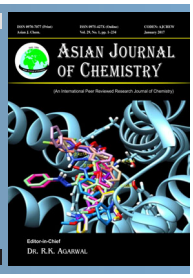
Asian Journal of Chemistry; Vol. 29, No. 2 (2017), 239-241

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2017.20027



Preparation, Characterization and Antibacterial Activity of NiO Nanoparticles

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Received: 13 April 2016; *Accepted*: 12 July 2016; *Published online*: 30 November 2016; AJC-18137

In present investigation, the synthesis of nickel oxide (NiO) nanoparticles is performed using thermal decomposition method. The As-prepared NiO nanoparticles was characterized by X-ray diffraction analysis, Fourier transform infrared spectroscopy, scanning electron microscopy and energy dispersion X-ray spectroscopy. Antibacterial activity of NiO nanoparticles was tested against *Bacillus subtills, Streptococcus pneumonia, Escherichia coli* and *Proteus vulgaris*. The results show that the synthesized NiO nanoparticles will be great potential in the field of nanomedicine.

Keywords: NiO, Nanoparticles, Dimethylamine, Antibacterial activity.

INTRODUCTION

In order to control infectious bacterial diseases, different kinds of nanostructured inorganic metals and their compounds have been utilized as antibacterial agents. Among them, noble metals such as silver and gold metallic nanoparticles have been studied widely as antibacterial agents because of their superior antibacterial activity [1]. However, high costs limits the applications of the noble metals-based antibacterial agents.

Among the different kinds of nanomaterials, nickel oxide (NiO) nanoparticles have been extensively studied due to its mechanical, optical and electrical properties. Nickel oxide is a p-type semiconductor which has been widely used in catalysis, sensors, supercapacitors, electrochromic devices, fuel cells, drug delivery and solar cells [2-4]. However, to the best of our knowledge reports on antimicrobial activity of NiO nanoparticles is very less. Therefore, we have planned to synthesize NiO nanoparticles as antibacterial agents. Nickel oxide nanostructures can be prepared by different methods such as hydrothermal method, sol-gel method, forced hydrolysis, thermal decomposition, electro spinning technique and green synthesis method [5-8]. Among these methods, thermal decomposition method will be a better approach for synthesis of NiO nanoparticles due to its easy procedure, creation of large surface area and low cost.

In this work, NiO nanoparticles were synthesized by a simple, low-cost and facile thermal decomposition method. Furthermore, the antibacterial activity of NiO nanoparticles has been examined.

EXPERIMENTAL

Thermal decomposition method was used for the synthesis of NiO nanoparticles. Nickel sulphate ($NiSO_4$) and dimethylamine (DMA) was purchased from Qualigens and used as received. A typical procedure is given below:

1.5 g of $NiSO_4$ was dissolved in 150 mL of distilled water. To this, 50 mL of 0.01 M aqueous dimethylamine solution was added drop wise with constant stirring. The above reaction mixture was continuously stirred for 5 h. The precipitate formed was filtered and washed with adequate amount of water. The dried powder was calcined at 600 °C for 6 h in a muffle furnace. The obtained black colour NiO powder was utilized for further characterization.

X-ray diffraction pattern was obtained by a Rich Siefert 3000 diffractometer with Cu-$K_{\alpha 1}$ radiation (λ = 1.5406 Å). FT-IR spectrum was recorded using a Shimadzu FT-IR 8300 series instrument. Morphology was examined by using a Hitachi-SU6600 FESEM instrument equipped with energy dispersive X-ray spectroscopy.

Antibacterial experiment: The antibacterial activity of NiO nanoparticles was screened by agar well diffusion method [9] using *Bacillus subtilis, Staphylococcus aureus, Escherichia coli* and *Proteus vulgaris* as bacterial stains. In agar well diffusion method, NiO nanoparticles showed significant antibacterial activity on all the four bacterial stains. 20 µg of NiO nanoparticles was gently pushed over the nutrient agar plate for intimate contact of nanoparticless with bacterial cell. Then

the nutrient agar plates were incubated at 35 °C for 20-38 h. The zone of inhibition was measured in millimeter of the every well and the values were noted. The above antibacterial studies were conducted in triplicates and the average values were calculated.

