*Наносистеми, наноматеріали, нанотехнології*
*Nanosistemi, Nanomateriali, Nanotehnologii*
2022, т. 20, № 3, сс. 821–827



PACS numbers: 68.37.Hk, 81.07.Pr, 82.35.Np, 87.19.xb, 87.85.Rs

# Fabrication of NiO–$In_2O_3$-Nanoparticles-Doped Organic Polymer Films for Antibacterial Applications

Huda Bukheet Hassan[1], Ahmed Hashim[1], and Hayder M. Abduljalil[2]

[1]*College of Education for Pure Sciences,*
*Department of Physics,*
*University of Babylon,*
*Hillah, Iraq*
[2]*College of Sciences,*
*Department of Physics,*
*University of Babylon,*
*Hillah, Iraq*

Nanocomposites of PEO, namely, PEO/NiO and PEO/NiO–$In_2O_3$ nanostructures, are fabricated by using casting technique as antibacterial films for biomedical applications. The films of PEO/NiO–$In_2O_3$ nanocomposites are tested for gram-positive organisms (*Bacillus cereus*) and gram-negative organisms (*Salmonella*). The experimental results indicate that PEO/NiO–$In_2O_3$ nanocomposites have highest antibacterial activity for gram-positive organisms and gram-negative ones.

Нанокомпозити на основі поліетиленоксиду (ПЕО), а саме, наноструктури ПЕО/NiO та ПЕО/NiO–$In_2O_3$, виготовляються методом лиття як антибактерійні плівки для біомедичних застосувань. Плівки нанокомпозитів ПЕО/NiO–$In_2O_3$ тестуються на грампозитивні організми (*Bacillus cereus*) та грамнеґативні організми (*Salmonella*). Результати експерименту вказують на те, що нанокомпозити ПЕО/NiO–$In_2O_3$ мають найвищу антибактерійну активність для грампозитивних організмів і грамнеґативних.

**Key words:** NiO, $In_2O_3$, PEO, nanocomposites, antibacterial agent, biomedical engineering.

**Ключові слова:** NiO, $In_2O_3$, поліетиленоксид, нанокомпозити, антибактерійний засіб, біомедична інженерія.

*(Received 7 February, 2022)*

## 1. INTRODUCTION

Polymer composite films are gaining importance in recent research, especially in fabrication of polymer nanocomposites due to their high elasticity, high aspect ratio and specific surface area [1].

Polymer nanocomposites attained great interest that nominates them to be used in several technological and industrial applications such as flexible screens, radio frequency interference shielding for cables and medical applications. Combining organic polymers with inorganic nanomaterials opens new applications for the host polymer [2].

Polymer nanocomposite materials have attracted increasing attention recently because of their unique physical and chemical properties resulting from the combination of organic and inorganic materials in single compounds.

Polymer nanocomposites are defined as materials, in which inorganic nanomaterials are embedded into an organic polymer matrix. Therefore, polymer nanocomposite technology has been developed to reinforce and provide new characteristic materials. This technology has been applied to a wide range of polymers using many different nanoscale fillers. Incorporation of the nanoparticles into the polymer matrix affects the properties of polymers, where the addition of even a small amount of nanoparticles into the polymeric matrix can strongly change the optical, mechanical, thermal and other properties of a material [3].

Polymer nanocomposites are a promising type of polymeric material that can be used instead of conventional polymers and other materials. It has been discovered in recent decades that adding small amounts of nanofillers to polymers can increase their thermal, mechanical, barrier, and flammable properties compared to conventional polymers, and it is one of the low-cost and easy methods to modify the structure of polymers. When compared to pure polymers or conventional composites, filler-dispersed nanocomposites have much better properties due to their nanoscale diameters. Mixing organic materials with inorganic nanoparticles is a rapidly growing research field to meet new challenges and requirements to enhance the performance properties of the resulting materials that enable current and future development and progress of society. Nanoscale systems have a small length scale that directly affects the energy band structure, which can lead to changes in the associated atomic structure [4].

With advancements in all areas of industry and technology, people's attention has been attracted to nanoscale materials due to their outstanding physical and chemical properties. Today, many kinds of nanocrystalline metallic oxides have been studied extensively, such as ZnO, SnO, $TiO_2$, NiO and $In_2O_3$. Indium oxide is one of the most commonly used *n*-type semiconducting material with a band gap of 3.6 eV. It has received considerable attention among the semiconducting oxides because of its distinctive electrical, optical and chemical properties. Body centred cubic (b.c.c.) $In_2O_3$ is very common, and it can be used in field emission devices, flat panel displays, biosensing, catalysis, sensors, transparent electrodes in solar cells, optics and data storage, *etc.* [5].

