Egypt. J. Chem. **Vol. 66**, No. 8 pp. 339 – 345 (2023)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

The Effect of Addition Nanosilica on Mechanical Properties of Poly (methyl methacrylate)

Mohammed Amin Alabadi[a,*], S.M.Thahab[b], Iman Jaber Alshaibani,[a]

[a]*Materials Engineering Department, Faculty of Engineering, University of Kufa, Iraq*
[b] *Nanotechnology and Advanced Material Research Unit, Faculty of Engineering, University of Kufa, Iraq*

Abstract

This research focuses on using silica nanoparticles prepared from rice husk ash and commercial nano silica to successfully produce PMMA/Sio_2 nanocomposite with various Sio_2 weight loadings (0.05, 0.1, and 0.15 % wt.). The samples were manufactured by utilizing an ultrasonic machine and a solution mixing. The characterization of the resulting PMMA/Sio_2 nanocomposites were investigated using hardness, impact testing, flexural strength, and SEM.. The results showed that the best value percentage of RH is (0.05wt%) for Impact strength and (0.05wt%) for flexural strength, which gives the highest strength .and The best value percentages that gives the highest strengths for NP is (0.05wt%) for Impact strength and (0.1wt%) for flexural strength. SEM were also tested to find the structure of Sio_2 and dispersion quality.

Keywords: . Polymethylmethacrylate, nanosilica, impact, hardness, flexural transverse, SEM

1. Introduction

Over the last two decades, composites research has resulted in the creation of qualities in materials that include not just parent materials but also traditional micro composites[1][2]. Composite materials are hybrid materials that combine several matrices with diverse fillers/reinforcements having at least one dimension in the micro nanometer scale[3]. The dispersion of the various fillers inside the polymer matrices results in significant interfacial contacts between the organic and inorganic phases, resulting in an interfacial material with a distinct shape and superior characteristics compared to the bulk polymer phase. As a result, even at low filler loadings, significant increases in composite characteristics may be observed[4]. One of the primary disadvantages of polymers in industrial applications is their poor surface properties. The purpose of incorporating various forms of filler into a polymer matrix was to improve the required physical and mechanical characteristics of polymer composites[5] .In prosthetic dentistry, polymethylmethacrylate (PMMA) is one of the most commonly utilized materials. It offers a straightforward manipulation process, a low price, and a pleasing aesthetic result. PMMA-based materials can be used to create less bulky and cost-effective dentures that can be modified and corrected as needed. Denture wearers' most common complaint is a broken denture, according to physicians. It could be caused by the induced stiffness of the denture base prosthesis as a result of long-term fatigue failure caused by repeated masticatory stresses, or by excessive extra oral forces generated by the prosthesis's inadvertent prognosis [6] .the dental materials must have excellent properties and good

*Corresponding author e-mail: alibadimohammd@gmail.com; (Mohammed Amin Alabadi)
Received date 08 February 2022; revised date 27 February 2022; accepted date 13 March 2022
DOI: 10.21608/ejchem.2022.120635.5419

biological activity to function properly [7]. According to previous researches, 67 percent of dentures are ruined within a few years of manufacturing [8]. Researchers should concentrate on preparing and producing a material with exceptional mechanical qualities in order to improve the quality and properties of denture bases. The use of Nanosilica in conjunction with PMMA has been tested. Nanomaterials are distinguished by their small size, large surface area, and high surface area to volume ratio [9]. PMMA has been effectively combined with silica nanoparticles. Several experimental experiments have revealed significant influences on these materials' mechanical characteristics [10]. However, if the inappropriate type or dose of nanoparticles is used, mechanical properties may suffer [11].

The goal of this study was to investigate how two type of Nano silica affected the mechanical properties of PMMA matrix .such as flexural transverse strength test, impact test and hardness test. Characteristics of Sio_2 Prepared from rice husks were further studied using XRD and the SEM to reveal dispersion of Nano silica inside PMMA matrix.