RESULTS AND DISCUSSION

Characterization of NiO nanoparticles: X-ray diffraction analysis is the primary tool for the characterization of metal oxide nanoparticles. Fig. 1 displays the XRD pattern of NiO nanocrystalline powder synthesized by thermal decomposition method. Diffraction peaks at 35.1°, 32.5°, 38.3°, 44.0° correspond to hexagonal wurtzite structure of NiO nanoparticles. This result is consisted with the other report [10]. There is no indication of any other secondary phase NiO in the XRD pattern. However, the existence of noise peaks is due to organic impurities. Also significant peak broadening of NiO powder was observed which indicates the ultra-fine nature of the synthesized sample. The crystallite size was estimated from the line broadening in XRD using Debye-Scherer's formula. The estimated average crystallite size of NiO is 42 nm which confirms the formation of nanocrystalline NiO.

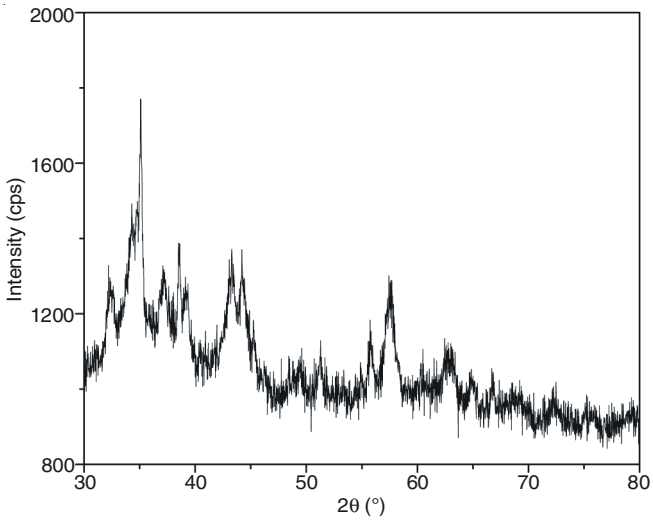

Fig. 1. XRD pattern of NiO nanoparticles

Fig. 2 shows the FTIR analysis of NiO nanoparticles. It shows five bands at 3373, 1499, 1388, 904 and 471 cm^{-1}. The strong absorption at 1499 cm^{-1} is due Ni-O stretching vibration. This result is similar to that reported by Davar *et al.* [11]. The band at 3373 cm^{-1} is assigned to O-H stretching vibrations of water molecule. The presence of peak at 1388 cm^{-1} is due to C-C bond which indicates the existence of organic impurity in the sample.

The SEM image of NiO powder is shown in Fig. 3(a-c). From this image it is clearly seen that the NiO nanoparticles have been agglomerated. Also the sample is porous in nature which may be due the liberation of gaseous product during calcination process. The diameter of the NiO sample is in the range of 80-130 nm.

Further, quantitative analysis of EDS spectrum shown in Fig. 3(d) finds that the atomic ratio of Ni:O is about 1:1, indicating that a stoichiometric sample (Ni/O = 1:1) is obtained and is consistent with stoichiometric NiO, in agreement with present XRD result.

