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Preparation of antibacterial textile using laser ablation method

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ABSTRACT

A facile in situ laser ablation synthesis of Copper nanoparticles on cotton fabric is reported in this paper. This synthetic method is a laser ablation based fabrication of Cu nanoparticles on cotton fabric for improved performance and antibacterial activity. The treated cotton fabric was characterized using scanning electron microscopy, energy dispersive X-ray spectroscopy, UV–Visible spectroscopic techniques and antibacterial counting test.

Very good antibacterial behavior of treated fabrics achieved. This fabric can be used as medical and industrial textiles.

1. Introduction

Nowadays nanoparticles (NPs) are synthesis widely by chemical and physical methods due to their great range of applications. NPs typically exhibit different properties as a result of their increased surface area to volume ratio and the quantum confinement effect, in compare with larger-scale particles [1]. Nanoparticles have many applications in different areas, such as electronics, biomedicine, textile production etc. [2,3].

Various techniques such as micro emulsion, chemical reduction, reverse micelle, pulsed laser ablation in liquids, etc can be used for growing nanoparticles [4]. Nanosecond laser ablation is used for nanoparticle (NP) production [2]. This is an efficient and simple method. Material purity and dimensions control is good and variety of materials can be produced. Also, collection of nanoparticles in the liquid environment as colloidal solutions is easy [5].

Pulsed laser ablation liquid is simple and needs no purification after synthesis. It is a low cost technique and there is no by product with the final product. Also the composition, size and shape of the nanoparticles can be controlled by the liquid medium and the laser parameters.

Gondal et al. in 2013 reported about pulsed laser with high pulse energy which was focused on the target surface, immersed in the liquid medium and this vaporizes the target surface and forms the flume that consists of atomic and ionic particles and clusters of high kinetic energy.

The ablated species were excited electronically and react with the liquid to generate nanoparticles that contain atoms of both target material chemically.

Liquid medium and the product are in the form of a suspension and further irradiation can change in the size composition and morphology of the nanoparticles. Different target materials, liquid media, laser parameters such as pulse duration, wavelength and fluence can produce wide variety of end products [6–8].

Synthesis of nanoparticles by laser ablation in liquid medium is trouble-free, inexpensive and convenient. Also, water can be used as combination of mediums. Wavelengths and laser energy density can be varied and nanoparticles are free from contamination [9,10].

Gold and silver nanoparticles were prepared both in solid and colloidal phases, in order to develop antibacterial particles by laser ablation method [11].

Copper nanoparticle has less cost than silver and gold. Copper has thermal and electrical conductivity and also antimicrobial properties [12–14].

Recently, researchers focused on exploring possibilities of using copper nanoparticles as antimicrobial agent because of low cost of Cu in compare with metals like silver and gold. Copper is one of the most widely used materials now a day. Copper nanoparticles have unusual potential applications and can widely used in biology and nano medicine. Copper is used as a water purifier, antibacterial, fungicide and antifouling agent. Copper ions play important role in healing of burn injuries and preventing the wound from

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infection and helping in formation of bone matrix. Copper nanoparticles (Cu-NPs) have been synthesized by different methods with controlled size and shape [15,16].

Antimicrobial textiles with improved functionality find a variety of applications in health and hygiene products, especially in garments worn close to the skin, and also have several medical applications in infection control and barrier materials [17].

Cotton fabrics provide an ideal environment for the growth of microorganisms such as bacteria and fungi because of their hygroscopic properties, which contribute to their strong moisture-absorbing abilities [18].

Cotton fabrics have many functional hydroxyl groups and can be used as a support for nanoparticles, reducing agent and stabilizer. Cellulose acts as a reactor preventing agglomeration [18].

In the present work, copper nanoparticles were in situ synthesized via pulsed laser ablation on cotton fabric and the antibacterial efficiency of prepared sample is investigated.

There has been increased attention paid to the in situ synthesis of nanoparticles in textile fabrics.

There is no scientific literature describing the in situ synthesize of copper and copper oxide nanoparticles in Deionized water using the laser ablation method on cotton fabric.

This way of synthesis is not expensive and is simple. Also, control over the desired properties of the nanoparticles is fine.

2. Experimental part

In this experiment, copper nanoparticles were in situ synthesized on cotton fabric by laser pulse ablation method and effect of laser pulse energy on the properties of the obtained nanoparticles and in situ synthesis of them on the cotton fabric were investigated. Laser ablation was carried out by focusing of Nd:YAG laser beam of 1064 nm wavelength and 7 ns pulse width on a 99.9% purity copper plate in a distilled water. The experimental setup of laser ablation is shown in Fig. 1.

