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INVESTIGATION OF ELECTROCHEMICAL PROPERTIES OF CHEMICALLY SYNTHESIZED NICKEL DOPED ZINC OXIDE NANORODS

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ABSTRACT: In the present study, ZnO nanorods are deposited using the chemical bath deposition (CBD), and structural, morphological, electrochemical properties are investigated. After synthesis of ZnO nanorods, different percentages of Ni atoms are doped in ZnO nanorods. The structural properties are studied using the x-ray diffraction spectroscopy, fourier transform infrared spectroscopy. The morphological properties are studied using the field emission scanning electron microscopy. The electrochemical properties are studied using the electrochemical impedance spectroscopy and using cyclic voltammetry.

Keywords: Zinc oxide, Nanorods, Chemical bath deposition

INTRODUCTION:

Zinc oxide (ZnO), a typical II-VI compound semiconductor with a direct wide bandgap of 3.37 eV and large exciton binding energy of 60 meV at room temperature, is regarded as a promising material in applications of short-wavelength optoelectronic devices [1-3]. Moreover, due to its superior conducting properties based on intrinsic defects, ZnO has been investigated as transparent conducting and piezoelectric materials for fabricating solar cells, electrodes, and sensors. Generally, ZnO reveals n-type conduction with a typical carrier concentration of 1017/cm3,which is smaller than the carrier concentration of 1018–1020/cm^3 in laser diode applications [4-6]. To enhance the electrical properties, ZnO was frequently doped with many metal ions like Nickel and chromium [7-8].As far as the electrochemical properties, Zinc oxide have used in a photoelectrochemical solar cell [9], super capacitor [10] as well as batteries [11].

The ZnO nanorods is an active material for the electron-conducting pathway and excellent mechanical support. Many research groups developed ZnO based nanorods from different methods and applications. Efafi et al. [12] have synthesized ZnO nanorods for Photoluminescence application by considering the thermodynamic Parameters. Chandrasekhar et.al [13] are developed High efficient perovskite solar cells using ZnO nanorods as well as a prepared electron transport layer. Gao et al. [14] enhanced gas-sensitivity and ferromagnetism performances by the Nidoping ZnO nanorods. It also demonstrates that the oxygen vacancies and transition metal ions creating bound magnetic polarons are responsible for the origin of ferromagnetism in ZnO nanorods.

In the present work, ZnO thin films are deposited using the chemical bath deposition, and structural, morphological, electrochemical properties are investigated. The structural properties are studied using the x-ray diffraction spectroscopy, and it shows the hexagonal structure. Also, fourier transform infrared spectroscopy employed to understand the structural investigation. The morphological properties are studied using the field emission scanning electron microscopy, and hexagonal nanorods are observed. The electrochemical properties are studied using the electrochemical impedance spectroscopy and using cyclic voltammetry. The efforts are deviated to understand the electrochemical properties than can have used for supercapacitor applications.

EXPERIMENTAL:

All reagents used for the experiment are analytical grade. First,50 ml of 0.1 M zinc acetate was prepared in double-distilled water. The ammonia solution was used to maintain the pH-11 of the zinc acetate solution. The whole system was kept in a water bath, which maintained at constant temperature 90^{o}C for 2 hours. After removing the substrates from a reaction bath. These films were dried at room temperature for two hours and annealed afterward at 400^{o}C for 4 h. The Nickel ions are doped in ZnO with different percentages of Ni atoms. For the doping, Ni nickel acetate was used. The four percentage is used to deposit the samples such as 0%, 1%, 2%, and 2.5% of Nickel nitrate. The four films draw at a different percentage of Ni atoms and names given as A, B, C, and D, respectively.