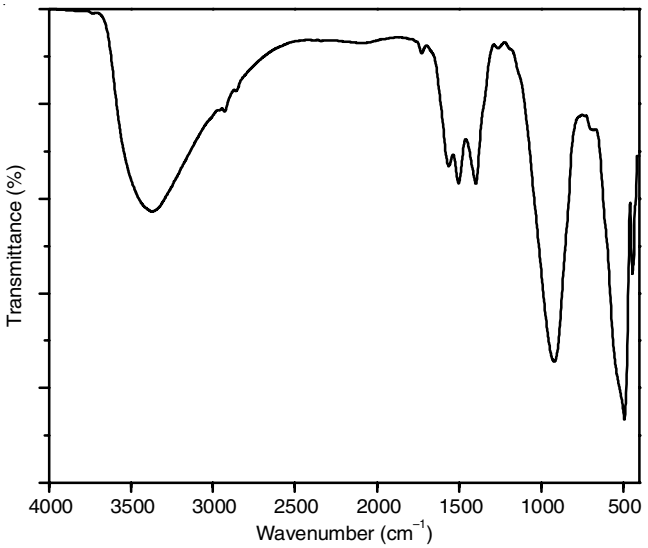

Fig. 2. FT-IR spectrum of NiO nanoparticles

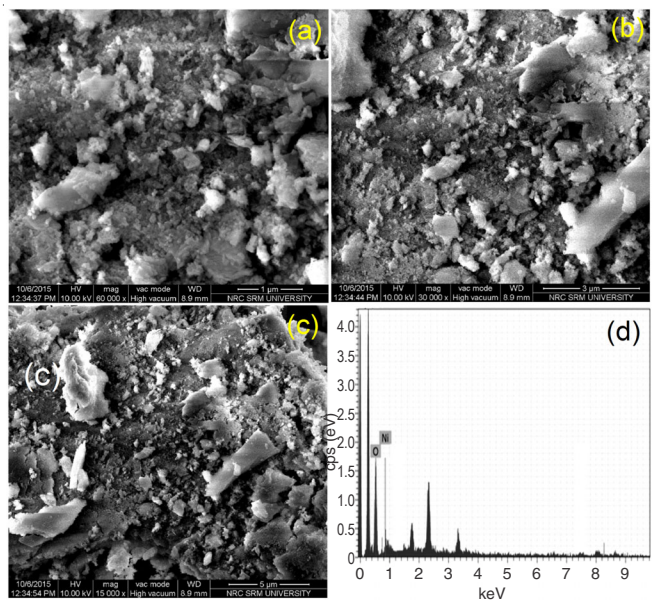

Fig. 3(a-d). SEM image and EDS of NiO nanoparticles with diffraction magnification

Antibacterial activity of NiO powder: Antibacterial activity of NiO nanoparticles against *B. subtilis, S. aureus, E. coli* and *P. vulgaris* with different solvents is shown in Table-1. It can be seen that the NiO nanoparticles exhibit maximum zone inhibition without using any solvent (Std). Maximum zone of inhibition was obtained in *B. subtilis, S. aureus, E. coli* and with a zone diameter of 21, 20 and 22 mm, respectively. Comparatively, lowest zone of inhibition was observed in *P. vulgaris* with a zone diameter of 19 mm. This result is higher

TABLE-1
ANTIBACTERIAL ACTIVITY OF NiO NANOPARTICLES

Tested organisms	Zone of inhibition (diameter in mm)			
	Standard	Ethanol	Methanol	Chloroform
B. subtills	21	10	9	13
S. aureus	20	11	13	15
E. coil	22	10	12	11
P. vulgaris	19	14	13	15

or comparable with previous reports [12,13]. The growth inhibition of bacterial cells may be due to distractions of cell membrane by NiO nanoparticles which results in breakdown of cell enzyme [14].

Conclusion

Facile method has been reported to synthesize NiO nanoparticles. The formation of NiO nanoparticles was confirmed by XRD and FTIR analysis. SEM images reveal the formation of agglomerated NiO nanoparticles. The antibacterial experiments show that the NiO nanoparticles exhibit good zone of inhibition against *B. subtilis, S. aureus, E. coli* and *P. vulgaris*. The synthesized NiO nanoparticles can become a potential candidate in the field of nanomedicine.

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