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Structural and Morphological Study of Nickel Doped Tin Oxide Nanoparticles Synthesized Via Sol-Gel Technique

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In the present paper nickel doped tin oxide nanoparticles were synthesized by using simple sol–gel technique. The as-synthesized sample was characterized by means of X-ray powder diffraction (XRD) spectroscopy and Energy-dispersive X-ray spectroscopy (EDX) techniques for its structural analysis. XRD spectrum reveals that all the nanoparticles are highly polycrystalline in nature and five major peaks were clearly observed. Ni-doped SnO_2 crystals existed mainly as tetragonal rutile structure. The average particle size of the nanoparticles was calculated by using the Scherrer formula and it was obtained 20 nm. EDX analysis confirms the presence of Nickel. No other impurities were found. The morphology of the nanoparticles was analyzed by using scanning electron microscope (SEM). The SEM image of the studied nanoparticles confirms the existence of very small, homogeneously distributed, spherical and crystalline nanoparticles.

Keywords: Nickel doped SnO_2 Nanoparticles, Sol-Gel, XRD, EDX, SEM.

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1. INTRODUCTION

Tin oxide is a widely used, a stable and intensively studied n-type semiconductor with many potential applications in various nanodevices. The success in many of its applications depends on crystalline SnO_2 with a uniform nano-size pore structure [1]. It is a well-known fact that materials at the nanoscale behave differently than their bulk counterparts because of large surface to volume ratio. Efforts toward the development of tin oxide nanomaterials with high sensitivity, excellent selectivity, quick response, and recovery behavior has been done over the years by using different synthesis techniques and various dopants. Tin oxide is used widely to control air pollution and to detect toxic or smelling gases at low levels in the air and in the field of domestic and industrial applications [2]. The tin oxide nanomaterials exhibit superior mechanical, thermal, chemical, electrical, and optical properties [3]. The doped SnO_2 nanoparticles with different dopants are synthesized by various techniques such as sol–gel, hydrothermal, co-precipitation, mechano-chemical, combustion route, spray pyrolysis, electrochemical deposition laser ablation, micro-emulsions technique etc. [4-10]. Among all the above mention techniques the sol gel method is most suitable for the synthesis of nanomaterial due to its comparatively low processing cost and better control over the particle size of the crystallite. It was observed that the solvent used in the sol-gel process played very important role on the particle size of nano-crystalline SnO_2 [11]. The aim of the present study is to synthesize and characterize nickel doped tin oxide nanoparticles [12] via sol-gel method.

2. EXPERIMENTAL DETAILS

The nickel doped tin oxide nanomaterials were prepared by sol-gel method. The x.Ni-(1-x).SnO_2 (x = 0.01) nano-powders were successfully prepared by means of dissolving tin chloride (hydrous $SnCl_2.2H_2O$ (98% merck)) and nickel chloride (hydrous $NiCl_2.6H_2O$ (98% merck)) in distilled water, this was followed by the addition of sufficient amount of aqueous ammonia to the above solution which was then stirred for 2h. The dropping rate must be well controlled for the chemical homogeneity. The resulting precipitate were collected, washed in distilled water, and then dried at 100°C for several hours. Heating treatment of the synthesized nanopowders was conducted in air for 2h at 350°C. The detailed characterization of the obtained sample was carried out using XRD, SEM and EDX spectroscopy. The XRD pattern was acquired by Cu K_α radiation (1.5406 Å; 45 kV, 30 mA) and the surface morphology was observed by Scanning Electron Microscope (SEM).

3. RESULTS AND DISCUSSION

The XRD pattern of as-synthesized nickel doped tin oxide nanoparticles was recorded and shown in Figure 1. The nickel doped tin oxide nanoparticles shows number of strong Bragg reflections peaks at different angles, which can be indexed to (110), (101), (200), (211), (002), (310), (112),(202) and (321) planes. All these diffraction peaks were perfectly indexed to the rutile SnO_2 structure (JCPDS File No. 77−0451, a=4.758Å and c=3.18Å). No additional characteristic peaks were observed, indicating that the Ni-doped tin oxide nanoparticles under study are highly crystalline and pure. The particle size (D) of Ni-doped SnO_2 nanoparticles was calculated from the width of the XRD peaks using the Scherrer formula [13].

