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A NOVEL GREEN SYNTHESIS OF NICKEL OXIDE NANOPARTICLES USING ARABIC GUM

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Abstract. Present work involves synthesis of NiO nanoparticles using Arabic gum by the sol-gel method. The synthesized NiO nanoparticles were characterized by Fourier transform infrared spectroscopy (FTIR), field emission scanning electron microscopy (FESEM) and X-ray powder diffraction (XRD). It was shown that the synthesized NiO nanoparticles of cubic phase have a spherical shape and an average size of 34 nm.

Keywords: NiO, Arabic gum, biosynthesis, sol-gel, nanoparticles.

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Introduction

Nowadays, there is an emerging interest in the synthesis of nanomaterials due to their properties that are not found in bulk. The behavior of nanomaterials is highly dependent on the shape and size of nanoparticles, and thus, a key factor in the use of nanoparticles [1-3]. Among the all known nanoparticles, nanoscaled metal oxide particles are highly regarded due to their applications in the field of gas sensors, solar energy, catalytic and electronics. Among these, nickel oxide nanoparticles are notable due to the properties of optical, magnetic, field emission and electrochemical properties [4].

Nickel oxide has many uses in the manufacturing alkaline battery cathodes, semiconductors, dye-sensitized solar cells, magnetic materials, solid oxide fuel cells, electrochromic films, *p*-type transparent conducting films, antiferromagnetic layers gas sensors and heterogeneous catalytic materials [5].

Various methods can be used to synthesize NiO nanoparticles. Sol-gel methods have many advantages, including the synthesis nanomaterials at a lower sintering temperature [6], easy preparation [7], low cost [8], controlled consolidation and shape modulation [9].

Arabic gum is a polysaccharide obtained from the branches of *Acacia Senegal* tree. Other names of this gum including: *Acacia Senegal*, *Acacia seyal*, *Acacia gum*. The color of the Arabic gum is orange-brown [10]. The principal use of Arabic gum is in confectionery as an emulsifier, for preserving the flavors of soft drinks. Arabic gum is also used in the pharmaceutical industry as a coating for pills and hair set products [11]. Recently, green synthesis in the presence of Arabic gum of various nanoparticles such as selenium nanoparticles [12], gold nanoparticles [13], magnetic nanoparticles [14] and silver nanoparticles [15] have been reported. Previously, we have reported synthesis of Ni-Cu-$ZnFe_2O_4$ and Ni-Cu-$MgFe_2O_4$ magnetic nanoparticles using tragacanth gum [16,17]. Alagiri, M. *et al.* reported synthesis of NiO nanoparticles in the presence of agarose polysaccharide by sol-gel method [18].

In this work, for the first time, we have synthesized nickel oxide nanoparticles using Arabic gum, nickel chloride as the nickel source and water as solvent by sol-gel process, without any surfactant and reducing agent, as a cheap and friendly approach to the nature. This method has many advantages such as nontoxic, versatile, low cost, environment friendly and could be used to synthesize other metal oxides. The obtained nanoparticles were characterized by Fourier transform infrared spectroscopy (FTIR), field emission scanning electron microscopy (FESEM) and X-ray diffraction (XRD).

Experimental

The Arabic gum was obtained from a local health food store. Nickel chloride ($NiCl_2.6H_2O$) was purchased from Daijung (Darmstadt, Korea) and used without further purification.

The IR spectra were recorded on a Jasco 6300 FT-IR spectrometer in solid phase using the KBr pellet technique in the range of 4000–400 cm^{-1}. The structural properties of synthesized nanoparticles were investigated using

X'Pert-PRO advanced diffractometer using Cu (Kα) radiation (wavelength: 1.5406 Å) at 40 kV and 40 mA at room temperature in the range of 2θ from 20º to 90º. The morphology of the surfaces of the sample was analyzed by field emission scanning electron microscopy (LEO Co., England, Model: 1455VP). The disc was coated with gold in an ionization chamber.

Synthesis of NiO nanoparticles using Arabic gum

To achieve a clear Arabic gel solution, 0.3 g of the Arabic gum were dissolved in 40 mL of deionized water and stirred for 120 min at 75ºC. Then, 1.5 g of $NiCl_2.6H_2O$ was added to the Arabic gel solution, and the container was placed on a sand bath. The temperature of the sand bath was fixed at 75ºC and stirring was continued for 12 h to obtain a yellow color resin. The final product was calcinated at 500ºC temperature in air for 4 h to obtain a green powder of NiO.

XRD analysis

The average crystallite size of NiO nanoparticles was determined from the full width at half maximum of the XRD patterns using the well- known Scherrer formula (Eq. (1)):

$$D = \frac{0.9\lambda}{\beta cos\,\theta} \quad (1)$$

where, D is the crystallite size (nm);
β is the full width at half maximum of the peak;
λ is the X-ray wavelength of Cu Kα= 0.154 nm;
θ is the Bragg angle [19].

Results and discussion

FTIR analysis

NiO nanoparticles calcinated at 500°C for 4 hours were analyzed using FTIR spectroscopy. The FTIR spectrum shows peaks at 463.8 cm^{-1}, 668.2 cm^{-1}, 1101.6 cm^{-1}, 1617.0 cm^{-1}, 2922.6 cm^{-1} and 3412.4 cm^{-1} (Figure 1).

