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Nano composites Based a Polymer Matrix and Their Advanced Applications, A Review

[1]Nabila Shihata Mohamed Shihata [2]Hanaa Jawad Kadhim [3]Balqees Mohamed Aldabbagh

[1]*Faculty of Postgraduate Studies for Advance Science, Beni-Suef University, Egypt*
nabila.shehata@yahoo.com
[2]*Polymer Engineering and Petro Chemical Industries Dep., Uni. of Babylon. Iraq*
mat.hanua.jawad@uobabylon.edu.iq
[3]*Applied Science Department , University of Technology, Baghdad , Iraq*
100007@uotechnology.edu.iq

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Abstract

This review covers the various types of reinforcement phases of nanocomposites, such as nanoparticles, nanofibers, carbon nanotubes, and natural nanopigments, with a focus on the requirement of these materials, their production processes, and some current knowledge about their structure, properties, and potential applications. The necessity for such potential materials as well as other intriguing uses are perspectives. Applications of nanocomposites offer new technical and commercial potential for numerous sectors of the coating, automotive, electronics as solar cell, food packaging, and other industries because to their environmental friendliness.

High performance materials with unique features include nanocomposites have a significant importance in the new advanced applications. Engineering plastics and elastomers have the fastest increasing requirement for fabrication as a nanocomposites with an expected annual growth rate of 25%. They are useful in a variety of applications, from packaging to biomedical ones, due to their great capabilities.

Keywords: *nanocomposites , nanofibers, nanoparticles, mechanical properties, surface properties, optical properties, thermal properties.*

Introduction

The last ten years have seen an increase in research into nanomaterials due to their numerous uses. Nanomaterials are used in both commercial and industrial applications. As an example, Nano zinc oxide (ZnO) is utilized for industrials and commercial fields. Nanomaterials exist in a variety of forms (see Fig. 1) and small sizes (less than 100 nm). Nanomaterials have been developed into nanocomposites, which have a wide range of uses. They achieved success in the field of material science according to its applications, a combination of its wide range of applications in the fields of energy production and storage, hydrophobic anticorrosion coating, medical applications, equipment, food packaging, filtration , and applications in environmental challenges. Nanotechnology has the potential to change daily life [1-2].

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In addition to improving other polymer properties, nanomaterials can improve the other properties of polymeric materials as shown in the table 1 which displays a variety of nanomaterial types along with an overview of their features and potential uses [3]

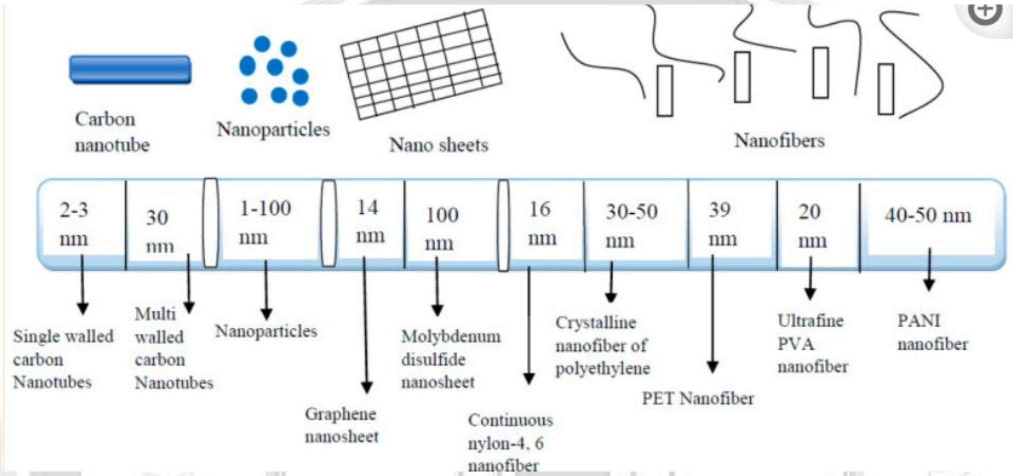

Fig 1. Nano Sizes Structure and Forms[1]

Table 1. Nanomaterials Types and Properties

Nanomaterials	**Properties**
Nanoparticles	It have : high aspect ratio, a high surfaces atoms, superior chemical and physical characteristics , very reactive and possess toughness, significant surface energy [4-7]
Carbon nanotubes	It have: a phenomenal electrical conductivity, high thermal conductivity, and a fantastic mechanical property, a significant (aspect ratio) of greater than 1000.A series of inter-stratum spacing has been seen in the photos of the actual space inspection of nanotubes [8]

