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The antibacterial properties of Ag/TiO_2 nanoparticles embedded in silane sol–gel matrix

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ABSTRACT

In this study, the antimicrobial effect of Ag NPs doped TiO_2 nanoparticles (Ag/TiO_2 NPs) embedded in (3-mercaptopropyl) trimethoxysilane (MPTS) and tetraethylortho silicate (TEOS) (TEOS–MPTS–Ag/TiO_2 NPs) was investigated. The morphology of Ag/TiO_2 was characterized by field emission scanning electron microscopy and atomic force microscopy, respectively. The Fourier transform infrared spectroscopy was taken to probe the MPTS–TEOS sol–gel. Disc diffusion assay showed that TEOS–MPTS–Ag/TiO_2 nanocomposites had stronger antibacterial activity than Ag/TiO_2 NPs and Ag NPs, but Ag/TiO_2 NPs displayed a stronger antibacterial activity by MIC and MBC methods. Furthermore, the induced couple plasma method indicated that Ag^+ were not released from the nanocomposite and disc diffusion method confirmed that silver nanocomposites were active against the bacterial species after 21 days exposure to water. In general, these results revealed that the new silver polymeric nanocomposite could be a low releasing nanocomposite with excellent antibacterial activity.

1. Introduction

In many cultures, silver has a long history of usage in medicine. Particularly, silver solutions have been considered for killing invasive bacteria in burn wounds in the last decades [1–3]. Recently, silver biocidal activity has been widely investigated. Contrary to bulk metallic forms or ionic forms, silver nano scales have more of an inhibitory effect [4]. Silver nanoparticles (Ag NPs) are known for their higher antimicrobial activity, due to their high specific surface area and the large surface to volume ratio against a broad spectrum of bacteria, fungi, and viruses [5,6]. It is clear that silver is released when it is in contact with liquid. Then silver ions combine with the cell surface proteins, *e.g.* bacteria, thereby developing their effect there [7].

Improving the bactericidal activity of silver nanoparticle is a new area of research. According to Cao et al. the microgalvanic effect between the Ag NPs and titanium matrix improve the antibacterial activity, cytocompatibility and also, contribute to the lower toxicity of silver surfaces [8]. Titanium dioxide is the most widely used material among other complex oxides because of its high stability, low cost, and well availability [9]. There are various methods for the preparation of Ag/TiO_2 composites [10,11]. However, Ag NPs doped in nano TiO_2 are one of the methods that can improve silver biocidal activity against bacteria and viruses [12].

One successful approach to make the dispersion of silver nanoparticles possible is the attachment of silver nanoparticles in the polymeric chains. Due to their specific chemical and structural properties, different polymers are used for the immobilization and fine dispersion of nanoparticles. Polymer nanocomposites are new practical materials consisting of nanoparticles dispersed into the polymeric matrix [13,14] and/or coated by polymer [15,16]. The produced new polymeric nanocomposites can show some properties of the original materials [17]. Dallas et al. have indicated that the antimicrobial activity of silver polymeric nanocomposites depends on particle size, size distribution, degree of particle agglomeration, silver content and the interaction of silver surface with the host polymer [18]. On the other hand, Ag^+ loaded in/on carriers may be released into water quickly due to the strong interaction between Ag^+ and H_2O molecules, causing the increase of cost but also harm to human's health. So, researchers have tried to decrease the release of the Ag NPs while keeping or enhancing the antibacterial activity. In our experiment, we embedded Ag/TiO_2 nanoparticles (Ag/TiO_2 NPs) in MPTS and TEOS. The TEOS is a chemical

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