail.com

Polymer blends are materials composed of mixing two or more polymers joined with each other in order to combine the characteristics of the individual materials [2].

Nano composites are composite materials with "nanos", which means extremely small particles [3]. Materials are especially important due to their bridging role between the world of thermal conducting polymers and inorganic materials. Nanomaterials have at least one dimension smaller than 100 nm. Compared with micro-size materials and bulk materials according to International System of Unit, the transition of microparticles to nanoparticles yields dramatic changes in physical properties. The nanomaterials have good properties as larger surface areas. The surface area per unit volume is inversely proportional to the particle diameter[4].

Cadmium oxide is a chemical composite that has the formula CdO, dark brown, FCC-like crystalline structure which is also similar to the crystalline structure of NaCl [5,6], and the Lattice constant of cadmium oxide is equal to  $(4.69\text{\AA})$ , Its molecular weight (128.2g / m), density (8.15gm /  $\text{cm}^3$ ) and high melting point (1773 C<sup>o</sup>), it is a material that dissolves in acids and does not dissolve in alkali [7,8]. Cadmium oxide has a relatively large energy gap ranging from 2.18 to 2.7 eV. Cadmium oxide can be obtained directly from the extreme heating of the cadmium [9,10]. Note that cadmium is decomposed at high temperatures [11,12].

Nano cadmium oxide is chemical composite with small particle size attracted great interest in recent years because of their unique chemical and physical properties, which are different from those of either the bulk materials or single atoms [13]. In recent years, researchers have focused on nano cadmium oxide (nanoCdO) due to its applications, specifically in the field of optoelectronic devices such as solar cells [14,15], photo transistors [16] and diodes [17], transparent electrodes [18], gas sensors, etc. These applications of nanoCdO are based on its specific optical and electrical properties [19].

The hardness of a material is its resistance to penetration under a localized pressure, in other words, hardness is a measure of a material's resistance to plastic deformation [20, 21].

In (2000), Harith I. J, the plates were made of epoxy and polyurethane (EP 80%/PU 20%) by simultaneous mixing method. Also, sheets of composites were prepared by hand lay-up technique. The fracture toughness of polymer blend reinforced by glass fiber, where Gradually added 20% of polyurethane to increase the elasticity of the polymer and decrease the resistance to fracture [22].

KH.R.AL-Rawi et al 2006, Binary blends have been formed for epoxy (EP) and polyurethane (PU), the concentration was chosen to give 4 compatible thermoset-thermoset blends (80-20, 60-40, 40-60, 20-80) EP-PU. Mechanically tested by Charpy test either as prepared or after being heat treated, aged at 75c for 3, 6, and 9 hrs. The results showed that the increment and/ or decrement of impact toughness depend on blend concentration, and thermal aging to some (EP + PU) blends [23].

In (2010), Ban A. Y, used of Epoxy and Novolac resins mixed with either polyurthane (PU) or polysulphide (PSR) rubbers to compose ternary polymer blends. These polymeric blends are the matrix reinforced with (TiO<sub>2</sub>) powder with volume fraction of (10%). Results show that samples of blends reinforced with (TiO<sub>2</sub>) powder possess better mechanical properties of impact strength, tensile strength, compression strength, hardness and wear resistance [24].

In (2017), Rana M. S, some mechanical and physical properties (i.e. the impact strength, hardness, flexural strength, thermal conductivity and diffusion coefficient) of (epoxy / polyurethane) blend reinforced with nano silica powder (2% wt.). Results showed that water had affected the bending flexural strength and hardness, while impact strength increased and thermal conductivity decreased [25].

In 2017, Abdul-Adheem Zuily studied some physical, mechanical and image analyses of (EP/Al<sub>2</sub>O<sub>3</sub> & EP/TiO<sub>2</sub>) and hybrid composite ,as well as the effect of chemical solution and UV irradiation on some physical mechanical properties. He shows the hardness increases when weight fraction increase [21].