Nano sheet	Possesses a substantial amount of active oxygen-containing groups on their surfaces, which is useful for the creation of good reinforced polymeric composites , Have super mechanical and thermal conductivity characteristics, excellent thermal and electrical conductivity; outstanding photo- and thermo-catalytic activity; excellent catalytic activities [9]
Nanofibers	It has the same properties of the nanoparticles approximately in addition to they have high pore volumes and tight pore sizes, which make them suitable for a wide variety of filtration applications. Finally, they have extremely high adsorption capacities. [10]

Numerous recent research about the improvement of polymer properties with the addition of nanomaterials in various forms have been published. In 2016, Alshimary and Aldabbagh published a study about the utilization of nano- and microfibers to improve the mechanical properties of polyester. Additionally, a comparison of the mechanical property enhancement ratios of polyester microcomposites and nanocomposites was also performed. In this study, the nanocomposites of polyester reinforced with PVC nanofibers of 100 nm in diameter and polyester reinforced with PVC composite fibers of 2-4 µm in diameter are prepared. Density, Shore D hardness, impact strength, and bending strength of various composite materials were tested for the purpose of comparison. For reinforced unsaturated polyester, a volume percentage of nano and micro PVC fibers ranging from 25% to 75% was employed. The results show that nanocomposites (NPVC.UPS) have advanced in every aspect more than micro composites (MPVC.UPS). This study refers to using the nanorange of the reinforcement phase leads to more enhancement in the mechanical properties due to their small sizes and high aspect ratio.

The ability of the nanofibers to merge strongly with the substrate lowers defects in the final material and enhances its mechanical properties. In comparison to employing microfibers, which enhanced the bending strength of nanocomposites by 25%, using nanofibers resulted in a 40% increase. Additionally, the density of the nanocomposites samples rose when microfibers were used as reinforcement while it dropped as the nanofiber ratios increased [11].

In 2020 , Alesa et al. published an paper about using the nano composites thin film of PVA/ natural nano pigment for solar cell applications. In this study, polyvinyl alcohol (PVA) was used to create thin films for solar cells together with an extract of a local flower's natural color. Four samples of polyvinyl alcohol were prepared at a concentration of 0.1g/ml in water, and different amounts of plant pigment (0, 15, 25 and 50%) were added to each of the

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four solutions separately to create thin films of PVA with low, medium, and high dye concentrations, respectively. Additionally, contact angle was examined by contact angle drop analyzer . The results show that adding more natural pigment and increasing its concentration to a PVA thin film lead to increase UV and FTIR absorption. The addition of 15% concentration raises the melting point of PVA whereas the addition of 50% concentration decreases it. The Contact angle is reduced from 46 ^{o} to 35 ^{o} , as well as the energy gap decreased from 3 eV for pure PVA to 2.3 eV for the PVA and the dielectric constant increased by adding more natural pigment in higher concentrations[12].

In a work published in 2021, Aldabbagh et al. proposed using MgO nanoparticles to increase PMMA's sensitivity for high sensor efficiency, as a solar cell . 0.2 con. w/v of PMMA / DMF was used. MgO nanoparticles also used as a reinforcement phase with 0.02 percent, Nano MgO dispersed through prepared solution using an ultrasonic dispersion unit. In order to produce thin films with a diameter of 0.02 mm, the samples were cast into glass containers. The results of DSC proved that the addition of MgO nanoparticles causes a slight rise in glass transition temperature, from (80 °C) to (82 °C), softening point drops from 132 °C to 120 °C and the melting point drops from 173 °C to 135 °C. Using atomic force microscopy, it was demonstrated that adding nanoparticles causes the surface roughness decreased from 2.08 nm to 1.7 nm while increasing the bearing index from 0.369 to 0.582. The energy gap measurements also demonstrated that the presence of nanoparticles causes the energy gap to shrink from (4.3 - 4.1) eV, increasing electrical sensitivity [13].

In 2021 , Ahmed et al. published an paper about using the mixture of nanoparticles (Ag^{+} and SiO_2) for improving the mechanical and antibacterials properties of EVAc for food packaging applications . Different weight percentages of nanoparticles (0.25, 0.5, and 1) were employed. Nano composite films reinforced with SiO_2 and (Ag+) nanoparticles were created using the spin coating process. Roughness, surface area ratio, valley fluid index, and bearing index were measured using atomic force microscopy (AFM). The agar well diffusion method was also used to investigate the anti-bacterial activity against gram positive and gram negative bacteria. The results of FTIR test demonstrated a physical contact between the added nanoparticles and the EVAc copolymer, and the AFM measurements demonstrate an increase in film roughness with increasing nanoparticle weight percentages. In addition to the results already mentioned, the bearing index also reduced as the weight percentage of SiO_2 NPs increased, also was the valley fluid index. The lone exception to the data above was the fourth sample, which was reinforced with 1% SiO_2 NPs. Results from antibacterial tests against two distinct types of bacteria (grams negative and positive) indicated an inhibitory zone [14].

