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Preparation of Nanomaterials by Laser Ablation and Plasma Jet Techniques for Antibacterial Activity

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Abstract

Nanoparticles are currently considered a powerful tool and the most effective area for research because of their unique properties that depend on their size. In recent years, a new type of hybrid NPs called "core/shell NPs" has been developed, consisting of two or more types of single nanomaterials

In this study we used pulse laser ablation in liquid to synthesize NP from Zinc, Titanium, and Nickel targets using Nd:YAG laser with 200 and 800 mJ for each target. The optimum parameters were chosen to make a core/shell using a two-step PLAL, where the prepared NP was NiO@ZnO and NiO@TiO_2. In addition, a plasma jet method was used to prepare NP from Zn and Ti targets. The last method was our proposed hybrid method, which consists of PLAL first and then the plasma jet method to prepare ZnO@NiO and TiO@NiO core/shell NP. The morphological and optical properties of the prepared NPs are investigated using transmission electron microscopy, field emission scanning electron microscope, atomic absorption spectrometry, X-ray diffraction, contact angle, and UV-Visible.

The results show that PLAL and plasma jet succeed in the preparation of NP, but PLAL has smaller size and lower concentration, while the plasma jet yields a higher concentration and larger size. In addition, the two proposed methods for core/shell synthesis, and the results were confirmed using TEM images. The two-step method showed a thick shell material and NP size for the ZnO@NiO core/shell ranging from 20 to 100 nm, with an average particle size of 50.9 nm and a nearly spherical shape. The hybrid method produced a high concentration and smaller particle size where the NiO@ZnO core/shell NPs had a size distribution of 30-100 nm (average = 60.73 nm) and the TiO_2@NiO core/shell had a size of 10-28 nm and an average size of 20 nm, which was the smaller NP prepared in this work. In addition, all the prepared NP had a CA lower than 90°, which means that all the prepared NPs have high biocompatibility due to their excellent wettability, which is a crucial biomaterial property. Finally, higher wettability shows that colloids cover a larger area, which is a sign of strong antibacterial activity, and it is also suitable for many biological applications.

Antibacterial activity was investigated using the well diffusion method on two types of bacteria, *E. coli* and *S. aureus*. Three diluted concentrations were used for all synthesized NPs colloids (25, 50, and 75 %). The results showed a good inhibition rate for all concentrations, where

the maximum inhabitation rate for NP prepared using PLAL was 62.8 % and 59 % *S. aureus* while for NP prepared using the plasma jet was 53 % and 50 % for *E. coli* and *S. aureus*, respectively. These results were enhanced using core/shell NP, where the NP prepared using the two-step PLAL showed excellent enhancement. For NiO@ZnO NP, the results were 74 % and 71 % for *E. coli* and *S. aureus*, respectively, while for NiO@TiO_2 NP, they were 80 % and 75 % for *E. coli* and *S. aureus*, respectively, because of their smaller particle sizes. In addition, another enhancement was achieved using NP prepared with the hybrid method (ZnO@NiO, TiO_2@NiO), which had an excellent inhibition rate larger than that prepared using two-step PLAL. Where the inhabitation rate for ZnO@NiO NP was 80.6 % and 82% for *E. coli* and *S. aureus*, respectively, and for TiO2@NiO was 85 % and 87 % for *E. coli* and *S. aureus*, respectively. Moreover, all the prepared NP showed good cell viability. In addition, we can use a lower concentration to obtain the effect of NPs, which shows good cell viability and lower cell toxicity.