## 1. Matrix materials

### 1.1 Epoxy resin (EP)

Epoxy resin used in this work is Sikadur - 105 which has two components, low viscosity epoxy resin system in the form of transparent liquid (which transforms into solid state after adding the hardener to it in a percentage of (2:1).

## 1.2 Polyurethane resin(PU)

Polyurethane in this study (PU) which has two components composed of a base resin and curing agent (hardener), low viscosity polyurethane system in the form of transparent liquid, which transforms into solid state after adding the hardener to it in a ratio (1:2). Which supplied by Fosroc Company, United Kingdom. It has density equal to (1.1-1.3)gm/cm<sup>3</sup>.

## 2. Reinforcing materials

### Micro Cadmium oxide (micro CdO)

Micro Cadmium Oxide powder (CdO) (USSR), prepared from a company (REACHIM). With particle size (20µm) the micro (CdO) powder and the specifications show in the Table-1.

### Nano Cadmium oxide (nanoCdO)

Cadmium Oxide Nano Particles (CdO) powder (CdO Nano Powder) prepared from a company (SIGMA –ALDRICH, USA), with density (8.15g/cm<sup>3</sup>) powder and the specifications show in the Table-1.

**Table 1**-specifications of nano and micro Cadmium Oxide by the manufacturer

Product	N CdO	M CdO
Density	8.15g/cm <sup>3</sup>	8.15g/cm <sup>3</sup>
Purity	>99.9%	99%
Particle Size	10-30 nm	20µm
Molecular weight	128.41 g/mol	128 g/mol
Type Color	Dark brown	brown
Melting point	900-1000°C	-

## Sample preparation

Method was used hand layup method in the preparation of the samples, and summarized by the following steps: -

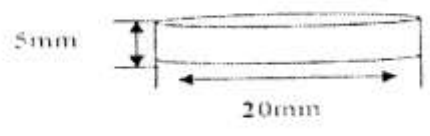
- First: the metal panels must be cleaned before you start the process of sample preparation and glass used for removal of suspended solids and then thoroughly washed with soap and water, and then placed in the oven (60-50) ° C for (10-20) minutes for drying.
- Second: preparing the polymer blend in the proportions selected, as follows: -
  - 1- Prepare Epoxy resin and its hardener in the ratio (2:1).
  - 2 - Prepare polyurethane resin with its hardener in the ratio (2:1) to mixing with epoxy with the certain percentage (90 EP/10 PU , 80 EP/20 PU, 70 EP/30 PU, 60 EP/40 PU ) %.
- Third : preparing the composite materials with the selected ratios, as follows: -
  - 1- Prepare the best polymer blend by tested by impact strength which it is function of better toughness and choose the optimum ratio (80-20)% from epoxy and polyurethane as matrix.
  - 2- Prepare the reinforcement materials in the particulate and nano (CdO) with weight fraction (2, 4, 6, 8)wt% mixing additive materials and matrix at room temperature. In a special pot mixing by the electric mixer to a maximum of (1 – 10) min, The cured time takes (48) hours to hard and then put in oven with temperature 50 °C for 2 hours to complete the formability.

## Hardness Test Results Discussion

The hardness is a measure of resistance to penetration at the surface of materials and, hence, will not be greatly affected by the matrix [26]. Sample's dimensions shows in the Table-2.

**Table 2**-Sample's dimensions and standard specification

Test	Sample's dimensions	Standard Specifications
------	---------------------	-------------------------

hardness		according to specification of instrument
----------	---	--

Shore (D) method used to measure the hardness of samples in natural condition, after exposure to UV irradiation (24h). The experimental results for all samples are shown in subsequent tables.

Practical result of hardness value of particulate and nano (CdO ) composites are shown in Table-3 in natural condition(N.C) and Table-4 after exposure (24h) to UV irradiation . From Figure-1 and Figure-2 we notice that the hardness increases with increasing the weight fraction for all samples.

This result belongs to the role of the foundation of filler particles which can be described by the interaction between outer surface of polymer and particles giving an increase in effective the complicated linkage density, abounding between large molecules and surface of particles can be treated as adding cross link in a researching in this field supported by research [27].

