Int. J. Bio-Inorg. Hybr. Nanomater., 9(3): 131-136, Autumn 2020

Antibacterial effect assessment of ZnO nanoparticles, ZnO: Fe nanoflower and magnetic fields

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Received: 20 April 2020; Accepted: 23 June 2020

ABSTRACT: Chemical precipitation method was used in order to synthesize of ZnO quantum dots (2-3nm) and ZnO:Fe nanoflower. Their physical properties and characteristics were assessed by X-ray diffraction (XRD), ultraviolet-visible (Uv) spectrophotometer and Transmission Electron Microscope (TEM) and it was shown that the obtained ZnO:Fe quantum dots have a hhexagonal crystal structure of a high-quality. Antibacterial effects of ZnO:Fe nanoparticles against some pathogenic bacteria were investigated. *Staphylococci aurous* and *Escherichia coli* were used as test microorganisms. Disc bacteriological tests were used in order to assess the effects of ZnO:Fe concentration (0.35 to 6 mg/mL) as antibacterial. The magnetic field with nanoparticles with different concentrations of iron-contaminated oxide has no effect on stopping the growth of Staphylococcus aureus and Escherichia coli bacteria in the field. The sizes of inhibition zone were different according to the type of bacteria and the concentrations of ZnO:Fe nanoflower, the maximum diameter being observed for *Staphylococcus aurous*.

Keywords: *Antibacterial effect, Escherichia coli, Quantum dots, Staphylococci aurous.*

INTRODUCTION

Colloidal semiconductor nanocrystals which generally consist of II-VI or III-V groups of elements' table are named quantum dots (QDs). Similar to other nanoparticles, QD optical and electrical properties show that their characteristics are strongly size dependent [1-3]. They have many useful applications in different fields like industry and life sciences. On the other hand, most of the chemical materials used for their production are toxic, expensive, and even explosive [4-6]. Recent advances in the field of nanotechnology, in particular, the ability of nanoparticle synthesis in different shapes and sizes, have led to the production of a wide range of antimicrobial agents. Materials in nanoscale have a higher surface to volume ratio than larger particles with the same chemical composition, and this makes them biologically more active [2]. Antimicrobial activity of silver compounds and zinc oxide (ZnO) is known from the very distant past and has many applications in disinfecting medical devices, water purification, and wound healing, creams, lotions, and antibacterial

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creams [2]. A large surface to volume ratio of nanoparticles in comparison with bulk one, is increasing the range of probable interaction with cell surface [6, 7]. The antibacterial effect of nanoparticles such as ZnO, MgO, TiO_2, SiO_2 is considerable and therefore their selective toxicity towards biological systems suggests their potential application as therapeutics, diagnostics, surgical devices and nanomedicine based antimicrobial agents [8]. In this study, an attempt is to assess the antimicrobial activity of ZnO QDs and ZnO:Fe nanoflower on the two pathogenic bacteria (*Staphylococci aureus* and *Escherichia coli*) and the effect of the magnetic field and ZnO:Fe nanoflower in different concentrations on the zone of inhibition diameter.

MATERIALS AND METHODS

Synthesis and assessment of properties

Chemical precipitation method was used in order to synthetize ZnO:Fe nanoparticles. At first four solutions of Iron sulfate mercaptoethanol (ME), Sodium hydroxide (NaOH) and zinc chloride, (all from Merck Company) were prepared in the distilled water, under vigorous stirring. After that, zinc chloride solution was poured into three spout balloon container. Then, Iron sulfate and mercaptoethanol solution was added to the same balloon one droplet every 3 seconds. Finally, Sodium hydroxide was added to the balloon by the same way. In order to extract any impurity aggregate, the final solution was washed several times by deionized water and then was centrifuged. The precipitated sample was dried. All processes were done at room temperature [1, 2, 9, 11-14]. XRD (X-Ray Diffraction, Bruker D8 ADVANCE λ= 0.154 nm Cu Kα radiation) and UV-Vis spectrophotometer (Ultra Violet–Visible, UV-2600 Shimadzu, Japan) were used to investigate ZnO:Fe QDs optical and structural properties. Particle size distribution was assessed by TEM (Transmission electron microscope, Mashhad Firdausi University).

