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Nano composites of PAM Reinforced with Al_2O_3

Balqees M. Al-dabbag [1] ***Hanaa Jawad Kadhim*** [2*]

[1]Department of Applied Science, University of Technology, Baghdad, Iraq.
[2]Polymer Engineering Department, College of Materials Engineering, University of Babylon, Babylon, Iraq.
*Corresponding author: mat.hanua.jawad@uobabylon.edu.iq
E-mail address: 100007@uotechnology.edu.iq

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Abstract:

The aim of this investigation is to determine how different weight percentages of alumina nanoparticles, including 0.02, 0.04, and 0.06 percent wt, affect the physical characteristics of Poly Acrylamide (PAAM). Using a hot plate magnetic stirrer, 10 g of poly acrylamide powder was dissolved in 90 g of di-ionized distillate water for 4 hours to produce PAAM with a concentration of 0.11 g/ml. Four sections of the resulting solution, each with a volume of 20 ml, were created. Each solution was added independently with alumina nanoparticles in different ratios 0.0, 0.02, 0.04, and 0.06 to create four nano fluid solutions with different alumina nanoparticle contents based on each weight percent. The hand casting process for nanocomposites samples, which entailed pouring the prepared solution into an appropriate plastic mold, allowing it to cure for 24 hours, and then cutting the resulting thin film according to each test, was used to create the nano composited membranes. The tensile test was used to study tensile strength, Young's modulus, elongation, and toughness. Additionally, a test using Fourier transition infrared radiation (FTIR) was conducted to examine the chemical and physical connections between polyacrylamide and alumina nanoparticles. The morphology of the materials was examined using scan electron microscopy. The contact angles of samples were tested to limit the hydrophilicity behavior of these samples. To control the hydrophilicity behavior of these samples, the contact angles of the samples were evaluated. The results showed that including alumina nanoparticles into the PAAM matrix improves the mechanical characteristics of the resulting nanocomposites. Tensile strength increases from 1 GPa to 2.5 GPa with an increase in alumina nanoparticle content from 0 to 0.06 percent wt. For the same prior ratios, Young's modulus likewise increased, rising from 1.3 to 2 GPa. For the higher weight ratio of alumina nanoparticles (0.04 percent wt), toughness rises to 240 J/cm2. On the other hand, the addition of alumina nanoparticles increased the PAAM surface's contact angle from 55 degrees to 67 degrees, and it exhibited hydrophilic behavior

Keywords: Alumina nanoparticles, Nanocomposite, PAAM, Physical properties, Tensile.

Introduction:

Materials known as nanocomposites mix nanoparticles with a matrix of basic material. The nanomaterials are added to the basic materials in order to enhance their properties and get additional qualities for the new nanocomposites materials that are produced. The addition of nanoparticles improved the mechanical, thermal, optical, and antibacterial properties of nanocomposites because dimensionality significantly influences material properties [1-6] Water-repellent or water-repellent qualities are how materials react to water [7-8]. In contrast to hydrophobic materials, which tend to reject water and have self-cleaning surfaces, hydrophilic materials tend to form hydrogen bonds with water and have a contact angle of less than 90 degrees [9-10]. The nanoscale has a diameter of around 10^{-9} m, which is an extremely small range in material size and corresponds to the atomic level of matter. The characteristics of materials are improved by reducing their dimension and increasing their surface energy, which results in a nanocomposite that is more homogeneous and integrated with the matrix materials [11]. Nanocomposites are employed in storage regions that depend on storage capacity for a variety of applications, including shock protection and greater durability. The biological and antibacterial properties of nanoparticles are essential to biological domains[12]. Numerous studies in various branches of nanotechnology have been published, such as the use of nano-TiO2 as anti-bacterial food packaging materials by Rehim and Alhamidi[13], whose also evaluate the use of TiO_2 nanoparticles for Enviro nmental cleaning [13]. Ricardo J et al [14], they prepared an simple and cheap nanocomposote of copper incorporated with bio cellulose polymer for antibacterial activity versus *Staphylococcus aureus and Klebsiella pneumonia,* they concluded the activity of antibacterial increased with increasing the copper content in nanocomposites [13]. Shokry J [14], studied the zinc oxide nanoparticles as novel materials for antibacterial nanocomposites membrane as wound dress. In 2013, Ricardo J [14], prepared a straightforward and inexpensive copper nanocomposote with biocellulose polymer for antibacterial activity against Staphylococcus aureus and Klebsiella pneumonia. They came to the conclusion that the antibacterial activity increased with increasing the copper content in nanocomposites[14]. Zinc oxide nanoparticles were investigated by Shokry J [14] as innovative materials for antibacterial nanocomposites membrane as wound dressing. For testing, they used various weight ratios ranging from 5% to 30% w/v to the nanocomposites that had been created. In this search, SEM, FTIR, XRD, and antibacterial activities were evaluated. They come to the conclusion that the antibacterial activity enhanced as ZnO nanoparticle content in nanocomposites increased [15]. Using polyacrylic acid and kaolin nanoparticles, Barbooti [15], investigated the fabrication and characterisation of nano composite thin films for removing heavy metals from water. The use of nano kaolin improves the mechanical qualities (tensile strength, shore D hardness, and workability). Additionally, sorption effectiveness was investigated. The following conditions were ideal for the maximum sorption efficiency: pH: 10.0 g L-1 of sorbent and 100 minutes of contact [16].