RESULTS AND DISCUSSION:

3.1 X-ray diffraction & fourier transform infrared spectroscopic study-

Fig. 1 shows the structural properties of ZnO and Ni doped ZnO nanorods. Fig. 1 (a) shows the XRD pattern of ZnO nanorods. The observed d spacing values of ZnO well agreed with standard values (JCPDS: 00-036-1451). The ZnO nanorods having hexagonal structure with a=b= 3.24A°, c=5.20A° & α=β=90° &γ=120°. Fig. 1(b) shows the crystal structure of ZnO nanorods developed using observed XRD and standard JCPDS data from space group P63mc. Fig. 1 (c) show the polyhedral of ZnO nanorods. The FTIR spectra are a vital characterization tool for finding atomic and molecular bonding in nanomaterials. Fig. 1 (d) shows the FTIR spectra of Ni-doped ZnO nanorods. The FTIR spectra are recorded for samples A, B, C, and D. The peak at 528 cm^{-1} is belongs to the characteristic vibration of Zn-O. The peak near about 3500 cm^{-1}has belonged to the O-H group. As a Ni doping percentage increases in ZnO, change has been observed in the intensity of ZnO peaks [13, 15].

3.2. Field Emission Scanning Electron Microscopy-

The FESEM, a tool, is used to investigate the morphology of ZnO thin film. Fig. 2 shows the FESEM images of ZnO nanorods with different percentages of Ni. Fig,1 (A) shows the FESEM image of pure ZnO; it shows the hexagonal nanorods like morphology of ZnO.

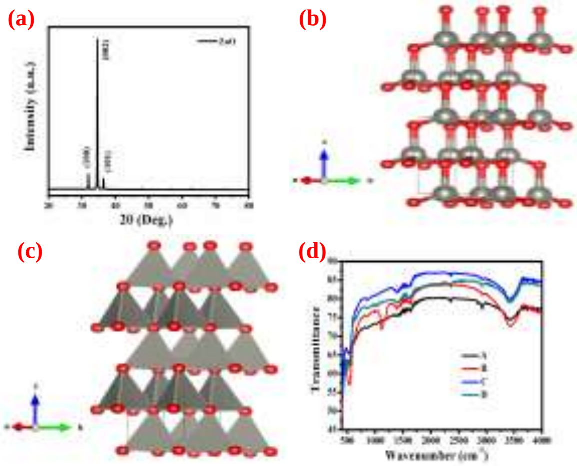

Fig. 1 structural properties of Ni-doped ZnO thin film, (a) XRD pattern of ZnO, (b) crystal of ZnO developed using XRD pattern, (c) polyhedron of ZnO developed using the XRD, (d) FTIR spectra of Ni-doped ZnO thin film

The hexagonal nanorods are having a width of 250 nm, and these results are consistent with XRD results. Fig.1 (B) shows the 1% Ni-doped ZnO, after the doping of Nickel, The size of a head of a nanorod is decreased, and the width and length of rods are observed to be increased. Fig. 2 (C) shows the 2% Ni-doped ZnO nanorods, the nanorods are well organized and shows the flower-like nature. At 2.5 % of nickel, the ZnO rods also shows flower-like nature with a little bit over growth shown in Fig. 2 (D). Also, mostly the nanorods are developed becouse seed layes as well as grouth in Z direction only [16-17]

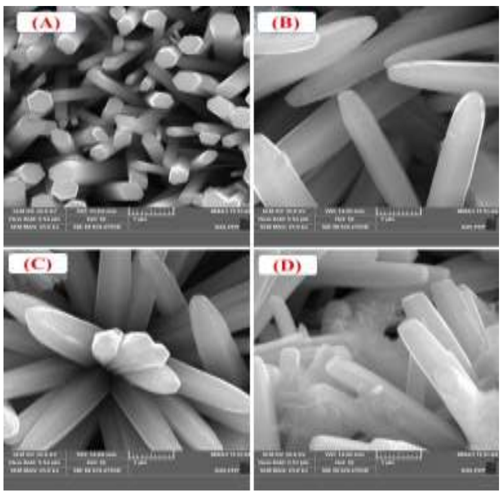

Fig. 2 FESEM images of Ni-doped ZnO nanorods with different percentages of nickel.

3.3. Electrochemical Impedance spectroscopic study-

The electrochemical impedance spectroscopy is a tool used to investigate the charge transfer process at the solid-liquid interface [18-19]. The solution resistance, charge transfer resistance, capacitance, and Warburg coefficient is calculated from results. The Fig. 3 shows the Nyquist plot and equivalent circuit diagram. The parameters calculated from the circuit diagram have mentioned in Table. 1. Table. 1 shows the near about the same value of charge transfer resistance and higher values of charge transfer resistance.

