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Fabrication, Structural and Biological Application of SiC/TaC-Nanoparticles-Doped Polycarbonate (PC)

Wissam Obeis Obaid[1] and Ahmed Hashim[2]

[1]Ministry of Education,
Bab Al-Sharqi,
Baghdad, Iraq
[2]College of Education for Pure Sciences,
Department of Physics,
University of Babylon,
Hillah, Iraq

The structural properties of polycarbonate/silicon carbide–tantalum carbide nanocomposites are investigated for antibacterial application. The nanocomposites are prepared by casting method with various ratios of SiC/TaC nanoparticles: 1.2, 2.4, 3.6 and 4.8 wt.%. The experimental results show that high distribution of SiC–TaC nanoparticles inside the polycarbonate matrix. The antibacterial activity of the nanocomposites increases with the increase in the SiC–TaC-nanoparticles' concentration. Finally, the prepared nanocomposites have high antibacterial activity with a low cost, flexibility and lightweight.

Досліджено структурні властивості нанокомпозитів полікарбонат/карбід Силіцію–карбід Танталу для антибактеріяльного застосування. Нанокомпозити одержують методом лиття з різними співвідношеннями наночастинок SiC/TaC: 1,2, 2,4, 3,6 і 4,8 мас.%. Результати експерименту показують високий розподіл наночастинок SiC–TaC всередині полікарбонатної матриці. Антибактеріяльна активність нанокомпозитів зростає зі збільшенням концентрації SiC–TaC-наночастинок. Нарешті, підготовлені нанокомпозити мають високу антибактеріяльну активність з низькою вартістю, гнучкістю та легкістю.

Key words: polycarbonate, tantalum carbide, SiC, nanocomposites, antibacterial agent.

Ключові слова: полікарбонат, карбід Танталу, SiC, нанокомпозити, антибактеріяльний засіб.

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1. INTRODUCTION

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 the organic polymer matrix [1]. Nanocomposites consist of polymers, which may be natural or synthetic, and they are nanomaterials, which refer to materials with nanosize topography or composed of nanosize structural components [2].

Although the terms 'nanomaterials' and 'nanocomposite' represent new and exciting areas in materials science, they have been used for centuries when they exist in nature. However, methods for characterizing and controlling the structure at the nanoscale have been stimulated much later only [3]. Polycarbonate (PC) as a thermoplastic polymeric matrix is considered of hardest polymer materials with the transparency of highest level. Then, films of polycarbonate-based nanocomposites manifest not only flexibility but excellent tensile strength as well [4]. Tantalum carbide TaC demonstrates huge individual characteristics like very elevated melting point, elevated hardness, high elastic modulus, elevated density, and excellent chemical stability [5]. Silicon carbide SiC is one of major fillers for developed elevated-power and elevated-temperature electronic fields. SiC has devised in the structural ceramics improvement with elevated behaviour in the materials' fabrication, which demands a low thermal-expansion coefficient and elevated thermal-conductivity properties [6].

Carbides' nanocomposites were tested for thermal-energy storage and saving solar energy [7, 8]. The nanoinorganic and inorganic-material-doped polymers have various applications in different fields like electronics and optoelectronics [10–28], sensors [29–34], bioenvironmental, radiation shielding and antibacterial agents [35–41]. The present work aims to prepare of PC/SiC–TaC nanostructures for antibacterial application.

2. MATERIALS AND METHODS

Polycarbonate (PC)–tantalum carbide (TaC)–silicon carbide nanostructures' films were fabricated by employing the casting method. The polymer (PC) solution was synthesized by dissolving of 1 gm in chloroform (30 ml). The SiC–TaC nanoparticles were added with ratio (1:1) to solution (PC) by contents of 1.2%, 2.4%, 3.6%, and 4.8%. The structural characteristics of PC/SiC–TaC nanostructures were measured using optical microscopy and FE–SEM; antibacterial activity was investigated by diffusion method.