Materials and Method:

As a white powder with medium Mw, (N251) and Nonionic type, polyacrylamide (C_3H_5NO) was employed as a matrix material. It is a biomaterial with hydrophilic properties. The SIGMA Aldrich manufacturer supplied nano-Al_2O_3 with a purity of 99.7% and a diameter of 100 nm, and di-ionized distilled water was used as the solvent. 10 grams of polyacrylamide powder were dissolved in 90 grams of di-ionized distill water using a hot plate magnetic stirrer for four hours, yielding concentrations of polyacrylamide of 0.11 g/ml. The resulting mixture was divided into 5 portions, each 20 ml in volume. For the purpose of creating four nanofluid solutions with various alumina nanoparticle contents in accordance with each weight percentage, alumina nanoparticles in varied ratios 0.0, 0.02, 0.04, and 0.06 were combined with each solution independently. The nano composited membranes were made using the hand casting process for nanocomposites samples, which involved pouring the prepared solution into the appropriate plastic mold and letting it sit for 24 hours to cure. The membranes were then cut to size for each test (tensile test with dimensions of 2 x 5 cm2, FTIR, SEM, and contact angle with dimensions of 1 x 1 cm^2).

Results and Discussions:

FTIR analysis

Fig.1 displays the FTIR spectra of pure PAAM and the resulting nanocomposite membrane enhanced with 0.06 percent Al_2O_3. We can observe the absorption peak at 3600 cm^{-1}, which is caused by the polyacrylamide's NH_2 stretching vibrations, as well as peaks at 1048 to 1600 cm^{-1}, which are caused by the amide I C=O stretching, the amide II N-H deformation, and the amide's C-N stretching, and three minor peaks at 2930, 1447, and 1414 cm^{-1}, which are caused, respectively, by the polyacrylamide's C-H [17]. Alumina nanoparticles act as a cross-linker between Polyacrylamide chains, allowing for more diffusion between them, as seen in SEM images of nanocomposites sample reinforced with 0.6 percent of nano alumina in Fig2. c. The black curve represents the FTIR spectrum of (Polyacrylamide + 0.6 percent wt Al_2O_3)[18]