2. Experimental Work

2.1. Materials Used

The used PMMA were purchased from Otto bock Health care made in the German with boiling point of 212.9 °C, . Nano silica was purchased from Changsha Santech Co. with purity equal to 99.8%, true density of 2.4 g/cm3, Melting point of 1610°C and the particle size is 30 nm, and silica was prepared from Rice Husk using The precipitation method involves refluxing silica from Rice husk ash in boiled solution (2.0 N NaOH) (in Nanotechnology and Advanced Materials Research Unit , Faculty of Engineering, University of Kufa, Najaf,IRAQ).

2.2. *Methods*

Preparation of Polymer and silica Nanocomposite

The polymer was dissolved with acetone as solvent (15 ml solvent / 150 mg weight)

To calculate the weight of the nanoparticles that are added to the polymer matrix, the following equation (1) was used:

$$V_f = \frac{\frac{W_m}{\rho_m}}{\frac{W_m}{\rho_m}+\frac{W_p}{\rho_p}} \quad (1)$$

The nano-particles (NP-RH) were introduced at 0.05, 0.1, and 0.15 percent by weight to liquid (PMMA), and the nano-filler was thoroughly disseminated in the monomer for three minutes using an ultrasonic mixing device (1200W),with a quality sound-proof chamber and stainless steel elevating platform .It is designed for disperse liquid with a small quantity, homogenize liquid phase from co-precipitation and mix multi chemical in one solution more efficiently than any other method as shown in fig.1.

Two different metal molds were used to prepare the test samples. The first mold measuring 65 mm×10 mm×2.5 mm (length, width and height respectively) was used to prepare the samples to be tested for transverse flexural strength and surface hardness. The other mold measuring 63.5 mm×12.7 mm×2.5 mm (length, width and height respectively) was used to prepare samples for impact strength test .

The prepared mixtures were packed in a rectangular mold in standard shown in Fig. 2. The samples were deflasked and cleaned from impurities. The specimens were alternately polished with silicon carbide (SiC) papers, at different grits to attain soft edges shown in Fig. 3. The ASTM (D256-04) impact specimen is the industry standard (ASTM, 2010)[12].

Fig. 1: ultrasonic mixing device

Fig. 2: Mold preparation

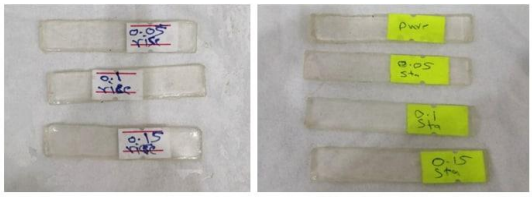

Fig. 3: Pure PMMA and their nanocomposite samples were tested for each mass fraction of Sio_2.

3. Results and discussion

3.1. Characterization of Silica-RH.

3.1.1. Field emission scanning electron microscopy

Figure (4) shows the SEM photographs which displays morphology and the particle size of the silica nanoparticles synthesized from Rice husk. the average particles size of the nano silica was found at (24.7 nm) for as shown in Fig. 4b .The nano silica particles produced were irregular and jagged and do not show clear boundaries as they are in agglomerate and amorphous form and The agglomeration effect may be due to the dominance of strong cohesive intramolecular forces instead of gravitational force can be observed. Therefore, SEM data confirmed that the size of the silica particles synthesized from rice husk is in the nano range (1-100 nm)[13].

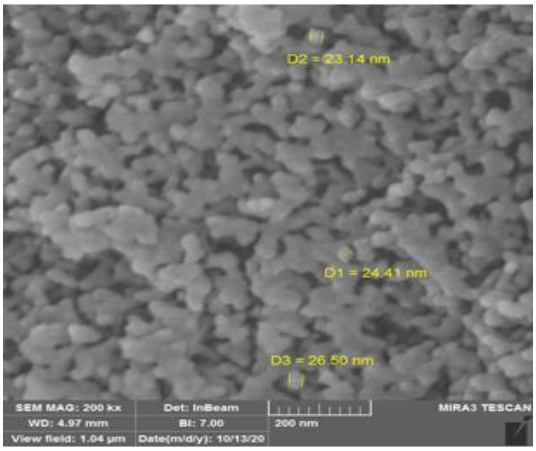

Fig. 4. SEM images of Sio_2-RH

3.1.2. X-ray diffraction nano silica-RH

An X-ray powder deviation pattern of precipitated SiO2 is shown in Figure (5). The spectrum for SiO_2 (RH) is exhibited as a broad band with the Bragg angle (2) = (31.6°), indicating that the crystal material. The presence of strong peaks indicates that the produced silica has a regular crystal structure[14].