3. RESULTS AND DISCUSSION

Figure 1 show the images of PC/SiC–TaC nanocomposites for samples with different concentrations of SiC–TaC nanoparticles at magnification power (10×). The figure shows that the SiC–TaC nanoparticles (NPs) are aggregated as clusters at low concentrations. When the concentration of SiC–TaC nanoparticles is increasing, the nanoparticles form paths of network inside the polymer matrix [42].

Figure 2 shows the scanning electron microscopy (FE–SEM) images of PC/SiC–TaC nanocomposites. The film surfaces morphology of the PC/SiC–TaC nanocomposites show many aggregates or chunks of randomly distributed nanoparticles on the film surfaces [43].

The antibacterial properties of the PC/SiC–TaC nanocomposites were studied against gram-positive (*Staphylococcus aureus*) and gram-negative (*Escherichia coli*) bacteria, and the obtained data are presented in Figs. 3, 4. The antibacterial mechanism of SiC–TaC nanoparticles is like the creation of reactive oxygen species (ROS), the interaction of nanoparticles with bacteria and then damaging the bacterial cell [44]. Numerous studies have shown that the antibacterial mechanism of nanoparticles is owing to the construction of (ROS) such as superoxide anion $^{-}O_2$. It has been reported that the increase of the surface area of particles clues to an increase of the $^{-}O_2$ concentration and, therefore,

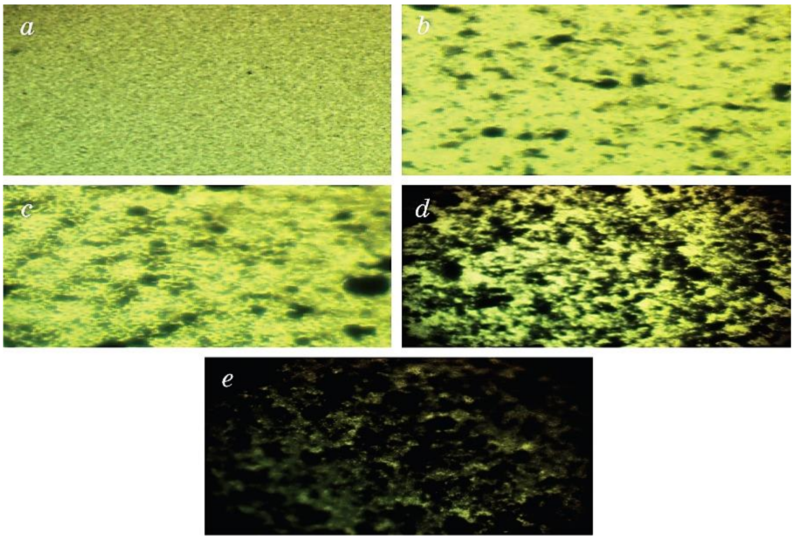

Fig. 1. Microscope images (×10): (*a*) pure PC, (*b*) 1.2 wt.% SiC–TaC NPs, (*c*) 2.4 wt.% SiC–TaC NPs, (*d*) 3.6 wt.% SiC–TaC NPs and (*e*) 4.8 wt.% SiC–TaC NPs.