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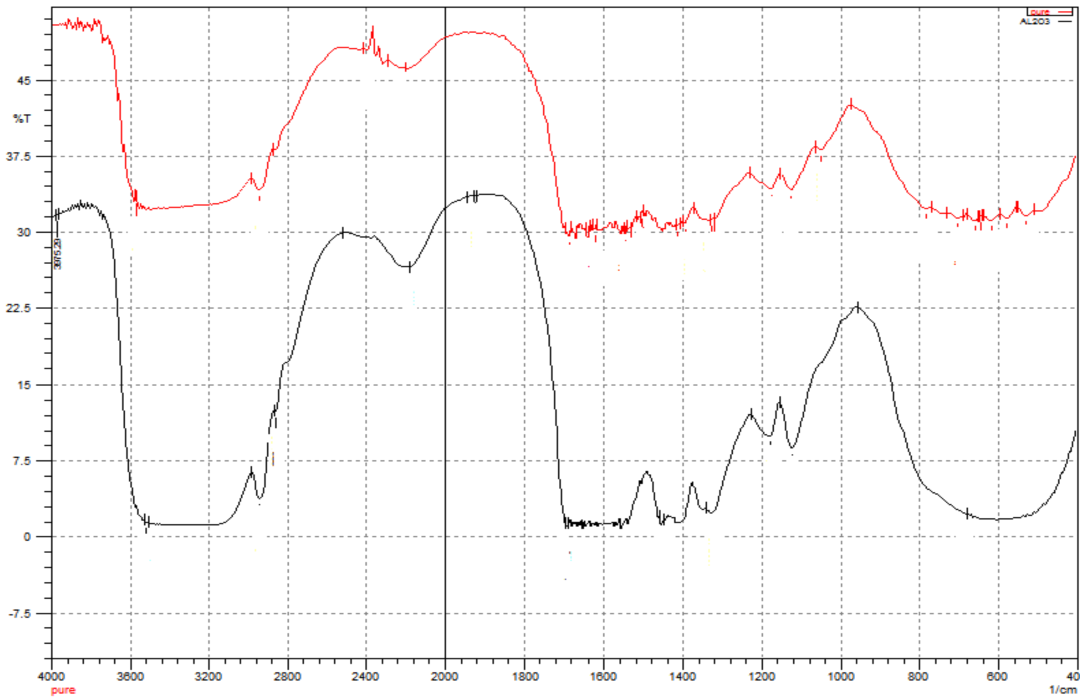

Figure 1. a FTIR analysis of (a) PAAM (b) PAAM + (0.06 %) wt. Al_2O_3

Morphology by SEM analysis

Fig. 2a-d, demonstrate the SEM morphology of PAAM and PAAM reinforced with 0.02, 0.04, and 0.06 percent weight of nano alumina, respectively. Fig 2.a, shows the SEM morphology of pure PAM; notice how the microstructure of PAAM consists of a smooth surface with semi-homogenous and continuous grain boundaries of polymer chains, whereas when 0.02 percent alumina nanoparticles were added, discontinuous polymer chains appeared, as shown in fig 2.bThe SEM morphology of PAAM and PAAM reinforced with 0.02, 0.04, and 0.06 % weight of nano alumina, respectively, is shown in fig. a–d. Fig.2 a displays the SEM morphology of pure PAAM; note how the microstructure of PAAM has a smooth surface with semi-homogenous and continuous grain boundaries of polymer chains; in contrast, Fig2.b displays the appearance of discontinuous polymer chains after 0.02 percent alumina nanoparticles were added. In addition, as shown in Fig. 2c-d, increasing the ratio of alumina nanoparticles to 0.04 and 0.06 percent weight results in more diffusion between polymer chains than the sample supplemented with 0.02 percent weight of nano alumina. As demonstrated in Fig.c–d, increasing the ratio of alumina nanoparticles works as a cross-linker between the polymer chains. This supports Gagandeep & Neelam's analysis[19].