Antibacterial materials can be broadly divided into the following two categories based on their chemical properties: (1) organic antibacterial materials, which are characterized by their high performance and rapid action; (2) inorganic antibacterial materials, which provide safe and long-lasting action. Although organic antibacterial materials offer the advantage of superior performance, their short duration of action and high toxicity lead to environmental pollution and adverse effects on human health. In contrast, inorganic antibacterial materials possess good chemical and physical properties, produce less environmental pollution, and affect human health to a smaller extent. Currently, most studies have focused on combining nanomaterial science techniques with the inherent antibacterial activity of inorganic metal oxides, to develop metal oxide nanoparticles for use as novel antibacterial materials. The application of metal oxides is a suitable alternative to the current antibacterial methods, as most metal oxides provide sterilizing effects [6]. This work deals with fabrication of PEO/NiO–$In_2O_3$ nanostructures for biomedical applications.

## 2. MATERIALS AND METHODS

The nanocomposite films of PEO, PEO/NiO and PEO/NiO–$In_2O_3$ are fabricated by dissolving 1 gm of PEO in 40 ml of distilled water, then added the NiO with ratio 1.8 wt.% to PEO and the indium oxide ($In_2O_3$) were added to the PEO/NiO with ratios are 1.8, 3.6, and 5.4 wt.%. The components of PEO, PEO/NiO and PEO/NiO–$In_2O_3$ are mixed using a magnetic stirrer for 1 h to obtain homogeneous solution. The casting method is used to fabricate the films of PEO/NiO–$In_2O_3$ nanocomposites in the template (Petri dish has diameter of 10 cm). The PEO/NiO–$In_2O_3$ nanocomposite films are prepared with thickness of 140 μm. Antibacterial activity of PEO/NiO–$In_2O_3$ nanocomposites is tested using a disc diffusion method. The antibacterial activities were done by using gram-positive organisms (*Bacillus cereus*) and gram-negative organisms (*Salmonella*).

## 3. RESULTS AND DISCUSSION

Figures 1, 2 show the microscopic and SEM images of PEO/NiO–$In_2O_3$ nanocomposites.

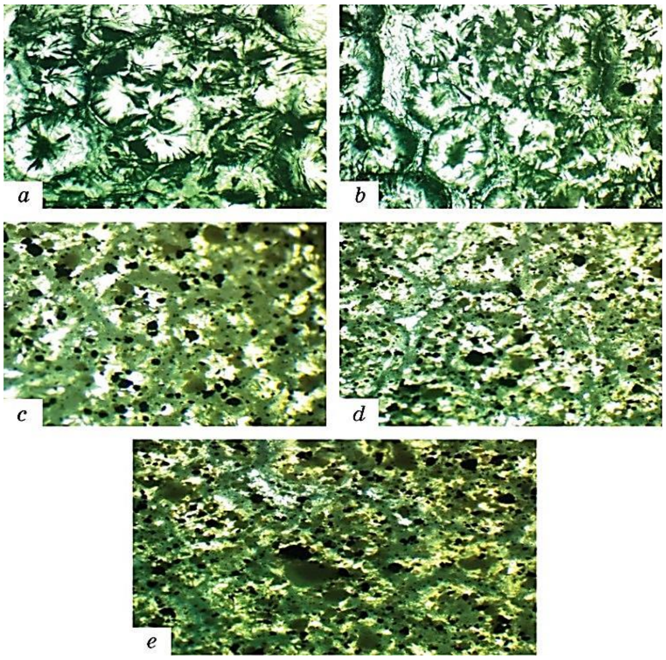


**Fig. 1.** Microscope images of PEO/NiO–$In_2O_3$ nanocomposites: *a*—PEO; *b*—1.8 NiO NPs; *c*—1.8 $In_2O_3$ NPs; *d*—3.6 $In_2O_3$ NPs; *e*—5.4 $In_2O_3$ NPs (in wt.%).