Focal length of the lens was 8 cm and the spot size of the laser pulse before the lens was 6 mm, leads to spot size of about 30 μm on the surface of target. Repetition rate of the laser pulse was 10 Hz. Laser ablation experiment was done using the laser fluencies of 1, 1.5, 2, 2.5 and 3 J/cm^2. Samples were prepared using 4000 laser pulses and the Cu nanoparticles were in situ synthesized on cotton fabrics and labeled as S1 to S5 respectively.

Colloidal nanoparticles suspensions and treated cotton samples were characterized by several methods. Optical absorption spectra of prepared nanoparticles were measured by UV–Vis–NIR spectrophotometer from PG Instruments (T-80).

The morphology of the fabrics and nano particles was observed using a scanning electron microscope (SEM; LEO 440I, made in England). Untreated and treated samples were gold coated before examination.

An EDX unit connected to the SEM microscope was used to determine the percentage of atomic contents of elements present in the treated fabrics, and then the amounts of copper on the surface of untreated and treated fabrics were compared. The crystallinity and shape of unit cells were investigated using X-ray Diffraction method.

The antibacterial efficiency of prepared samples was examined using colony counting method according to AATCC 100-2004. Luria-Bertani media (LB) broth was used as the growing medium for *Staphylococcus aureus* (gram-positive), in the bacteria counting test. To reach a cell concentration of 1×10^8 (CFU)/ml, bacteria were dripped into 10 ml of LB broth and then was diluted to a cell concentration of 1×10^6 (CFU)/ml. The cotton fabric samples with size of 1 cm^2 were put into a 1 ml bacteria suspension. Samples were incubated at 37 °C for 24 h. Then 100 μl of solution, from each incubated sample was taken and distributed over an agar plate. All plates were incubated again for 24 h, and the colonies formed on them were counted. By the following equation, percentage of reduction was calculated:

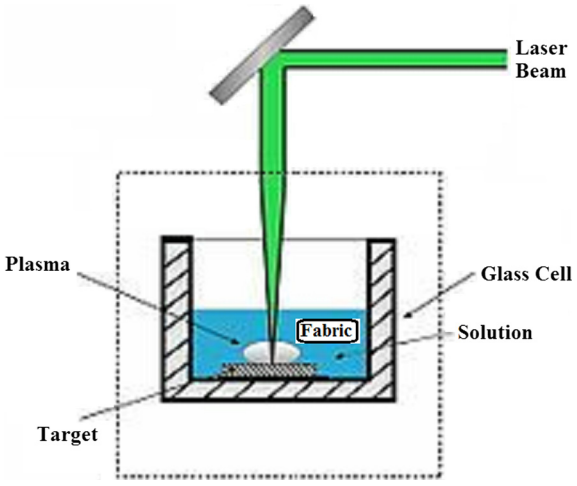

Fig. 1. Schematic illustration of the laser ablation experimental setup.

$$\text{Reduction } (\%) = (C - A)/C$$

in which C and A indicate the colonies counted on the plates of the control and the treated samples, respectively.

3. Results and discussion

In this research, Cu Nano particles were in situ synthesized using laser ablation method on cotton fabrics. The concentration of nano particles in colloidal aqueous liquid after laser ablation in different fluencies were compared using UV–VIS-NIR spectrophotometry.

Absorbance measurements of the obtained suspension of Cu nanoparticles after Laser Ablation of copper target in the domain of 400–800 nm are reported. Results are shown in Fig. 2. The results imply that the number of the expelled nanoparticles due to laser irradiation depends on the incident laser fluencies. The absorbance curve corresponding to sample S5 (with the laser fluency of 3 J/cm^2) indicates a maximum of plasmon resonance. This can be interpreted as a higher degree of oxidation or as corresponding to larger nanoparticles.

Absorption peak of prepared Cu nano particles is seen >600 nm, which is the Cu nano particles surface plasmonic resonance wavelength. Surface plasmonic resonance of Cu oxide occurs at $\lambda > 600$ nm according to report [19]. Results confirmed that the nano-particles contained copper and copper oxide.

The copper content of fabrics increases with laser pulse energy and the surface plasmon resonance (SPR) peak that is a signature of the formation of Cu nanoparticles appears in visible spectra of these fabrics.

The intensity of absorption peaks for samples are different. Plasmon resonance absorption spectrum peak of nanoparticles will be shifted toward larger wavelength if the size of nanoparticles increases, according to Mie theory [20].

Nanoparticles concentration in the suspensions related to the intensity of peaks. From the results, it can be concluded that number of nanoparticles in sample 5 is more and larger than the other samples.

The morphological analyses of the synthesized Cu nanaparticles were done with SEM analyses. The samples were gold coated to avoid charging effect of the images.

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