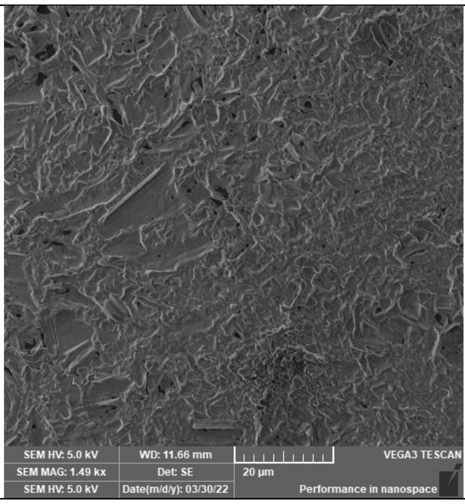

Figure a: poly acryl amid

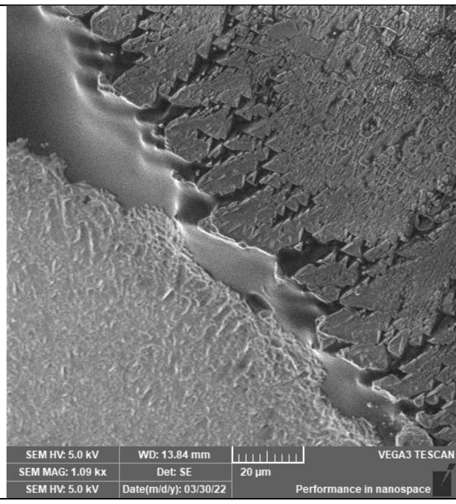

Figure b: poly acryl amid + 0.02 wt. Al_2O_3

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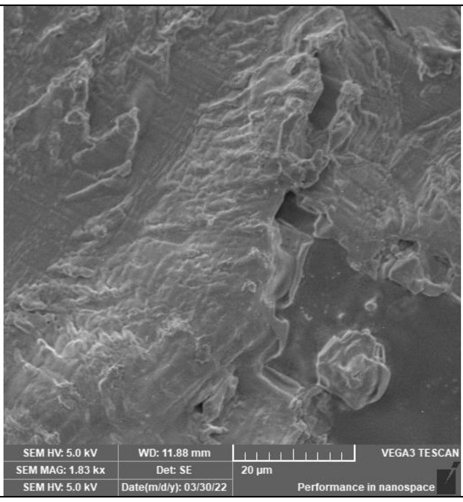

Figure c: Polyacrylamid+0.04 wt. Al_2O_3

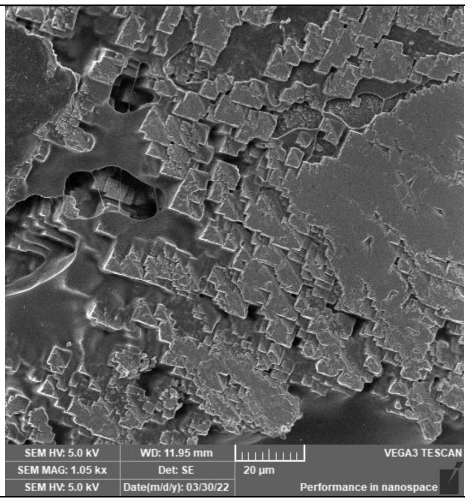

Figure d: Poly acryl amid + 0.06 wt. Al_2O_3

Figure 2. SEM images of Poly acryl amid and its composites

Mechanical Properties

Table. 1, and Fig. 3 a-d, show the mechanical properties of polyacrylamide and its nanocomposites which tested by tensile test. We observe that the mechanical properties of PAAM are enhanced by the addition of alumina nanoparticles; however, elongation declines as the nanoparticle ratio rises because the action of alumina nanoparticles with 0.04 & 0.06 percent wt. prevents chain motion by causing cross-linking to take place between them. We also discover that the tensile strength and toughness increase as the weight ratio of alumina nano - particles rises due to the greater absorption energy needed for sample breakdown. The Young's modulus increases when the weight ratio of alumina nanoparticles does so because diffusion between the polymer chains occurred as a result of the cross-linker alumina nanoparticles' action [20].

Table 1. Mechanical Properties of PAM and its composites

No. of sample	Al_2O_3 wt%	Tensile strength GPa	Elongation %	E Gpa	Toughness J/cm^2
1	0.0	1	2.6	1.3	260
2	2	1.1	1.3	1.3	130
3	4	2	1.2	1.6	240
4	6	2.5	1.1	2.0	30