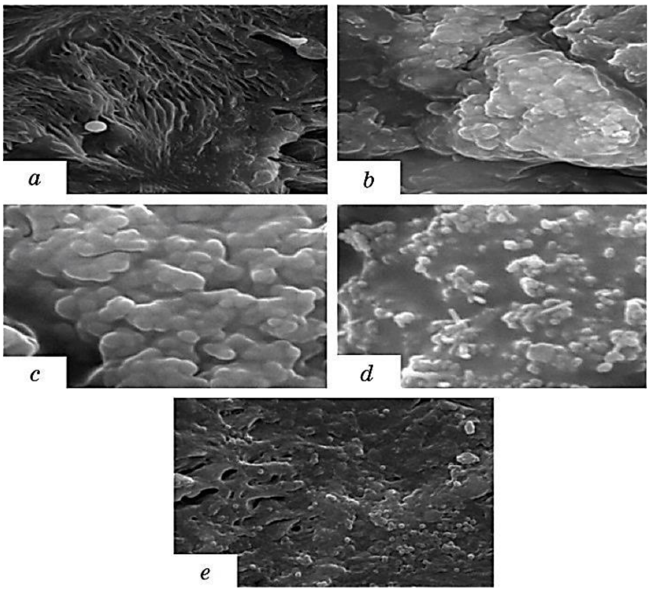


**Fig. 2.** SEM images of PEO/NiO–$In_2O_3$ nanocomposites: *a*—PEO; *b*—1.8 NiO NPs; *c*—1.8 $In_2O_3$ NPs; *d*—3.6 $In_2O_3$ NPs; *e*—5.4 $In_2O_3$ NPs (in wt.%).

These figures represent the NiO–$In_2O_3$ nanoparticles' arrangements in the polymer matrix (PEO). At low concentrations, the nanoparticles is aggregated as a clusters while it form a paths network inside the polymer matrix at high concentrations [7–12].

Figures 3, 4 show the antibacterial activity of PEO/NiO–$In_2O_3$ nanocomposites against gram-positive organisms (*Bacillus cereus*) and gram-negative organisms (*Salmonella*). From these figures, the inhibition zone increases with increase of the concentration of NiO–$In_2O_3$ nanoparticles. This behaviour attributed to the metal oxides carrying the positive charge while the microorganisms carry negative charges; this causes electromagnetic attraction between microorganisms and the metal oxides that leads to oxidization and, final-

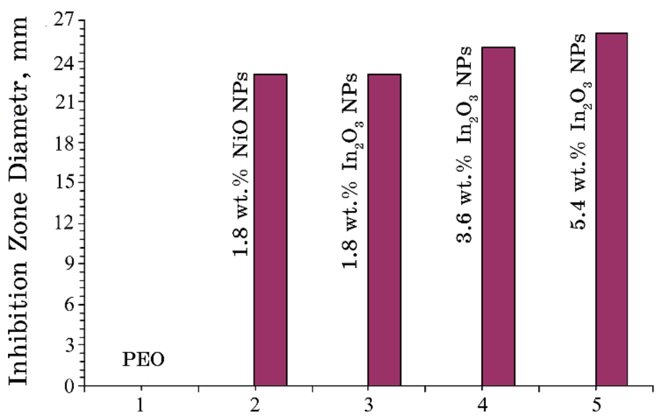


**Fig. 3.** Antibacterial activity of PEO/NiO–$In_2O_3$ nanocomposites against gram-positive organisms (*Bacillus cereus*).

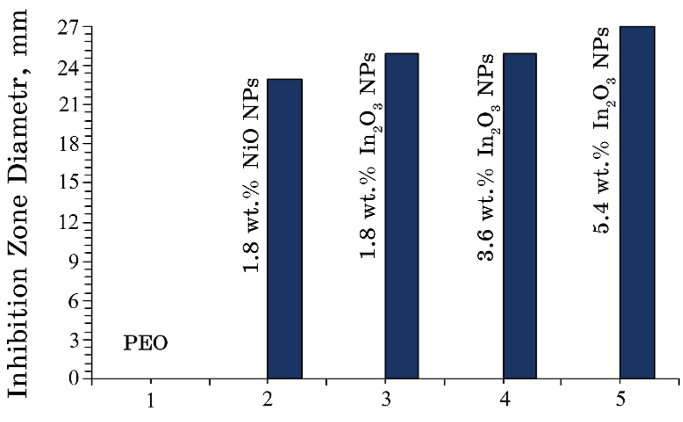


**Fig. 4.** Antibacterial activity of PEO/NiO–$In_2O_3$ nanocomposites against gram-negative organisms (*Salmonella*).

ly, to death of microorganisms. Nanomaterials also could deactivate the cellular enzymes and DNA by co-ordinating to electron-donating groups, such as: thiols, carbohydrates, amides, indoles, hydroxyls, *etc*. [13–17].

