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Adsorption and photocatalysis efficiency of magnetite quantum dots anchored tin dioxide nanofibers for removal of mutagenic compound: Toxicity evaluation and antibacterial activity

Ali Fakhri[a,b,*], Mahsa Naji[c], Pedram Afshar Nejad[d]

[a] Young Researchers and Elites Club, Science and Research Branch, Islamic Azad University, Tehran, Iran
[b] Department of Chemistry, Central Tehran Branch, Islamic Azad University, Tehran, Iran
[c] Department of Materials Engineering, Karaj Branch, Islamic Azad University, Karaj, Iran
[d] Department of Microbiology, Ayatollah Amoli Branch, Islamic Azad University, Amol, Iran

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ABSTRACT

The Magnetite Fe_3O_4 quantum dots anchored SnO_2 nanofibers (Fe_3O_4 QDs/SnO_2 NFs) have been synthesized using the facile one step hydrothermal method. The characteristic structure of synthesized Fe_3O_4 QDs/SnO_2 NFs was analyzed using X-ray diffraction, Transmission electron Microscopy, Scanning electron microscopy, UV–vis diffuse reflectance, photoluminescence spectroscopy, and N_2 adsorption-desorption instrumental techniques. The crystallites size of Fe_3O_4QDs/SnO_2 NFs was 7.0 nm. The average diameters of Fe_3O_4QDs/SnO_2 NFs were 7.25 nm. BET surface area of Fe_3O_4QDs/SnO_2 NFs has been found 53.064 m^2/g. The activity of Fe_3O_4 QDs/SnO_2 NFs samples were compared towards adsorption and degradation of mutagenic compound such as Ethyl methanesulfonate (EMS). The Fe_3O_4 QDs/SnO_2 NFs demonstrates 93.85% and 56.85% photo degradation and adsorption activity towards 10 ppm EMS solution in 30 and 40 min, respectively. Fe_3O_4 QDs/SnO_2 NFs shows maximum removal of EMS at pH 5. Additionally, cytotoxicity test showed that the newly developed catalyst has low cytotoxic effects on three kinds of human cells. The antibacterial activity evaluation against two bacterials, including *Staphylococcus aureus* (ATCC 43300), and *Pseudomonas aeruginosa* (ATCC 27853) was considered. It was found that the MIC values for the antibacterial assay in the presence of Fe_3O_4 QDs/SnO_2 NFs were around 0.38 mM with 83.4, and 85.5% inhibition for the *S. aureus*, and *P. aeruginosa* bacterial strains, respectively.

1. Introduction

Ethyl Methanesulfonate (EMS) is a sulfonoxyalkane with carcinogenic and teratogenic properties (Table 1). Ethyl methanesulfonate is a monofunctional ethylating agent that has been found to be mutagenic in a wide variety of genetic test systems from viruses to mammals. It has also been shown to be carcinogenic in mammals [1]. At present, the techniques used for removal of organic pollutants may be broadly divided into four categories: i.e., membrane-separation, ion exchange, precipitation-coagulation and adsorption [2–5]. In contrast to these, adsorption or photocatalysis process is economically effective and ultimate fate of many contaminants in aquatic environment [6]. Nowadays, a most studies were made to synthesis of high efficiency adsorbents, for the removal of pollutants compound [7]. Nanostructured materials with high specific surface area and active sites, have been in the center of attention as an emerging water treatment methods [8].

One-dimensional (1D) nanomaterials have stimulated great interest due to their importance properties and broad technological applications such as optoelectronic. The 1D tin oxide nanostructures are the focus of current scientific research efforts in nanotechnology fields since they are the major minerals on the Earth due to chemical, and physical structural properties.

Quantum dots (QDs), a new material, have attention research due to their major properties, such as robustness, chemical inertness, chemical stability against photo bleaching, and low cytotoxicity [9–11]. Nowadays, QDs have also been applied as a photocatalyst due to high electron-accepting and-transport and photo-luminescence properties [12–40].

Therefore, in the present work, a synthesis of Fe_3O_4 quantum dots anchored SnO_2 nanofibers, characterization, and use for adsorption and removal. The toxicological effects of the catalyst on several kinds of human cells and the effect of oxidation as pretreatment were also investigated. Then, removal or decompose of EMS is very important due to The EMS have mutagenic properties. The novelty of this work is

* Corresponding author.
E-mail address: ali.fakhri88@yahoo.com (A. Fakhri).

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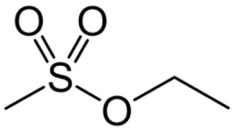
Table 1
Physicochemical properties of EMS.

Ethyl methanesulfonate	
Chemical structure	
Molecular weight	124.16 g/mol
Density	1.1452 g/cm^3
Boiling point	85–86 °C

synthesis of nano sample for degradation this pollution. Moreover, synthesized catalyst has attention due to non-toxic in nature.

2. Materials and Methods

2.1. Materials

All the chemicals were obtained from Sigma-Aldrich Ltd, USA.

2.2. Synthesis of Fe_3O_4 Quantum Dots

To 0.5 g of $FeCl_3.6H_2O$ dissolved in a mixture of deionized water (25 mL) and CH_3COOH (5 mL) under magnetic stirring. The mixture was heated in a Teflon lined autoclave at 180 °C for 10 h and then cooled to room temperature. The precipitate was separated to obtain the Fe_3O_4 QDs.