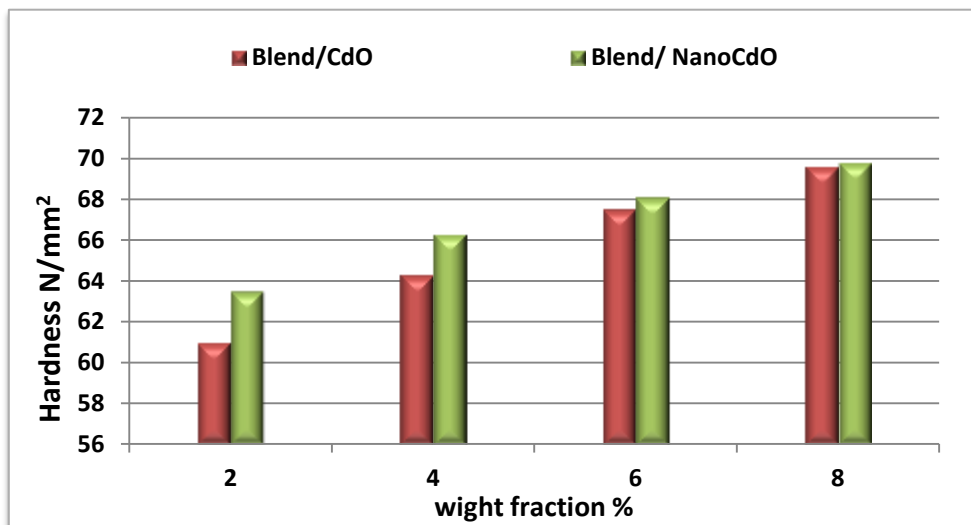
For particulate and Nano (CdO) in (N.C) case we see from Table-3 and Figure-1 that the hardness increases with increasing the weight fraction .

The value of hardness for particulate (CdO ) increases from (61N/mm<sup>2</sup>) at(2%) weight fraction (wt%), to value (69.6 N/mm<sup>2</sup>) at (8%) weight fraction(wt), while for Nano (CdO) the hardness increases from (63.5 N/mm<sup>2</sup>) at (2%) to value (69.8 N/mm<sup>2</sup>) at (8%) weight fraction (wt), We notice from Figure-1 that the value of hardness for (Nano CdO) samples more than that of particulate (CdO) for the same weight fraction.

The reason of that is related to the grain size of Nano particle which permeates into the matrix (Ep+ PU). This helped to increase the stacking of composite material prepared and reduced movement of polymer molecules, resulting in increased resistance to scratching or cutting material and thereby increase a material hardness. This consistently agrees with [28].

**Table 3**-Hardness value for particle and Nano of ( CdO ) samplesat natural condition

Wight Fraction Wt%	Hardness (N/mm <sup>2</sup> )	
	CdO	Nano CdO
( 2 +98 Blend )	61	63.5
( 4 + 96 Blend )	64.3	66.3
( 6 + 94 Blend )	67.5	68.1
( 8 + 92 Blend )	69.6	69.8



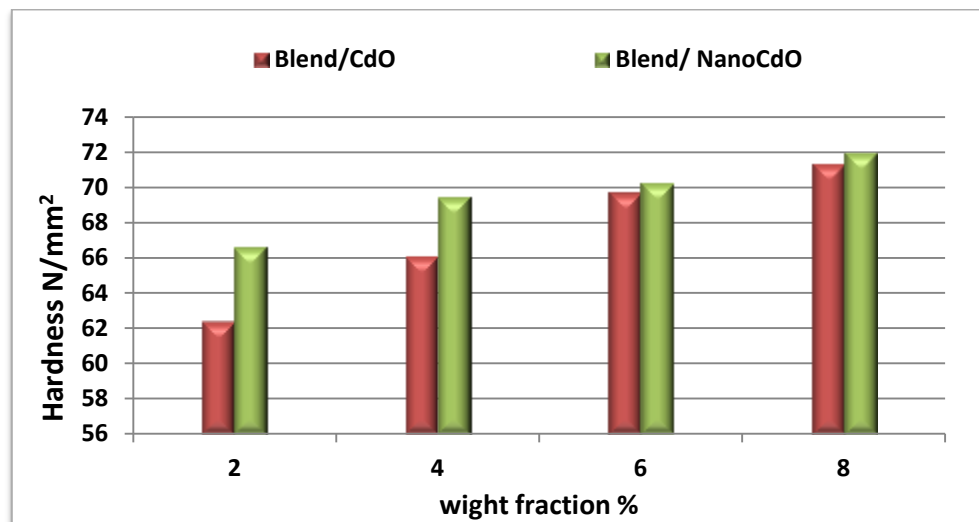
**Figure 1**-the Hardness value relation with weight fraction for particles and nano (CdO + Blend) at natural condition.