Antibacterial activity assay

The antibacterial effect of *Staphylococci aurous* and *Escherichia coli* were studied by the culture method. They were grown aerobically in nutrient broth culture environment for 24 h at 37°C before using as target organisms. Then 1cc of each bacterium was planted to a plate. The plates were previously prepared by Mueller Hinton Agar culture environment. After that, a well was created in the plates by the Pasteur pipette. The concentrations of 0.35 to 6 mg/ml of ZnO:Fe 10% were adjusted in wells. After inoculation and cultivation of different target bacteria on top of nutrient agar, wells were placed in selected areas on different plates. The zone of inhibition was measured after 24 h of incubation. We also investigated the effect of direct and alternating 2 and 24 hour magnetic fields on bacterial plate containing nanoparticles with Isfahan Tak device with 24 volt voltage and 230 ohm coil.

RESULTS AND DISCUSSION

Fig. 1 indicates the XRD pattern of the ZnO:Fe. As it can be seen, the sample has the Hexagonal crystal structure and also is in a single phase. These findings are according to the standard JCPDS (Joint Committee on Powder Diffraction Standards) card No. 36-1451 and the diffraction peaks correspond to the crystal planes: (100), (002), (101), (102), (110), (103), (200), (112), (201), (004) and (202). The mean size of the particles was calculated as being 28 nm by Debye-Scherer formula [1, 2, 9, 11-14]. As the Fig. 2 shows, the results of the transmission electron microscope indicate that the size of the nanoflower produced is about (200-500 nm).

The absorption spectra of ZnO:Fe QDs the absorption peak shift is slowly decreased by the iron increase. The details are listed in Table 1. The size can

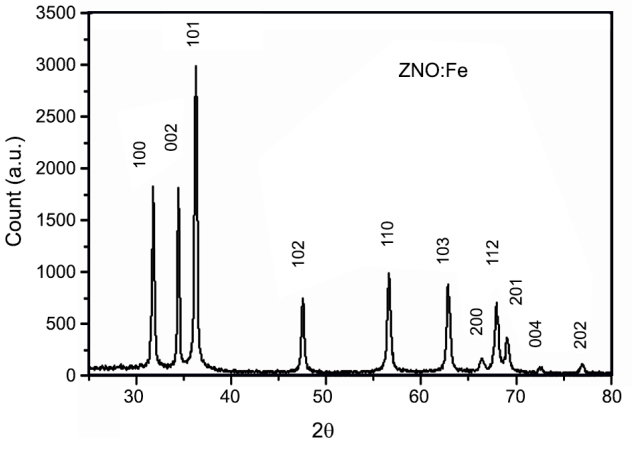


Fig. 1. XRD patterns of the ZnO:Fe QDs.