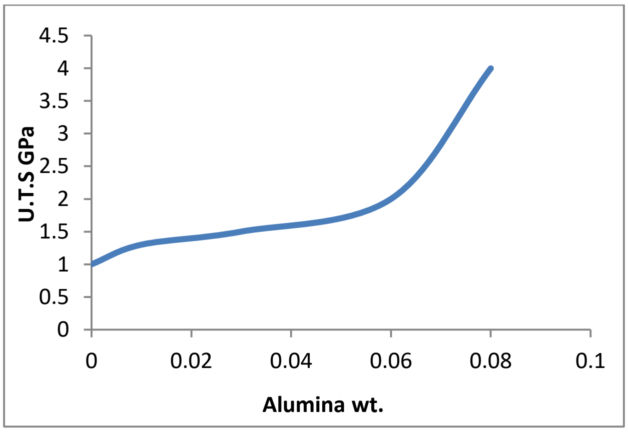

Figure a: tensile strength of Nanocomposites samples

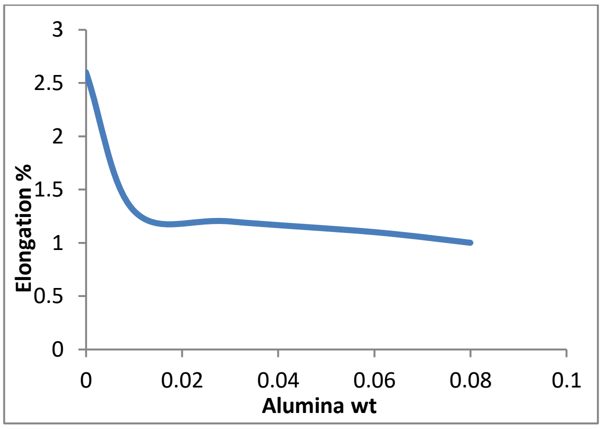

Figure b: Elongation of Nanocomposites Samples

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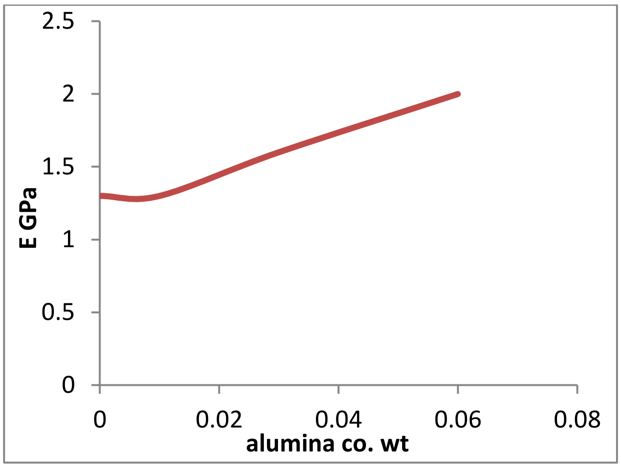

Figure c: Young's Modulus of Nanocomposites Samples

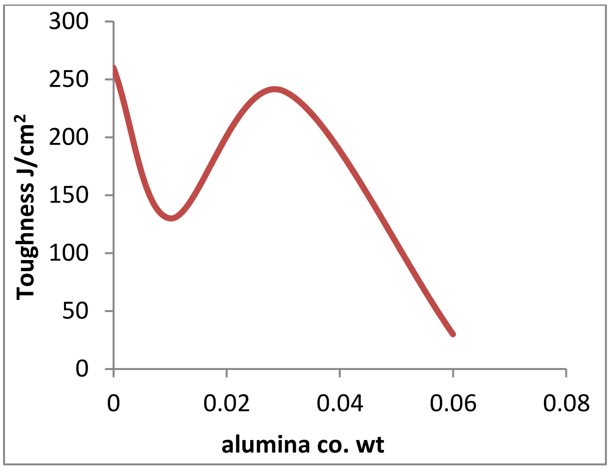

Figure d: toughness of Nanocomposites samples

Figure 3. a-d show the mechanical properties of PAAM and its nanocomposites with weight ratio of Al_2O_3 NPs a. tensile strength b. Young's modulus c. elongation% d. Toughness

Contact Angle:

The contact angle of PAAM and its composites is shown in Figs. 4a–d. Fig 4b shows how adding a very small amount of Al_2O_3 (0.01% wt) makes the PAAM matrix hollow and reduces the contact angle from 55° for pure PAAM to 44.94° for PAAM with 0.02 wt NPs (Fig. 4b). On the other hand, the contact angle increases to 63.644° when the alumina nanoparticle weight ratio is increased to 0.04 percent weight (Fig. 4c), and it climbs to 67.238o with 0.06 percent weight (Fig. 4d). This is caused by PAAM chain diffusion, which was triggered by alumina cross linker nanoparticles, as shown in Fig.4. c-d. In general, PAAM is hydrophilic because the H-binding formation has the potential to bind water.