In the case of UV irradiation the value of hardness for particulate (CdO ) increases from ( $62.42\text{N/mm}^2$ ) at(2%) weight fraction (wt%), to value ( $71.34\text{ N/mm}^2$ ) at (8%) weight fraction(wt), while for Nano (CdO) the hardness increases from ( $66.67\text{ N/mm}^2$ ) at (2%) to value ( $72.01\text{ N/mm}^2$ ) at (8%) weight fraction (wt), as shows in Table-4 and Figure-2.

In the case of UV irradiation for the time interval (24 h) . From Table-4, and Figure-2, we find that the hardness value for all samples exposure to UV irradiation are more than that in natural condition where the values of hardness have increased after irradiation. This is due to the function of ultraviolet radiation, which gives a similar function of heat treatment by increasing the tangles and increasing the thickness. Thus, increased hardness of the surface of the material also belongs to reform and recombine the polymer chain reorientation of polarization [28] .

**Table 4-**Shown Hardness value for particle and Nano of (CdO) samples exposure to UV

Wight Fraction Wt%	Hardness (N/mm <sup>2</sup> )	
	CdO	Nano CdO
( 2 +98 Blend )	62.42	66.67
( 4 + 96 Blend )	66.13	69.5
( 6 + 94 Blend )	69.71	70.3
( 8 + 92 Blend )	71.34	72.01



**Figure 2-**the Hardness value relation with weight fraction for particles and nano(CdO + Blend) exposure to UV

### Conclusions

Hardness increases with increasing the weight fraction for (micro and Nano CdO/blend) in natural condition after irradiation by(UV). Value of hardness for (Nano CdO) samples is more than that of particulate (CdO). For the same weight fraction values in the case of UV radiation are higher than values in natural condition.

### References

1. Mikell P. Groover, **1996**. *Fundamentals of Modern Manufacturing*. Prentice- Hall, Upper Saddle River, New Jersey.
2. Wells, J. K. and Beaumont, P. W. **1982**. Debonding and pull-out processes in fibrous composites. *J. Materials Science*. **17**(2): 397-405.