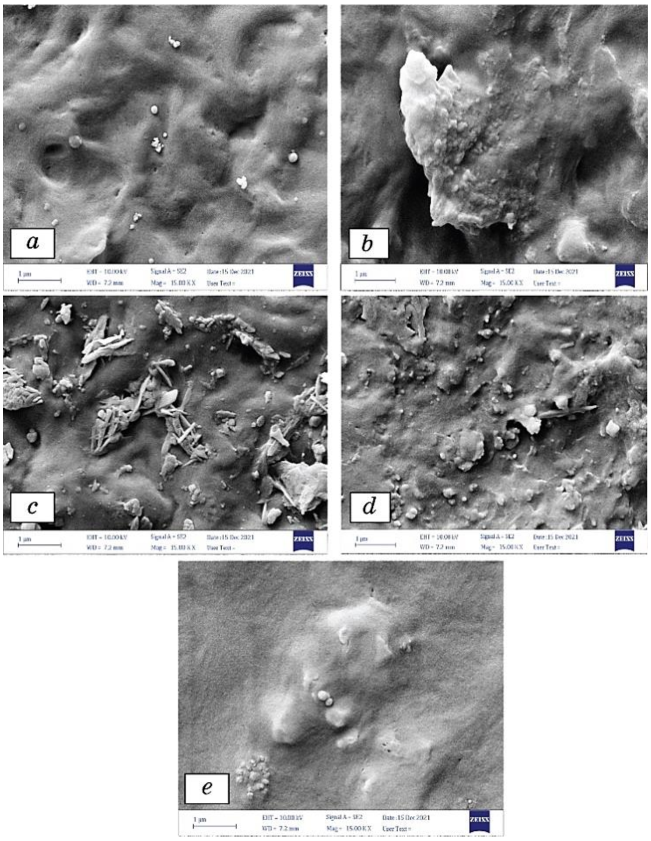

Fig. 2. FE–SEM analysis of (PC/SiC–TaC) nanocomposites: (*a*) pure PC (*b*) 1.2 wt.% SiC–TaC NPs, (*c*) 2.4 wt.% SiC–TaC NPs, (*d*) 3.6 wt.% SiC–TaC NPs and (*e*) 4.8wt.%SiC–TaC NPs.

results in a many effective damage of the cell wall of the bacteria [45]. This indicates that chemical changes have occurred in the proteins in the cell wall of the bacteria [46]. The nanocomposites are carrying the positive charges, and the microbes are having the negative charges, which create the electromagnetic attraction between the nanoparticles of nanocomposites and the microbes, and the microbes will be oxidized and die instantly [47].

4. CONCLUSIONS

The present work includes the preparing the PC/SiC–TaC new nanocomposite films. The structural properties of the (PC/SiC–TaC) nanocomposite were studied to use for antibacterial applications. The antibacterial activity results for the PC/SiC–TaC nanocomposites show

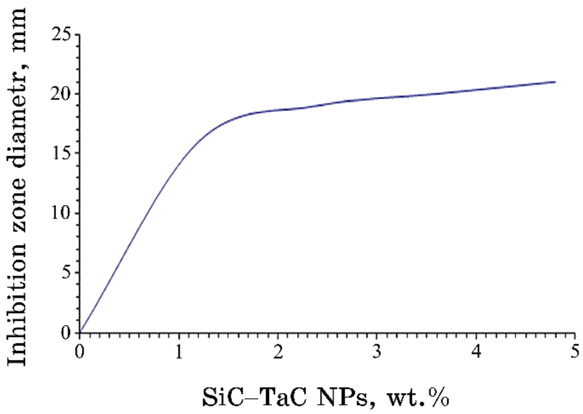

Fig. 3. Antibacterial effect of (PC/SiC–TaC) as a function of (SiC–TaC) nanoparticles' concentration on positive-gram (*S. aureus*) bacteria.

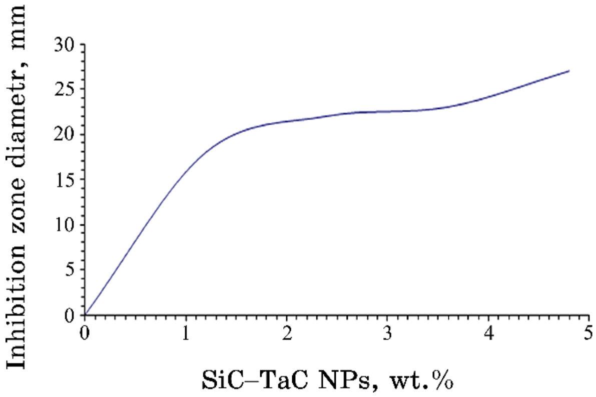

Fig. 4. Antibacterial effect of (PC/SiC–TaC) as a function of (SiC–TaC) nanoparticles' concentration on gram-negative (*E. coli*) bacteria.

that the inhibition-zone diameter increases with increasing the concentration of SiC–TaC nanoparticles against gram-positive (*Staphylococcus aureus*) and gram-negative (*Escherichia coli*) bacteria.

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