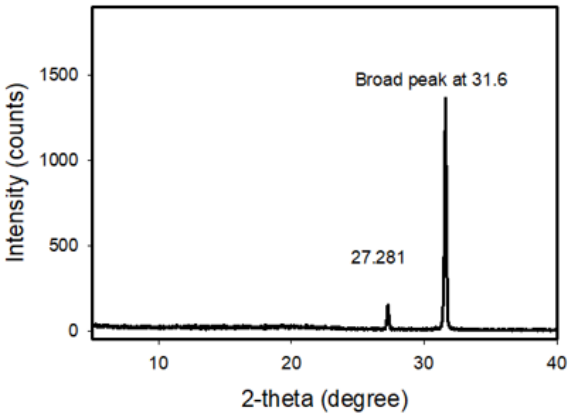

Fig. 5. XRD pattern for SiO_2 –RH

3.2. Characterization of PMMA/Sio_2 composite.

3.2.1. Microstructure analysis of nanocomposites.

The micrographs of the PMMA are shown in Figure 6A. The micrographs revealed a porous structure made up primarily of big pores. Numerous cracks were also discovered, indicating that the interaction process had not been completed, explaining the control mixture's weak hardness and strength[15].

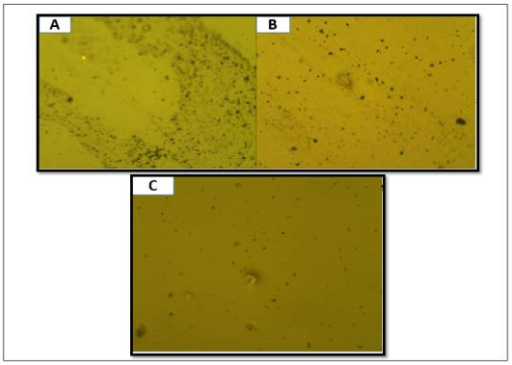

Fig. 6. Microstructure images with magnification power (50x) A- PMMA ; B- PMMA with NP ; C- PMMA with RH

Fig.6B shows micrographs of PMMA-NP prepared with 0.05 wt percent NP, size 30 nm, and Fig.6C shows micrographs of PMMA-RH prepared with 0.05 wt percent RH. It demonstrates that the

microstructure was dense and well structured, with small holes. There was a cohesive body structure with a lack of voids and cavities. In comparison to the control specimen, the structure was more uniform and homogeneous, demonstrating the material's exceptional strength. The material's apparent strength can be due to the high activity of nanoparticles, which help to stabilize the filler/matrix interphase and enhance structural connections[15].

3.2.2. Theory of Modification

Tables 1, 2 and 3 illustrate the effects of adding nanoparticles on the mechanical characteristics of PMMA. The variation of results in the tables can be explained by the variety of particle sizes distributed by NPs, variable concentrations of additional nanoparticles .The early fracture of resin composites is well known to occur at the NPs/matrix interphase. The surface area of the filler grows as the particle size decreases, resulting in huge surface energy in the interphase. As the particle size of the NPs decreases, the stress concentration at the NPs/matrix interphase decreases, resulting in better flexural strength of the related composites[16].