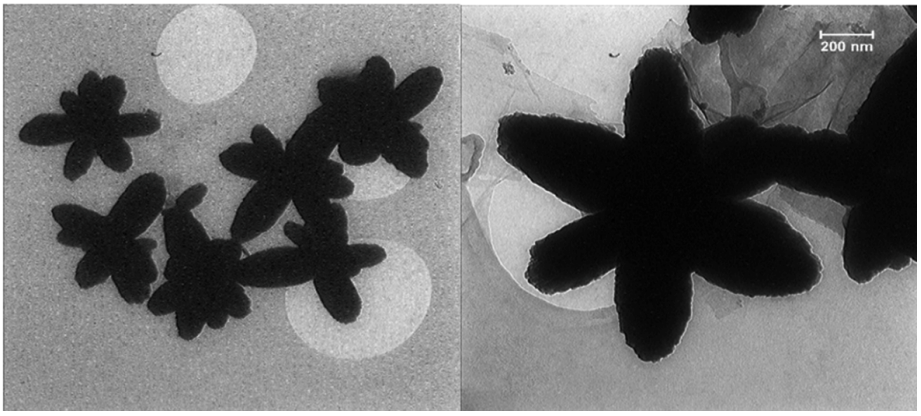
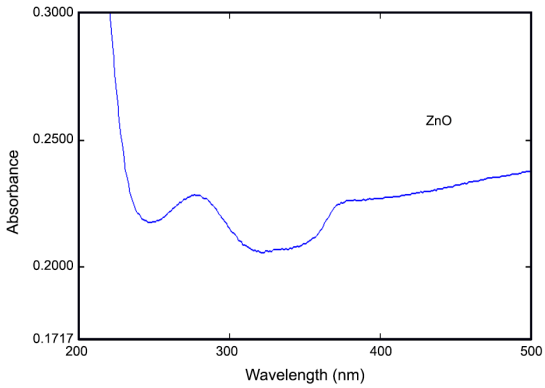
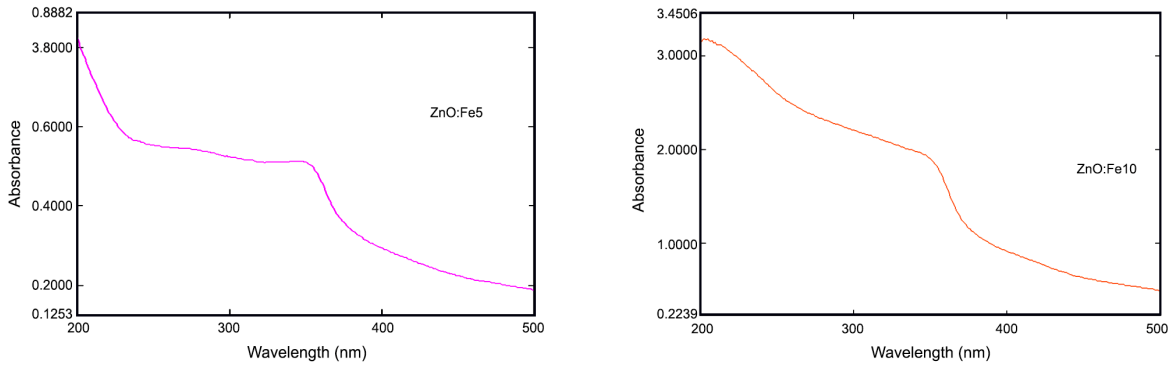


Fig. 2. Transmission Electron Microscope of ZnO:Fe nanoflower.



(a)

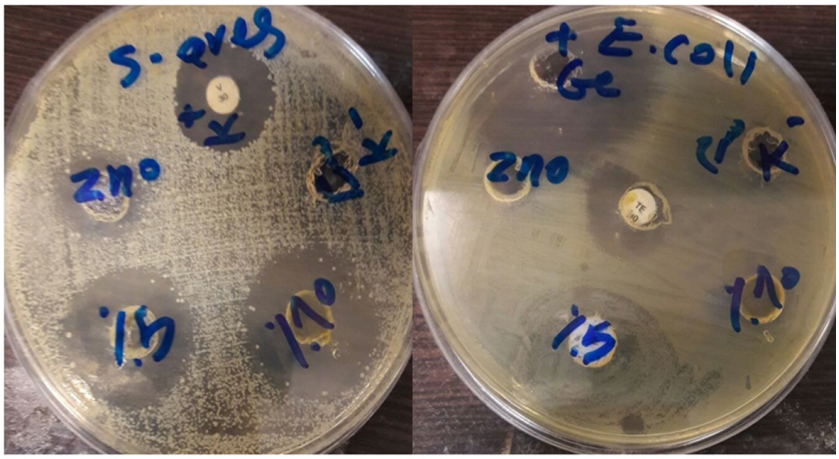


(b)

Fig. 3. (a) UV-Vis absorption spectrum of ZnO, (b) UV-Vis absorption spectrum of ZnO:Fe.

Table 1. The physical properties of the ZnO:Fe nanoparticles

Sample	l_{max} (nm)	E (eV)	Estimated particle size (Brusequation) (nm)	Crystal size (nm)
ZnO	371	2.67ev	2.78	---
ZnO:Fe 5%	352	3.52ev	2.78	---
ZnO:Fe 10%	350	3.54ev	2.78	28



Staphylococcus aureus *Escherichia coli*

Fig. 4. Antibacterial activity of ZnO, ZnO:Fe %5 and ZnO:Fe %10 nanoparticles Staphylococcus aureus and Escherichia coli.

Table 2. Zone of inhibition for different nanoparticle.