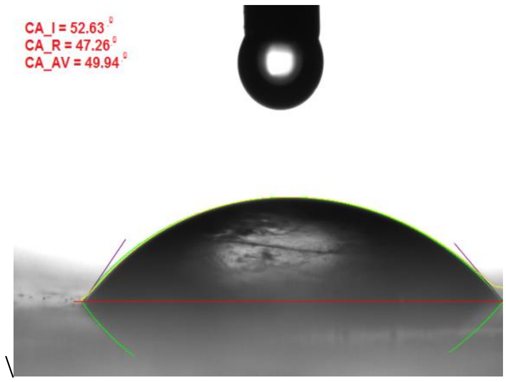

Figure a: PAAM

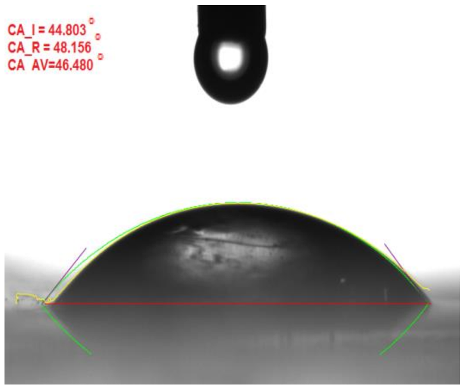

Figure b: PAAM + 0.02 Alumina

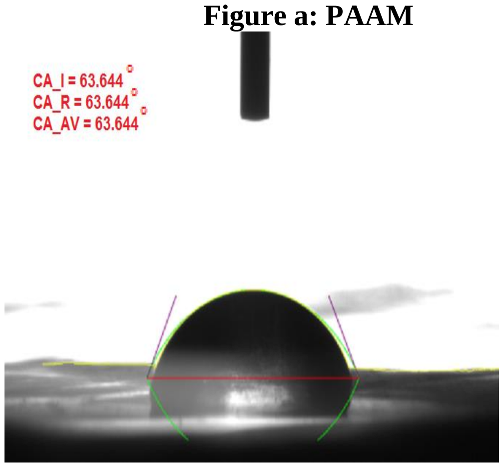

Figure c. PAAM + 0.04 Alumina

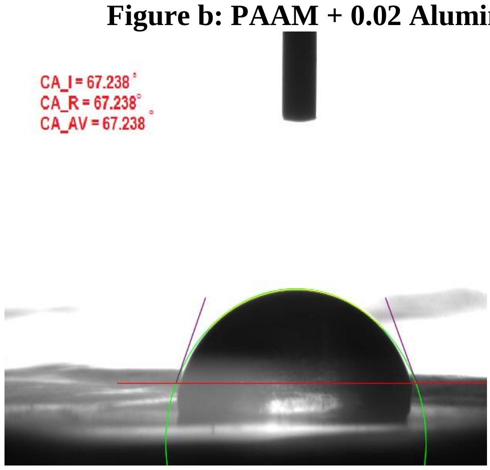

Figure d. PAAM + 0.06 Alumina

Figure 4. Contact angle of PAAM and it's composites

Conclusions:

This work led us to the conclusion that adding alumina nanoparticles to the PAAM matrix enhances the mechanical properties of the resultant nanocomposites. With increasing alumina nanoparticle content from 0 to 0.06 percent wt, the tensile strength rises from 1 GPa to 4 GPa, and the Young's modulus rises from 1.3 to 2.5 GPa for the same preceding ratios. Toughness increases to 240 J/cm2 with 0.03 wt of alumina nanoparticles, but drops to 30 J/cm2 with 0.08 wt, converting the fracture from ductile to brittle. However, adding alumina nanoparticles increases the PAAM surface's contact angle from 55o to 67o while keeping it within the range of hydrophilic contact angles.

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Authors' Declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours,have been given the permission for re- publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in University of Babylon.