Table 1. Effect of (NPs) add on Impact strength

N.	Sio_2 wt%	impact	Improvement Percentage of Impact (%)
1	0	0.9	-
2	0.05 NP	1.2	25
3	0.1 NP	0.95	5.5
4	0.15 NP	1.1	22.2
5	0.05 RH	0.99	10
6	0.1 RH	0.96	6.6
7	0.15 RH	0.98	8.8

Table 2. Effect of (NPs) add on Flexural Transverse strength

N.	Sio_2 wt%	Flexural Transverse strength	Improvement Percentage of flexural transverse (%)
1	0	0.28	-
2	0.05 NP	0.48	71
3	0.1 NP	0.51	82
4	0.15 NP	0.42	50
5	0.05 RH	0.37	32
6	0.1 RH	0.31	10.7
7	0.15 RH	0.36	28.5

Table 3. Effect of (NPs) add on Surface hardness

N.	Sio_2 wt%	average Surface hardness	Improvement Percentage of hardness (%)
1	0	76.1	-
2	0.05 NP	78.1	2.6
3	0.1 NP	70.2	-7.7
4	0.15 NP	78.0	2.5
5	0.05 RH	70.4	-7.5
6	0.1 RH	78.7	3.4
7	0.15 RH	69.3	-8.9

3.2.2.1. Effect of (NPs) add on Impact strength development of PMMA

The impact strength is shown in Fig.7 after adding various doses of NP and RH. The PMMA with NP at various percentages demonstrated stronger impact strength than the control group (0 percent NP). This could be owing to the nano particles' micro-filling action, which fills the spaces and holes of PMMA with nano particles.

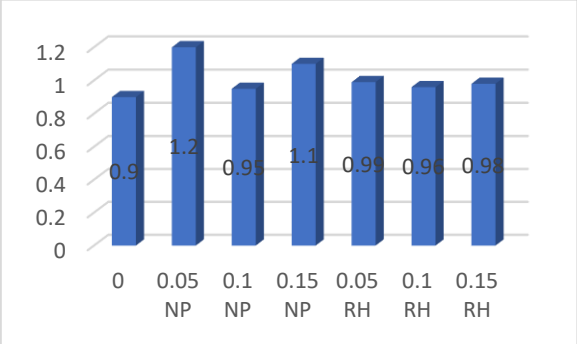

Fig. 7. Effect of NPs percentage on Impact strength

Different percentages of NPs were used to make PMMA-NPs. The mixtures containing 0.05 percent NP had a higher impact strength than the counterparts.

At the same particle size, the addition of 0.15 percent NP resulted in a lower impact strength . The reason for this is that raising the percentage of nanoparticles up to the optimum dose causes agglomeration of NPs due to the effective affinity of NPs to aggregate; nevertheless, nano-fillers are difficult to homogeneously scatter in polymers using standard procedures[17].

3.2.2.2. Effect of (NPs) add on flexural transverse strength development of PMMA

The flexural test was carried out in accordance with (ASTM D790) and (ADA Specification No.12, 1999) using the same tensile machine at an across head speed (strain rate) of (5 mm/min) and a weight of (5 kN) until the specimen was broken[18] .Figure (8) depicts the trend of increasing flexural transverse strength as the NPs percentage approaches the optimal value. Examining the transverse strength of PMMA-NS made with various percentages of NPs, it was discovered that with 0.05 percent NP, the transverse strength was 0.48 MPa, while with 0.1 percent NP, the transverse strength was 0.51 MPa. This confirmed that increasing the ratio of NPS to the optimum % boosts composite strength. It was also clear that adding NPs had much better results than adding 0 percent NPs. The interfacial strength between nanoparticles and matrix formed by cross-link bonding covering the nanoparticle fillers, which prevents fracture propagation, is responsible for the increased strength[19][20].

