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Antibacterial activity of magnetic iron oxide nanoparticles synthesized by laser ablation in liquid

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ABSTRACT

In this study, (50–110 nm) magnetic iron oxide (α-Fe_2O_3) nanoparticles were synthesized by pulsed laser ablation of iron target in dimethylformamide (DMF) and sodium dodecyl sulfate (SDS) solutions. The structural properties of the synthesized nanoparticles were investigated by using Fourier Transform Infrared (FT-IR) spectroscopy, UV–VIS absorption, scanning electron microscopy (SEM), atomic force microscopy (AFM), and X-ray diffraction (XRD). The effect of laser fluence on the characteristics of these nanoparticles was studied. Antibacterial activities of iron oxide nanoparticles were tested against Gram-positive; *Staphylococcus aureus* and Gram-negative; *Escherichia coli*, *Pseudomonas aeruginosa* and *Serratia marcescens*. The results showed a noteworthy inhibition on both bacterial strains. The preparation conditions were found to affect significantly the antibacterial activity of these nanoparticles. The synthesized magnetic nanoparticles were used to capture rapidly *S. aureus* bacteria under the magnetic field effect.

1. Introduction

Magnetic nanoparticles have a wide range of uses in many different applications [1]. Their possible manipulation by magnetic field has attracted many biomedicine and bioanalytical applications such as drug delivery [2], magnetic resonance imaging (MRI) [3], magnetic assays [4] and treatment of cancer [5,6]. The spread of infectious diseases recently has posed a serious threat to public health, especially with the emergence of bacterial strains resistant to antibiotics. Alternative antibiotics have become one of the most important research works which received a considerable attention [7]. In general, both Gram-positive and Gram-negative bacterial strains cause human diseases. Various synthesized metal oxide nanoparticles were found to be good inhibitors for different bacterial strains [8]. The activity of metal oxide nanoparticles is directly dependent on the bacterial strain i.e. Gram positive and Gram negative; as they have differences in their cell wall [9]. Metal oxide Nanoparticles can interact with cell membrane of the bacteria by electrostatic interaction which damages the bacterial membrane and induces toxic oxidative stress on the bacteria by free radical formation; the radical oxygen species (ROS) [10]. Iron oxide nanoparticles are of great interest due to their small size and high magnetism and low toxicity [11,12]. Iron oxide (IO) is widely used in biomedical applications because of its biocompatibility and magnetic properties [13]. The

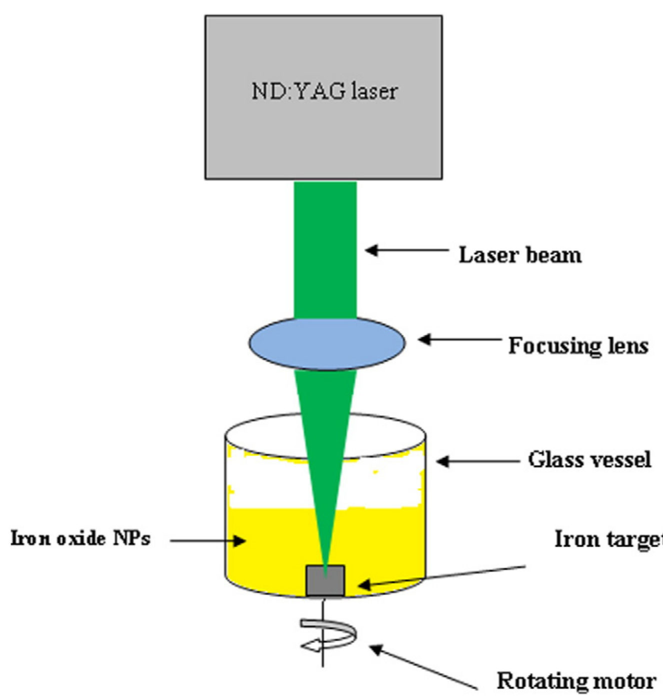

Fig. 1. Schematic diagram of PLAL system used in this study.