In 2022 , Amer and Jawad published a paper about using multi reinforcement phase with polystyrene nanofibers for enhancement the electrical properties of prepared nano composites. Using the electro spinning technique polymeric nano composites with MWCNT, PS nanofibers, and natural pigment were created. 0.12 wt% of solution was used with 0.063 g of natural pigment, and MWCNTs added in levels of 0, 100, 140, and 200 ppm . Results proved that the incorporation of MWCNT and natural pigment provides the smooth nanofibers and causes the formation of fewer beads. Tauc plot charts demonstrate that increasing the MWCNT with natural pigment addition leads to decrease the energy band gap from 1.18 eV to 0.2 eV for the sample of Polystyrene/200 ppm CNTs [15].

In a study published in 2023, Alhulw et al. discussed the use of the g-C3N4 Nano sheet to improve the structural and optical characteristics of PVC/PVP nanocomposites for sensor applications. This work describes the addition of g-C3N4 nanosheets to PVC/PVP polymer nanocomposites at ratios of 0.0, 0.3, 0.6, and 1.0 wt% . The nanocomposite samples passed through testing for XRD, FTIR, ESEM, TGA, and optical energy gaps. All of the PVC/PVP/g-C3N4 polymer mix films had semi crystalline structures, according to the XRD data scans. The FTIR and Raman analyses revealed the g-C3N4 surface and the OH groups of the intermolecular hydrogen bonding in the PVC/PVP network. FESEM morphological examination revealed homogeneous surface textures in nanocomposite films made of PVC, PVP, and g-C3N4. The TGA data showed greater thermal stability when g-C3N4 (0.0-1.0 wt%) was present when the decomposition temperature increased from 262 to 276 °C. Finally, as the percentage of g-C3N4 was increased, the values of the nonlinear refractive index improved. The DC conductivity increased from 4.21 108 to 1.78 106 S/cm with the addition of g-C3N4 up to 1.0 wt%. The results of this study demonstrate that PVC/PVP/g-C3N4 can be used well in optoelectronic fiber sensors [16].

Summary Conclusion

The results of the earlier studies indicate that adding nanoparticles as a reinforcing phase to composite materials lead to a significant improvement in their thermal, mechanical, and optical properties. Nanomaterials also improve the stability of the based material. The percentage of improving the characteristics of the produced materials with nano sizes is significantly higher than the percentage of improvement when employing the same reinforcement material in bigger sizes. Life can be made easier by using nanomaterials in more advanced applications.

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المواد النانوية المتراكبة ذات أساس بوليمير وتطبيقاتها المتقدمة – مراجعة

نبيلة شحاتة محمد شحاتة[١] هناء جواد كاظم [٢] بلقيس محمد ضياء الدباغ[٣]

[١]جامعة بني سويف كلية الدراسات العليا – مصر
[٢]جامعة بابل كلية هندسة المواد – قسم هندسة البوليمير والصناعات البتروكيمياوية – العراق
[٣]الجامعة التكنلوجية – قسم العلوم التطبيقية – العراق

الخلاصة :

في هذه المراجعة تمت تغطية الأنواع العديدة من مراحل التعزيز للمركبات النانوية مثل (الجسيمات النانوية، والألياف النانوية، وأنابيب الكربون النانوية، وأصباغ النانو الطبيعية)، مع التركيز على الحاجة إلى هذه المواد ، وطرق تصنيعها ، وبعض النتائج الحديثة حول بنيتها. والخصائص والاستخدامات الممكنة. ضرورة وجود مثل هذه المواد المحتملة فضلا عن استخدامات أخرى مثيرة للاهتمام. توفر تطبيقات المركبات النانوية إمكانات تقنية وتجارية جديدة للعديد من قطاعات الطلاء والسيارات والإلكترونيات مثل الخلايا الشمسية وتغليف المواد الغذائية والصناعات الأخرى بسبب ملاءمتها للبيئة. المواد عالية الأداء ذات الميزات الفريدة تشمل المركبات النانوية التي لها أهمية كبيرة في التطبيقات المتقدمة الجديدة. تعتبر اللدائن واللدائن الهندسية من اكثر المواد الهندسية التي تحتاج الى تصنيعها بهياة مواد نانوية متراكبة بسبب معدل النمو السنوي السريع بحدود ٢٥٪. المتراكبات النانوية مفيدة في مجموعة متنوعة من التطبيقات، من التعبئة والتغليف إلى التطبيقات الطبية الحيوية، نظرًا لقدراتها الكبيرة لذلك من الضرورة تسليط الضوء على هذه المواد وطرق معالجتها وبعض النتائج الجديدة التي تطرا على الهيكل والخصائص وكذلك والتطبيقات الممكنة.

الكلمات الدالة: المركبات النانوية، الألياف النانوية، الجسيمات النانوية، الخواص الميكانيكية، الخواص السطحية، الخواص البصرية، الخواص الحرارية