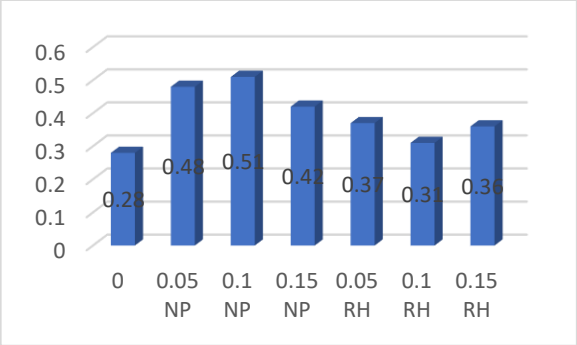

Fig. 8. Effect of NPs percentage on flexural transverse strength

3.2.2.3. Effect of (NPs) add on Surface hardness development of PMMA

Hardness is measured with an indentation charge and describes a material's resistance to plastic deformation.by taking an average of three measurements for each specimen at different points on the surface of specimens. The amount of filler loading in the polymer matrix and the dispersion uniformity of nano silica inside the material were found to be related to the increase in hardness of reinforced PMMA in the current investigation Figure (9). The increase in cross-linking density, which made the polymer more stiff and resistant to penetration, could possibly explain the nanocomposite's increased hardness. Due to nanoparticle dispersion in polymer, there is a minor increase in hardness since few nanoparticles are on the top and lower surfaces of the samples [21]. This study's small improvement in hardness may be consistent with the results of another study in which SiO2 nanoparticles were added to PMMA at a weight percentage of 5%[17].

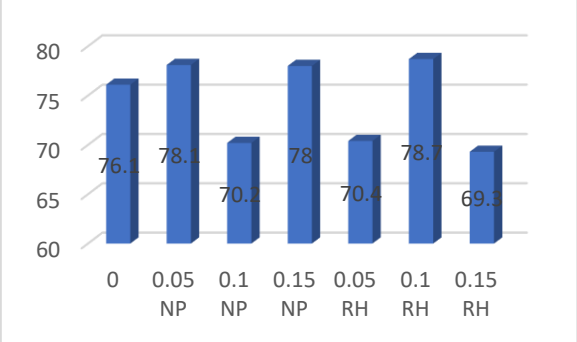

Fig. 9. Effect of NPs percentage on Surface hardness

3.2.3. SEM of PMMA/Sio$_2$ composite.

Fig. 10 shows SEM images of PMMA containing different nanoparticles. A difference is observed because of variation in the amount of the additive and this is due to agglomeration winning in the polymer matrix[22].

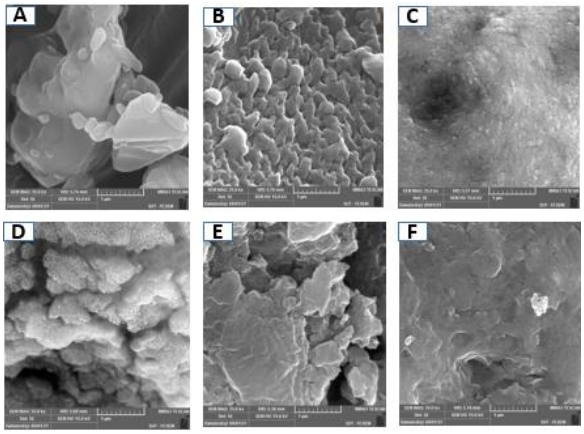

Fig. 10. Representative scanning electron microscopy images of specimens (A) 0.05% NP, (B) 0.1% NP, (C) 0.15% NP, and (D) 0.05% RH, (E) 0.1% RH, (F) 0.05% RH.

4. Conclusions

The current study has concluded that:

1. The present investigation was lead to assess and compare the impact of incorporation of two type of Nano silica to PMMA on mechanical properties of acrylic denture base.

2. PMMA with silica nanoparticles fillers enhances their mechanical properties (including impact strength flexural strength , and surface hardness) when compared with conventional PMMA .

3. Within the add ranges and particle size examined for RH fillers, the best value percentage of RH is (0.05wt%) for Impact strength and (0.05wt%) for Flexural strength, which gives the highest strength .

4. The best value percentages that gives the highest strength for NP is (0.05wt%) for Impact strength and (0.1wt%) for Flexural strength.

5. Acknowledgments

The authors would like to thank everyone who has helped to complete this work, especially, the employees of the Nanotechnology and Advanced Materials Research Unit/ Faculty of Engineering/ University of Kufa

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