2.3. Synthesis of SnO_2 Nanofibers

3 g of $SnCl_4{\cdot}5H_2O$ was added into mixture of PVP-ethanol/DMF solvent (weight ratio 1:1), under magnetic stirring at 25 °C for 24 h. Later, prepared solution was introduced in 10 mL syringe with a hypodermic needle (dia. 2 mm) in a controlled electro spinning setup (flow rate 0.2 ml/h; applied electric field 1.25 kV/cm). This electric field strength was needed to enable for the high stretch rates of the electrospun jet. The fiber obtained was then annealed to obtain SnO_2 nanofibers. The electrospun fibers were calcined at 550–650 °C for 4 h.

2.4. Synthesis of Fe_3O_4 Quantum Dots Anchored SnO_2 Nanofibers

SnO_2 nanofiber (200 mg) and Fe_3O_4 QDs (50 mg) were mixed into 20 ml of distilled water and 10 ml of alcohol. The mixture was kept stirring for 30 min at room temperature to make a clear dispersion of QDs. After that, the dispersed solution was transferred into a 40 ml Teflon-sealed autoclave and maintained at 140 °C for 4 h. Finally, the resulting solution was cooled, filtered, washed with distilled water three times and dried under vacuum at 40 °C overnight. The product was calcined at 400 °C for 2 h.

2.5. Characterization Instruments

A field emission scanning electron microscopy (SEM-Hitachi SU8000) and X-ray diffractometer (XRD) Philips X'Pert were used to examine the morphology of the catalyst synthesized here. The particle size of catalyst was measured using Transmission Electron Microscope (TEM) (Zeiss EM-900). The Brunauer–Emmett–Teller (BET) of the nanocomposites was analyzed by nitrogen adsorption instrument in an ASAP2020 surface area. Zeta potential measurements of the dilute dispersions (0.1 mg mL^{-1}) of the various the nanocomposites were performed with a Brookhaven NanoBrook Omni Instrument at 25 °C. Photoluminescence and UV–Vis spectroscopy were carried out using TEC Avaspec 2048 Spectrophotometer (excitation source = Xenon arc

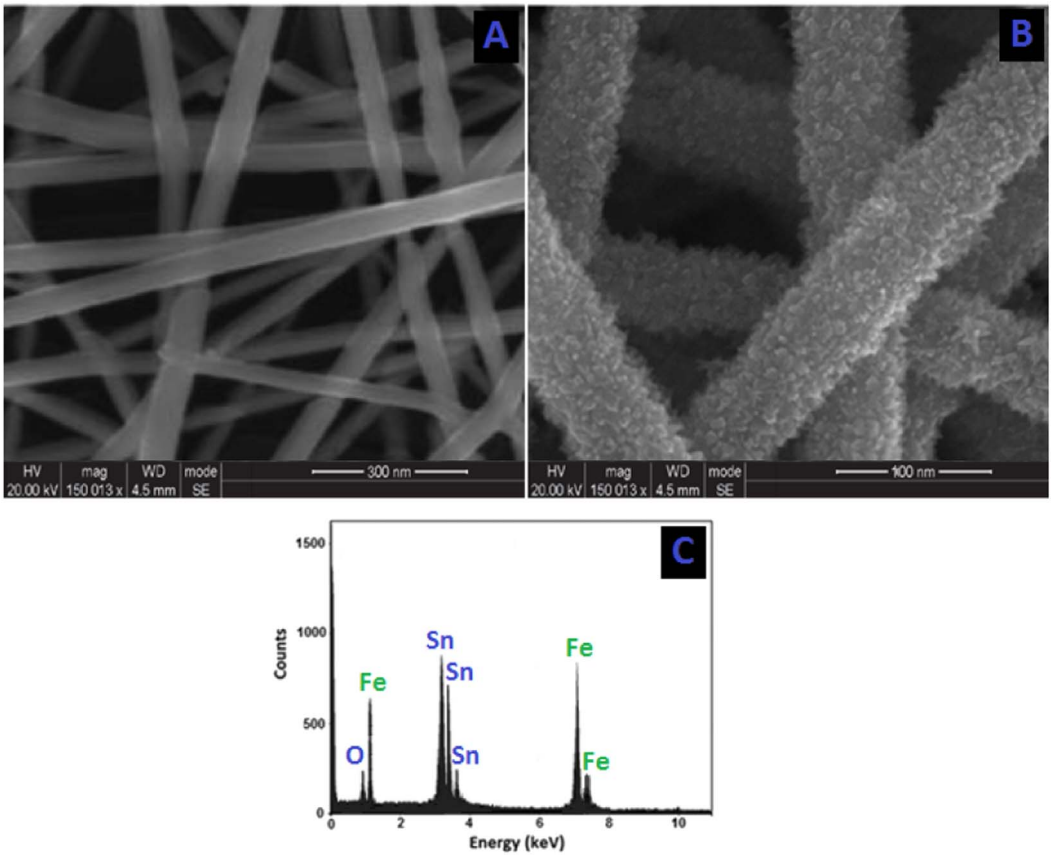


Fig. 1. SEM images of SnO_2 NFs (A), Fe_3O_4QDs/SnO_2 NFs (B) and EDS (C) of Fe_3O_4QDs/SnO_2 NFs.