Authors' Contributions Statement:

The contribution of each researcher was complementary to the contribution of the second researcher to complete this research in the final form. B. M. was interested in the mechanical properties and discussed its results. H. J. focused on the morphological, structural characteristics and the contact angle, in addition to discussing the results. Both researchers contributed to writing the conclusions.

References:

1. Hanaa J K, Al-Dabbagh B M, Rana MS, Ahmed S D. Nano composites films for food packaging applications. AIP Conf. Proce. 2021 Nov; 2372 (100002): 1-6.
2. Aldabbagh B M, Jawad H K, Mahdi R S. Study of the properties of MgO/ Poly methyl methacrylate Nano-composites. J Phys: Conf Ser. 2021 Nov; 2114 (012039): 1-7
3. Hameed T M, Al-Dabbagh B M, Jasim R K. Mechanical Properties of Heat Cured Acrylic Resin Reinforced with Natural Sisal Fibers Powder. J Phys: Conf Ser. 2021 Apr, 2114 (012023) : 1-10
4. Al-Zubaydi A S, Salih R M, Al-Dabbagh B M. Effect of nano TiO2 particles on the properties of carbon fiber-epoxy composites. Prog Rubber Plast Recycl Technol, 2021 Aug; 37(3) : 216–232
5. Al Dabbagh B M, Kadhim H J, Salih R M. Studying the effect of Polyamide 6 Nanofibers on Physical and Chemical Properties of Unsaturated Polyester Reinforced by Glass Fibers Composites. IOP Conf Ser: Mater Sci Eng. 2020 Nov; 757 (012001) : 1-6
6. Charles C O. Nanocomposites – An Overview. Int. J. Eng. Res. Dev., 2013 Jan; 8 (11) :17-23
7. Jaafar H T, Aldabbagh B M. Investigation of superhydrophobic/hydrophobic materials properties using electrospinning technique. Baghdad Sci J, 2019 Sep; 16 (3): 632–638
8. Talal J H, Mohammed D B, Jawad K H. Fabrication of Hydrophobic Nanocomposites Coating Using Electrospinning Technique for Various Substrate. J Phys: Conf. Ser. 2018 Apr; 1032 (012033): 1-13
9. Alesa H J, Aldabbag B M, Salih R M. Natural pigment -poly vinyl alcohol nano composites thin films for solar cell. Baghdad. Sci J, 2020 Sep; 17(3): 832–840
10. Jawad K H, Mohammed D B, Alsaffar M R. Performed of Filter Nano Textile for Purification of Aerosol Water by Electrospinning Technique. J Phys: Conf Ser. 2019 Sep; 1298(012023): 1-5
11. Cammarata R. Introduction to Nano Scale Science and Technology. 1 st Ed. Chap.8. USA. Springer. 2006. P. 199 - 212. https://link.springer.com/content/pdf/bfm:978-1-4020-7757-9/1
12. Charles C O. The Benefit and Applications of Nanocomposites. Int J Adv Engg Tech. 2014 Aug; 5(6): 12-18
13. Rehim M H, Alhamidi J. TiO_2 /Polymer Nanocomposites for Antibacterial Packaging Applications. J Adv Food Technol. 2018 Jan; 1(1) : 1-8
14. Ricardo J B, Sara D, Patrizia S, Carlos P N, Tito T. Antibacterial Activity of Nanocomposites of Copper and Cellulose. Bio Med Res Int. 2013 Feb; 2013 (280512): 1-6
15. Shokry H, Hassan M F, Hafez, E S. Novel Antibacterial Zinc Oxide Polymeric Nanocomposite Membrane as Wound Dress. J Nano Sci Nano technol Asia 2017 Jan; 7 (1): 62-72
16. Barbooti M M, Al-Dabbagh, B D, Hilal R H. Preparation, characterization and utilization of polyacrylic acid–kaolin composite in the removal of heavy metals from water. Int J Environ Sci Technol , 2019 Feb; 16 (8) : 4571–4582
17. Murugan R. FTIR and Polarised Raman Spectra of Acrylamide and Polyacrylamide. J Korean Phys Soc. 1998 Jan; 32(4): 505-512.
18. Olabode O O, William Z X, Paul A C. Adhesive RAFT agents for controlled polymerization of acrylamide effect of catecholend R groups. Rsc Adv. 2015 (5): 76919-76926
19. Neelam V, Gagandeep K. Colorimetric determination of Cu^{2+} ions in water and milk by apo-tyrosinase disc.