## 4. CONCLUSIONS

The present work includes a preparation of PEO, PEO/NiO and PEO/NiO–$In_2O_3$ nanocomposites by using casting technique to employ for antibacterial applications. The PEO/NiO–$In_2O_3$ nanocomposites films were tested for gram-positive organisms (*Bacillus cereus*) and gram-negative organisms (*Salmonella*). The results showed that the PEO/NiO–$In_2O_3$ nanocomposite films have high antibacterial activity against gram-positive organisms and gram-negative ones.

## REFERENCES


1. Chaitra Srikanth, Gattumane Motappa Madhu, Hemanth Bhamidipati, and Siddarth Srinivas, *AIMS Materials Science*, **6**, No. 6: 1107 (2019); doi:10.3934/matersci.2019.6.1107
2. Zein K. Heiba, Mohamed Bakr Mohamed, and Sameh. I. Ahmed, *Alexandria Engineering Journal*, **61**, Iss. 5: 3375 (2022); https://doi.org/10.1016/j.aej.2021.08.051
3. Ateyyah M. AL-Baradi, Samar F. Al-Shehri, Ali Badawi, Amar Merazga, and A. A. Atta, *Results in Physics*, **9**: 879 (2018); https://doi.org/10.1016/j.rinp.2018.03.039
4. L. H. Gaabour, *AIP Advances*, **11**: 105120 (2021); https://doi.org/10.1063/5.0062445
5. M. Jothibas, C. Manoharan, S. Johnson Jeyakumar, and P. Praveen, *J. Mater. Sci.: Mater. Electron.*, **26**: 9600 (2015); https://doi.org/10.1007/s10854-015-3623-x
6. N.-F. Chen, Y.-H. Liao, P.-Y. Lin, W.-F. Chen, Z.-H. Wen, and S. Hsieh, *Int. J. Mol. Sci.*, **22**, No. 23: 12913 (2021); https://doi.org/10.3390/ijms222312913
7. N. B. R. Kumar, V. Crasta, R. F. Bhajantri, and B. M. Praveen, *Journal of Polymers*, **2014**: 1 (2014); http://dx.doi.org/10.1155/2014/846140
8. A. Hazim, A. Hashim, and H. M. Abduljalil, *Nanosistemi, Nanomateriali, Nanotehnologii*, **18**, Iss. 4: 983 (2020); https://doi.org/10.15407/nnn.18.04.983

9 A. Hashim, A. J. K. Algidsawi, H. Ahmed, A. Hadi, and M. A. Habeeb, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, Iss. 1: 91 (2021); https://doi.org/10.15407/nnn.19.01.091

10. A. Hashim, A. J. K. Algidsawi, H. Ahmed, A. Hadi, and M. A. Habeeb, *Nanosistemi, Nanomateriali, Nanotehnologii*, **19**, Iss. 2: 353 (2021); https://doi.org/10.15407/nnn.19.02.353
11. A. Hashim and Z. S. Hamad, *Journal of Bionanoscience*, **12**, No. 4: 488 (2018); doi:10.1166/jbns.2018.1551

12. B. Abbas and A. Hashim, *International Journal of Emerging Trends in Engineering Research*, **7**, No. 8: 131 (2019); https://doi.org/10.30534/ijeter/2019/06782019
13. S. Behera, J. Patra, K. Pramanik, N. Panda, and H. Thatoi, *World J. of Nano Sci. and Eng.*, **2**, No. 4: 196 (2012); doi:10.4236/wjnse.2012.24026
14. A. Hazim, A. Hashim, and H. M. Abduljalil, *International Journal of Emerging Trends in Engineering Research,* **7**, No. 8: 68 (2019); https://doi.org/10.30534/ijeter/2019/01782019
15. A. Hazim, H. M. Abduljalil, and A. Hashim, *International Journal of Emerging Trends in Engineering Research*, **7**, No. 8: 104 68 (2019); https://doi.org/10.30534/ijeter/2019/04782019
16. A. Hashim, I. R. Agool, and K. J. Kadhim, *Journal of Bionanoscience*, **12**, No. 5: 68 (2018); doi:10.1166/jbns.2018.1580
17. M. Haghi, M. Hekmatafshar, M. B. Janipour, S. S. gholizadeh, M. K. F. F. Sayyadifar, and M. Ghaedi, *Int. J. of Adv. Biotech. and Res.*, **3**, No. 3: 621 (2012).