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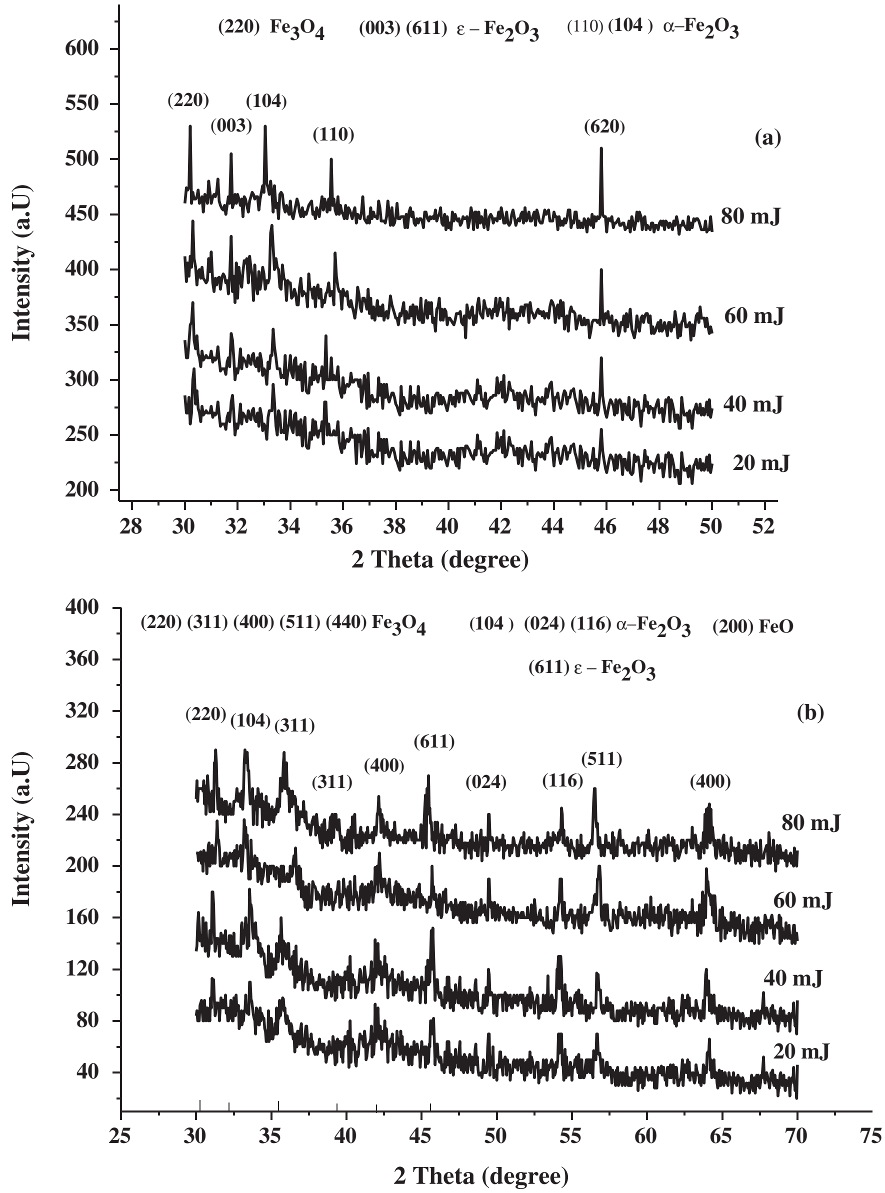

Fig. 2. XRD pattern of IO nanoparticles synthesized at different laser energies and solutions (a) DMF and (b) SDS.

bactericidal activity of such nanoparticles depends on (i) size, (ii) stability, and (iii) concentration of the growth medium [8]. Different methods have been adopted to synthesize IO nanoparticles like sol–gel method [14] hydrothermal method [15], laser ablation in liquid and co-precipitation method [16]. Pulsed laser ablation in liquid (PLAL) has become an increasingly important top-down method for fabricating nanoparticles [17,18]. This technique is simple, low-cost, requires minimum amount of chemical species, high control on ablation atmosphere and does not need any catalyst [19]. Many research groups have focused on this technique and a large variety of nanomaterials such as metals, metallic alloys, semiconductors, and polymers has been synthesized [20].

In the current study, magnetic iron oxide nanoparticles were synthesized by laser ablation of iron pellet in SDS and DMF solutions. Their activities against both Gram-positive (*Staphylococcus aureus*) and Gram-negative (*Escherichia coli*, *Pseudomonas aeruginosa* and *Serratia marcescens*) bacterial strains have been studied. The effect of ablated laser fluence on their properties and activity was investigated too.

2. Experimental work

2.1. Synthesis and characterization of IO nanoparticles

All chemical reagents used in the experiments were of analytical grade without further purification. Iron oxide (α-Fe_2O_3) nanoparticles were obtained by laser ablation of iron pressed pellet with purity of 99.99% in two types of solutions: Sodium dodecyl sulfate (SDS $CH_3(CH_2)_{11}OSO_3Na$) soluble in distilled water and dimethylformamide (DMF $(CH_3)_2NC(O)H$) at room temperature. The iron target was placed in the bottom of a quartz vessel filed with 6 ml of solution above the target. The colloidal solutions were synthesized by irradiation of iron pellet with pulsed Neodymium-doped Yttrium Aluminium Garnet (Nd:YAG) laser operated at $\lambda = 1064$ nm (type HUAFEI), 9 ns pulse width and 1 Hz repetition rate at room temperature. The iron oxide nanoparticles were synthesized at four different laser fluencies; 20 mJ, 40 mJ, 60 mJ and 80 mJ. 90 mm positive lens was used to focus the laser beam onto the material. Fig. 1 shows a schematic diagram of the laser ablation