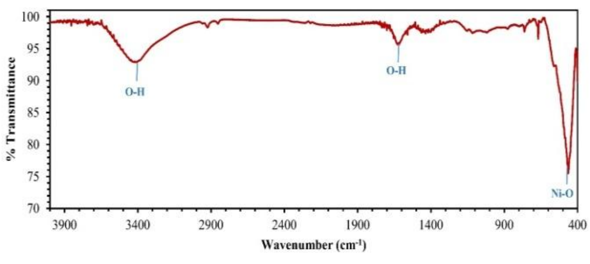

Figure 1. FTIR spectrum of NiO nanoparticles.

The strong band, corresponding to the Ni-O stretching vibration mode of NiO nanoparticles is seen at 463.8 cm^{-1} [4,18,19]. The bands at 3412.4 cm^{-1} and 1617.02 cm^{-1} are characteristic for hydroxyl group (O-H) [18,19], this is due to the adsorptions of water molecules onto the NiO surface when samples are exposed to the atmosphere.

XRD analysis

The crystal structure analysis was carried out by the X-ray diffraction, the obtained patterns are presented in Figure 2. XRD analysis showed a series of diffraction peaks at 2θ of 37.27°, 43.08°, 62.42°, 74.94° and 78.95° can be assigned to (111), (200), (220), (311) and (222) planes, respectively. All the diffraction peaks were readily indexed to a pure cubic phase of NiO (JSPDS Card no. 65-2901) with a=b =c= 4.197 Å, no impurity peaks were observed. Furthermore, the strong and sharp diffraction peaks confirm the high crystallinity of the synthesized nanoparticles. The average crystallite size of the obtained NiO nanoparticles was 34 nm.

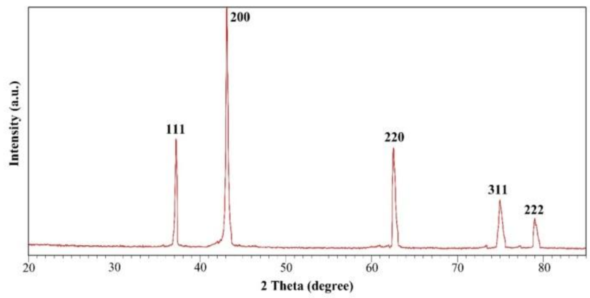

Figure 2. XRD pattern of synthesized NiO nanoparticles.

SEM analysis

The surface morphological features of synthesized nanoparticles were studied by field emission scanning electron microscope; the images were recorded with magnification of 500 and 10000 (Figure 3). The results indicate that NiO nanoparticles are in spherical shape. We can observe that the particles are highly agglomerated and they are essentially a cluster of nanoparticles.

The presence of some larger nanoparticles may be attributed to the fact that NiO nanoparticles have the tendency to agglomerate due to their high surface energy and high surface tension of the ultrafine nanoparticles.

Conclusions

In this paper, we have reported for the first time, the green synthesis of NiO nanoparticles that was carried out by the sol-gel method in Arabic gum gel as a bio-polymeric template. A pure cubic NiO phase was obtained after thermal treatment at 500°C for only 4 h. This method can be used for the synthesis of nanoparticles of oxides of transition metals and other materials with low production costs.

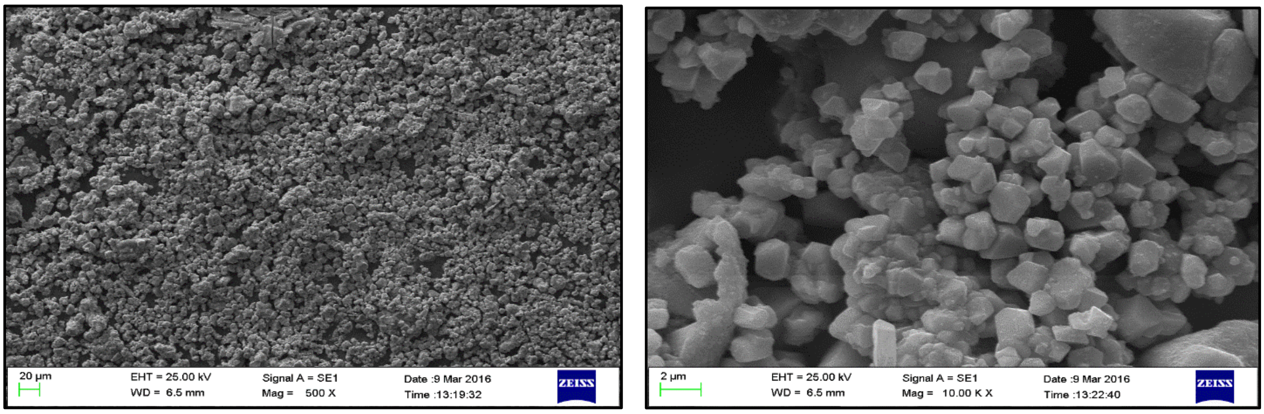

Figure 3. SEM images of NiO nanoparticles.

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