$$D = 0.94\lambda/\beta\cos\theta,$$

where D is the average crystallite domain size perpendicular to the reflecting planes, λ is wavelength (0.15418 Å) of X-rays used, β is the broadening of

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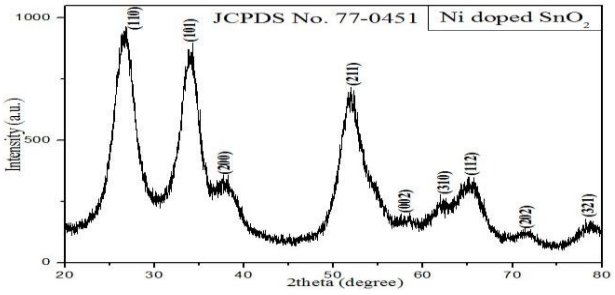


Fig. 1 – XRD pattern of Nickel doped tin oxide nanoparticles

diffraction line measured at half of its maximum intensity (in radian), full width at half maximum, and θ is the angle of diffraction.

From the calculation, the average particle size of the tin oxide nanoparticles under study was found 20nm. Backscattered electron image and quantitative analysis of the Ni-doped tin oxide nanoparticles was carried out by using Energy Dispersive Spectroscopy (EDX). The EDX spectrum obtained is shown in the figure 2. From the spectrum it is clear that only Sn and O are present along with small quantity of Nickel.

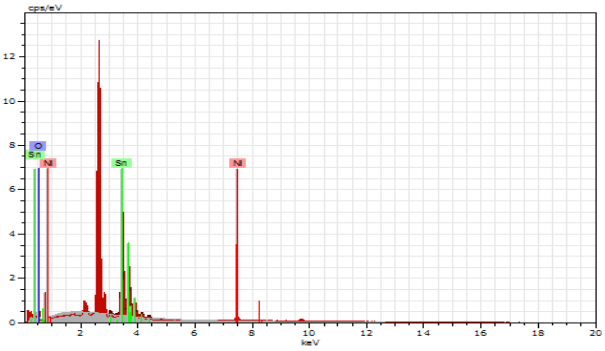


Fig. 2 – EDX images of as-prepared Ni- doped SnO_2 nanoparticles

The surface morphology of the nanoparticles was studied by SEM. Scanning electron microscopy (SEM) provided further insight into the morphology and size details of the nickel doped tin oxide nanoparticles. Figure 3 shows the SEM image of the as synthesized nickel doped tin oxide nanoparticles. SEM image of the studied nanoparticles confirms the existence of very small,

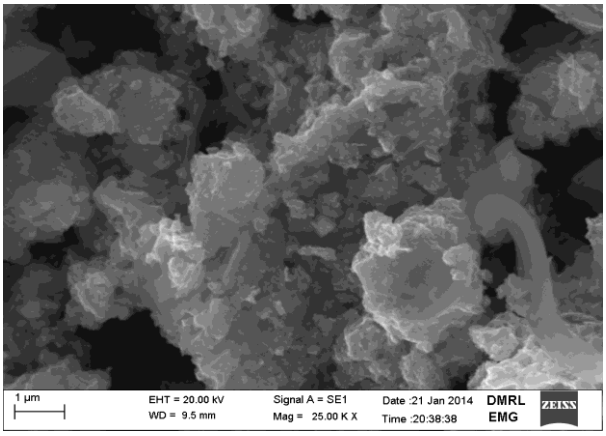


Fig. 3 – SEM morphology of as-prepared Ni- doped SnO_2 nanoparticles

homogeneously distributed and extremely crystalline nanoparticles.

Particle size and spreading of nanoparticles primarily depend upon the relative rates of nucleation and growth processes, as well as the extent of agglomeration [14].

4. CONCLUSIONS

The Mg- and Hg-doped nanostructured CdS thin films have been fabricated successfully from a low cost chemical bath deposition method at room temperature. The SEM studies reveal the leaf and seed type morphologies of the Mg- and Hg-doped nanostructured CdS thin films. The XRD study confirms the crystalline nature with cubic structure. The optical studies observed increased band gap of doped nanostructured CdS thin films in comparison with pure CdS thin film. The above studies reveal that Mg- and Hg-doped nanostructured CdS thin films with higher energy band gaps can be useful in future nanostructured solar cell and other optoelectronic devices.

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