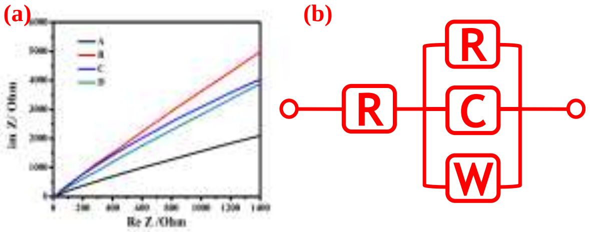

Fig. 3 EIS study of Ni-doped ZnO, (a) Nyquist plot of Ni-doped ZnO, (b) Equivalent circuit diagram for Ni-doped ZnO

Table 1 Observed parameters from EIS

Samples/ parameters	R1 (Ω)	C (µF)	R2 (Ω)	W ($\Omega.s^{1/2}$)
ZnO	15.08	4.26	0.388x 10^{18}	1.28x10^{12}
1% Ni doped ZnO	10.36	4.20	0.299 x 10^{21}	3.47x10^{12}
2% Ni doped ZnO	10.93	1.51	4.51 x 10^{18}	0.202x10^{12}
2.5 % Ni doped ZnO	12.78	3.43	0.509 x10^{22}	1.65 x10^{12}

3.4. Cyclic voltammetry study-

The cyclic voltammetry (CV) is a powerful and popular electrochemical technique commonly employed to investigate the reduction and oxidation processes of molecular species. The cyclic voltammetry study is shown in Fig. 4 (a,b,c,d) for pure ZnO, 1%, 2%, and 2.5% Ni dopedZnO nanorods, respectively. Fromfig. 4, it is observed that the maximum current and area under the curve is observed for 1% Ni-doped ZnO. The 1% Ni-dopedZnO sample shows more area under the curve than other deposited samples. It indicates that 1% of Ni-doped ZnO samples are more useful for supercapacitor applications. The 1% Ni-doped ZnO nanorods can produce more current than other doped, undoped ZnO Samples.

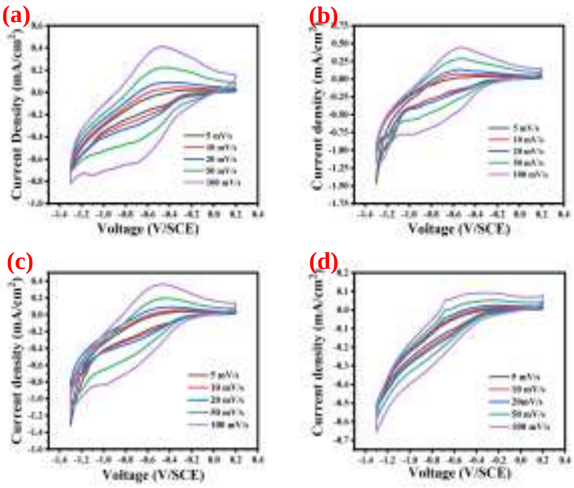

Fig. 4 Cyclic voltammetry study forNi-dopedZnO sample for different scan rate, (a) for ZnO sample, (b) for 1% Ni-doped ZnO sample, (c) 2% Ni doped ZnO sample, (d) for 2.5% Ni doped ZnO sample

CONCLUSION:

In conclusion, the ZnO nanorods are successfully synthesized using the chemical bath deposition technique. The well organized and nicely developed ZnO nanorods are synthesized. X-ray diffraction study reveals the hexagonal structure and consistent with FEEM results. The FTIR study shows the peak at 528 cm^{-1}, shows the characteristic vibration of Zn-O. The FESEM study indicates that successfully synthesized ZnO nanorods. The EIS study exposed all ionic processes. The cyclic voltammetry study shows the more area under the curve for 1% Ni doped ZnO nanorods. In conclusion, 1% of Ni-doped nanorods are useful for supercapacitors as well as 1% Ni doping is useful for improving the electrochemical properties.

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