3. Mathew, L. **2009**. Development of Elastomeric Hybrid Composite Based on Synthesized Nanosilica and Short Nylon Fiber. Ph.D. thesis, Department of Polymer Science and Rubber Technology Cochin University of Science and Technology.
4. Pascault, J.P., Sautereau, H., Verdu, J., Williams, R.J.J. **2002**. *Thermosetting polymers*. Marcel Dekker, New York.
5. Atheer, R. and alkhfagy, I.A. **2007**. Oxidation of cadmium thin films and studying some physical properties. Thesis from university of technology.
6. Cotton, F.A., Wilkinson, G., Murillo, C.A. and Bochmann, M. **1999**. *In Advanced Inorganic Chemistry*. John Wiley & Sons.
7. Hartnagel, H.L., Dawar, A.L. and Jain, A.K. **1995**. *Semiconducting Transparent Thin Films*. (Institute of Physics Publishing, Bristol).
8. Sirbu, D. et.al. **2011**. Microstructure, wettability and optical characteristics of ZnO/In<sub>2</sub>O<sub>3</sub> thin films. *Materials Science and Engineering B.*, **176**: 266–270.
9. Karunakaran, C. and Dhanalakshmi, R. **2009**. Selectivity in photocatalysis by particulate semiconductors. *Central European Journal of Chemistry*, **7**(1): 134. doi:10.2478/s11532-008-0083-7(2009).
10. Barote, M.A. **2014**. LPG Sensing Properties of Spray Deposited CdO Thin Films. *Indian Journal of Applied Research*, **4**, ISSN - 2249-555X.(2014)
11. Gurumurugana, K., Mangalaraj, D., A.K. Narayandassa, A.K., Y. Nakanishib, Y. **1996**. DC reactive magnetron sputtered CdO thin films. *Materials Letters*, **28**: 307–312.
12. Subramanyam, T.K., Uthanna, S. and Naidu, B.S. **1998**. Preparation and characterization of CdO films deposited by dc magnetron reactive sputtering. *Materials Letters*, **35**(3-4): 214–220.
13. Trindade, T., Brien, P.O. and Pickett, N.L. **2001**. *Chem. Mater.* **13**: 3843-3858.
14. Sravani, C., Reddy, K.T.R., Md. Hussain, O. and Reddy, P.J. **1996**. Solar Energy. *Soc. India*, **1**(6).
15. Su, L.M., Grote, N. and Schmitt, F. **1984**. *Electron. Lett.* **20**: 716.
16. Kondo, R., Okimura, H. and Sakai, Y. **1971**. *Jpn. J. Appl. Phys.* **10**: 1547.
17. Benko, F.A. and Koffyberg, F.P. **1986**. *Solid State Commun.* **57**: 901.
18. Shiori Jpn. **1997**. Patent No. 7(909)
19. Lide, D.R. **2001**. (Ed.), *CRC Handbook of Chemistry and Physics*, 77 thedn., CRC Press, Boca Raton, 1996/1997, 3/278, p. 12/97.3843.
20. Zhong, K. and Li, B. **2017**. *Polymer Nanocomposites for Dielectrics*. 1<sup>st</sup> Ed, CRC press, Taylor and Francis group, p. 208.
21. Abdul-AdheemZuaily Al-Mersomy. **2017**. Study of Some Physical, Mechanical and Image Analysis For (EP/Al<sub>2</sub>O<sub>3</sub>, EP/TiO<sub>2</sub>) and Hybrid Composites. Ph.D. Thesis, University of Anbar, College of Science, (2017).
22. Harith, I. **2000**. Investigation of interlaminar toughness of reinforced polymer blend. Ph.D. Thesis, University of Baghdad, College of Science.
23. AL-Rawi, Kh. R. and Yousif, R.H. and Najem, T.S. **2006**. Mechanical properties of epoxy-polyurethane polymer blends. *Um-Salama Science Journal*, **3**(4).
24. Yousif, B.A. **2010**. Development and characterization of ternary thermosetting polymer blends. Ph.D. Thesis, University of Technology, Department of applied sciences.
25. Rana M. S. **2017**. Effect of water absorption on some mechanical and physical properties of epoxy/polyurethane blend reinforced with nano silica powder. *Iraqi Journal of Physics*, **15**(32): 92-98.
26. Wetzel, B., Rossa, P., Hanpert, F. and Friedrieh, K. **2006**. Epoxy Nano composite, Fracture and Toughening Mechanism. *Journal of Engineering Fracture Mechanics, University of Technology, Germany*, **73**: 2375-2398.
27. Sapuan, M. and Maleque, A. **2003**. Mechanical properties of Epoxy/Coconut Shell Particles Composites. *The Arabian Journal for science and Engineering*, **28**: 480-490.
28. Rai S. K., Prakash S. D. Ravi, Ramakrishna H., Rajulu, V. and Varada, A. **2003**. Alignate/Poly(vinyl alcohol) Blend in Water by Viscosity, Ultrasonic, and Refractive Index Methods. *Journal of Applied Polymer Science, Wiley Periodicals Inc*, **90**: 33-39.