Sample	Staphylococcus aureus (mm)	Staphylococcus aureus (mm)	Staphylococcus aureus (mm)	Average Staphylococcus aureus (mm)
ZnO	11	17	18	15.33
ZnO:Fe 5%	25	25	20	23.33
ZnO:Fe 10%	25	26	24	25
Positive control of vancomycin	23	19	26	22.66

also be estimated by Brus equation, as being (2-3 nm) [9]. Therefore, ZnO:Fe band gap changes depending inversely on the nanoparticle impurity. Our findings are completely compatible with previous studies [9].

The antibacterial activity of ZnO and ZnO:Fe was estimated by the disc and well diffusion agar methods and the results are shown in Tables 2, 3 and 4, Figs. 4 and 5. The size of the inhibition zone indicated the antibacterial effect of ZnO:Fe [10]. As it can be seen, by increasing the ZnO:Fe concentration in wells and discs, the growth inhibition has been increased. The size of inhibition zone was different according to the type of bacteria and the concentrations of ZnO:Fe. Based on the results obtained (Fig. 4), the diameter of inhibition

Table 3. Zone of inhibition for the effect of magnetic field (alternating and direct) and nanoparticles with the same concentration on Staphylococcus aureus

Sample	No magnetic field	Under direct field 2 hours Dc	Under alternating field 2 hours Ac	Under direct field 24 hours Dc
ZnO	15.33	20	15	20
ZnO:Fe 5%	23.33	20	23	22
ZnO:Fe 10%	25	25	24	24
Positive control of vancomycin	22.66	20	18	20

Table 4. Zone of inhibition for concentration.

ZnO:Fe 10 concentration (mg/mL)	Staphylococcus aureus (mm)
6 gr/litr	28mm
3 gr/litr	25mm
1.5 gr/litr	22mm
0.7 gr/litr	20mm
0.35 gr/litr	18mm

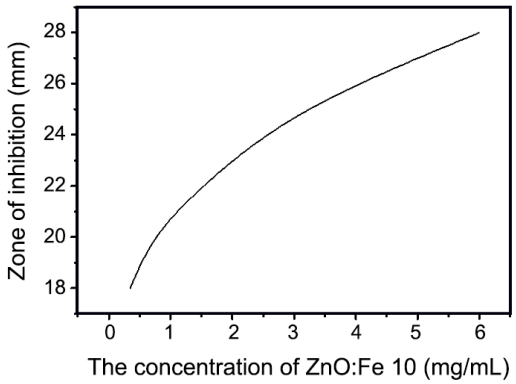


Fig. 5. Comparison of zone of inhibition for different concentration of ZnO:Fe %10 nanoflower.

zone for different bacteria, it can be concluded that the maximum inhibition activity is happened for *Staphylococci aureus* in comparison with *Escherichia coli*. Fig. 5 demonstrated the similar extended results for different concentrations of ZnO:Fe 10% nanoflower antibacterial activity and it can be seen that the same results obtained. We also researched the effects of the magnetic field of a plate on a direct and alternating magnetic field and found that a direct and alternating magnetic field had no effect on bacterial mortality.

CONCLUSIONS

In this study, ZnO:Fe QDs with dimension of (2-3 nm), were synthesized by chemical method. UV-Vis spectroscopy results indicates that the absorption peak of the ZnO:Fe nanoparticles is slowly decrease with Fe increase. The antibacterial activity of ZnO:Fe nanoparticles was assessed by the disc and well diffusion agar methods. By increasing the nanoparticle concentration in wells and discs, the growth inhibition and diameter of inhibition zone have also been increased. The sizes of inhibition zone were different according to the type of bacteria and the concentrations of ZnO:Fe nanoflower, the maximum diameter being observed for *Staphylococcus aureus*. The highest growth inhibition zone had a concentration of 6 gr/litr. The magnetic field with nanoparticles with different concentrations of iron-contaminated oxide has no effect on stopping the growth of *Staphylococcus aureus* and *Escherichia coli* bacteria in the field. For these and other reasons it is concluded that additional studies are needed for understanding how ZnO:Fe nanoparticles affect the bacterial cell.

ACKNOWLEDGEMENT

The authors are grateful to Faculty of Basic Sciences, Falavarjan Islamic Azad University for their cooperation and supply of the experimental equipments.

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