Sens Act B Chem. 2018 Jan ; 263(7): 524-532
20. Alfred C. Polymer Nanocomposites: The "Nano" Effect on Mechanical Properties. Poly Rev. 2007 Jan ; 47(2) : 217-229

المتراكبات النانوية لبولي اكريل امايد – الومينا

بلقيس محمد الدباغ[1] **هناء جواد كاظم** [2]

[1]قسم العلوم التطبيقية، فرع المواد، الجامعة التكنلوجية، بغداد ،العراق
[2] قسم هندسة البوليمير والصناعات البتروكيمياوية، كلية هندسة المواد، جامعة بابل، بابل، العراق

الخلاصة:

الهدف من هذا البحث هو تحديد مدى تأثير نسب الوزن المختلفة لجسيمات الألومينا النانوية بنسب وزنية مختلفة تشمل 0.02 ، 0.04، و 0.06 في المائة نسبة وزنية على الخصائص الفيزيائية لبولي أكريلاميد (PAAM) . تم استخدام جهاز الخلاط المغناطيسي الحراري للحصول على المحاليل من إذابة 10 غم من مسحوق بولي أكريلاميد في 90 غم من الماء المقطر المؤين لمدة 4 ساعات لإنتاج محلول PAAM بتركيز 0.11 غم / مل . تم تقسيم المحلول الناتج الى أربعة أقسام متساوية من المحلول ، كل منها بحجم 20 مل. تمت إضافة دقائق الالومينا النانوية لكل محلول بشكل مستقل بنسب مختلفة 0.0 ، 0.02 ، 0.04 ، 0.06 لتكوين أربعة محاليل نانوية سائلة بمحتويات مختلفة من جسيمات الألومينا النانوية بناءً على كل نسبة وزن. تم استخدام عملية الصب اليدوي لعينات المركبات النانوية ، والتي تضمنت صب المحلول المحضر في قالب من البلاستيك بحجم مناسب وتركت المحاليل لمدة 24 ساعة لاتمام عملية التصلب لإنشاء أغشية النانو المركبة ، ثم قطع الغشاء الرقيق الناتج وفقًا لكل اختبار ،. تم استخدام اختبار الشد لدراسة قوة الشد ، ومعامل يونك ، والاستطالة ، والمتانة. بالإضافة إلى ذلك ، تم إجراء اختبار الأشعة تحت الحمراء (FTIR) لفحص الروابط الكيميائية والفيزيائية بين بولي أكريلاميد وجسيمات الألومينا النانوية. تم فحص مورفولوجيا السطح باستخدام جهاز المجهر الالكتروني الماسح. تم اختبار زوايا الترطيب للعينات لتحديد السلوك اتجاه الماء لهذه العينات.. أظهرت النتائج أن اضافة جسيمات الألومينا النانوية الى البولي اكريل امايد يحسن الخصائص الميكانيكية للمركبات النانوية الناتجة. تزداد قوة الشد من 1 كيكا باسكال إلى 2.5 كيكا باسكال مع زيادة محتوى الألومينا النانوية من 0 إلى 0.06٪ نسبة وزنية .و بالنسبة لنفس النسب السابقة ، زاد معامل يونك كذلك ، حيث ارتفع من 1.3 إلى 2 كيكا باسكال للنسبة الوزنية لجسيمات الألومينا النانوية 0.04 بالمائة بالوزن ، ترتفع المتانة إلى 240 جول / سم ^{2}. من ناحية أخرى ، أدت إضافة دقائق الألومينا النانوية إلى زيادة زاوية التبلل لسطح PAAM من 55 درجة إلى 67 درجة ، وأظهرت سلوكًا محبًا للماء .

الكلمات المفتاحية : دقائق الالومينا النانوية، متراكبات نانوية، بولي اكريل امايد، خواص فيزيائية، الشد .