Structural, morphological and magnetic properties of Zinc oxide, Strontium doped Zinc oxide, Strontium copper codoped Zinc oxide, and Strontium nickel codoped Zinc oxide nanoparticles synthesized by co-precipitation method

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Abstract

Zinc oxide (ZnO), Strontium doped Zinc oxide (Sr:ZnO), Strontium copper codoped Zinc oxide (SrCu:ZnO), and Strontium nickel codoped Zinc oxide (SrNi:ZnO) nanoparticles (NPs) were synthesized through co-precipitation method. The XRD results confirmed the hexagonal wurtzite structure for ZnO, Sr:ZnO, SrCu:ZnO and SrNi:ZnO NPs. The FESEM image showed the spherical, spherical, spherical and trigonal structure ZnO, Sr:ZnO, SrCu:ZnO and SrNi:ZnO NPs. Chemical composition was identified by EDAX spectra. Magnetic measurements using VSM showed that the Sr:ZnO, SrCu:ZnO and SrNi:ZnO NPs exhibits ferromagnetic behaviour at room temperature.

Keywords: ZnO; XRD; VSM; and Magnetic properties.

Introduction

Diluted magnetic semiconductor (DMS) materials have great interest in the new field of spintronics through playing a dual role (spin and charge degrees of freedom) in a single substance. The field is a control of electron spins are corresponding with the charges for semiconductor properties should be integrated with magnetic properties, i.e. Spin-based devices. The spin-based devices are multifunctional materials used in various fields such as very high integration density, ultra-fast data processing speed and low electrical power consumption [1]. ZnO NPs are theoretically predicted room temperature ferromagnetism (RTFM) as well as direct wide band gap (3.37 eV) and large exciton energy (60 meV). This can enable the combination of magnetic and optoelectronic properties to the fabrication of new devices [2]. In the past decade, ZnO

doped with 3d TM ions have been intensively studied to obtain DMSs [3-6]. In the present investigation, the ZnO, Sr:ZnO, SrCu:ZnO and SrNi:ZnO NPs were synthesized by co-precipitation method. The structural, morphology and magnetic properties of the ZnO, Sr:ZnO, SrCu:ZnO and SrNi:ZnO NPs were studied.

Experimental methods

The following high purity chemicals such as zinc (II) nitrate hexahydrate (Zn $(NO_3)_2$. $6H_2O$), Copper (II) nitrate hexahydrate (Cu $(NO_3)_2$. $6H_2O$), Nickel (II) nitrate hexahydrate (Ni $(NO_3)_2$. $6H_2O$), Strontium nitrate (Sr $(NO_3)_2$) and sodium hydroxide (NaOH) were used as the precursors without further purification.

ZnO nanoparticles was prepared co-precipitation method. In this method, a solution was prepared by dissolving 0.1 M of Zinc nitrate in double distilled water. 0.8 M of NaOH solution was added into the Zinc nitrate solution. Then, the white precipitate was obtained. The solution with the white precipitate was stirred at the temperature of 60 ^oC for 4 h. Then, a clear solution was obtained, which found to be stable at ambient condition. Thereafter, the solution was washed several times with double distilled water and ethanol. Finally, the precipitate was dried at 120 $^{\circ}C$. Thus, ZnO nanopowder was obtained.

In case of Sr doped ZnO NPs, 0.006 M of Strontium nitrate (Sr $(NO_3)_2$) was dissolving in 100 ml of double distilled water, then added 0.094 M of zinc (II) nitrate hexahydrate (Zn $(NO_3)_2$. $6H_2O$) solution in barium solution. In order to use NaOH as a precipitating agent, 0.8 M of NaOH was added into the metal (Sr:Zn) metal solution. Then, the black precipitate was obtained. The black precipitate was stirred at room temperature for 20 minutes. The mixture was again stirred at a temperature of 60 $^{\circ}C$ for 4 hours. The solution was washed several times with double distilled water and ethanol. The precipitate was dried at 120 $^{\circ}C$.

However SrCu codoped ZnO NPs, 0.003 M of Strontium nitrate (Sr $(NO_3)_2$) and 0.003 M Copper (II) nitrate Hexahydrate (Cu $(NO_3)_2$. $6H_2O$) of was dissolving in 100 ml of double distilled water, then added 0.094 M of zinc (II) nitrate hexahydrate (Zn $(NO_3)_2$. $6H_2O$) solution in Strontium-copper metal solution. In order to use NaOH as a precipitating agent, 0.8 M of NaOH was added into the metal (SrCu:Zn) metal solution. Then, the black precipitate was obtained. The black precipitate was stirred at room

temperature for 20 minutes. The mixture was again stirred at temperature of 60 ˚C for 4 hours. The solution was washed several times with double distilled water and ethanol. The precipitate was dried at 120 ˚C.

Moreover SrNi codoped ZnO NPs, 0.003 M of Strontium nitrate (Sr $(NO_3)_2$) and 0.003 M Nickel (II) nitrate hexahydrate (Ni $(NO_3)_2$. $6H_2O$) of was dissolving in 100 ml of double distilled water, then added 0.094 M of zinc (II) nitrate hexahydrate (Zn $(NO_3)_2$. $6H_2O$) solution in strontium-nickel metal solution. In order to use NaOH as a precipitating agent, 0.8 M of NaOH was added into the metal (SrNi:Zn) metal solution. Then, the green precipitate was obtained. The green precipitate was stirred at room temperature for 20 minutes. The mixture was again stirred at temperature of 60 ˚C for 4 hours. The solution was washed several times with double distilled water and ethanol. The precipitate was dried at 120 ˚C.

The ZnO, Sr:ZnO, SrCu:ZnO and SrNi:ZnO NPs samples were annealed at 800 ˚C for 5 h, because the energy from the heat will enhance the vibration and diffusion of lattice atoms for atomic rearrangement. Also the annealing helped to remove the residual impurities.

Characterization techniques

The ZnO, Sr:ZnO, SrCu:ZnO and SrNi:ZnO NPs were characterized by X-ray diffractometer (model: X'PERT PRO PANalytical). The diffraction patterns were recorded in the range of 25º-80º for the ZnO, Sr:ZnO, SrCu:ZnO and SrNi:ZnO NPs samples where the monochromatic wavelength of 1.54 Å was used. The samples were analyzed by Field Emission Scanning Electron Microscopy (Carl Zeiss Ultra 55 FESEM) with EDAX (model: Inca). The vibrating sample magnetometer was recorded 15kOe using as a Lakeshore VSM 7410 and Electron Spin Resonance Spectrometer as recorded using JES-FA200.

Results and discussion

X-ray diffraction studies

Figure 1 shows the X-ray diffraction pattern of synthesized ZnO, Sr doped ZnO, SrCu : ZnO and SrNi :ZnO NPs are shown in the Fig. 1(a-d). From the XRD results shows the synthesized all ZnO nanoparticles exhibits hexagonal wurtzite structure, which is confirmed by the standard JCPDS data (Card No:

36-1451) and there is no impurity peaks are observed for Sr: ZnO, SrCu: ZnO and SrNi : ZnO NPs. The average crystallite size 53, 47, 42 and 38 nm for ZnO, Sr doped ZnO, SrCu:ZnO and SrNi:ZnO NPs respectively.

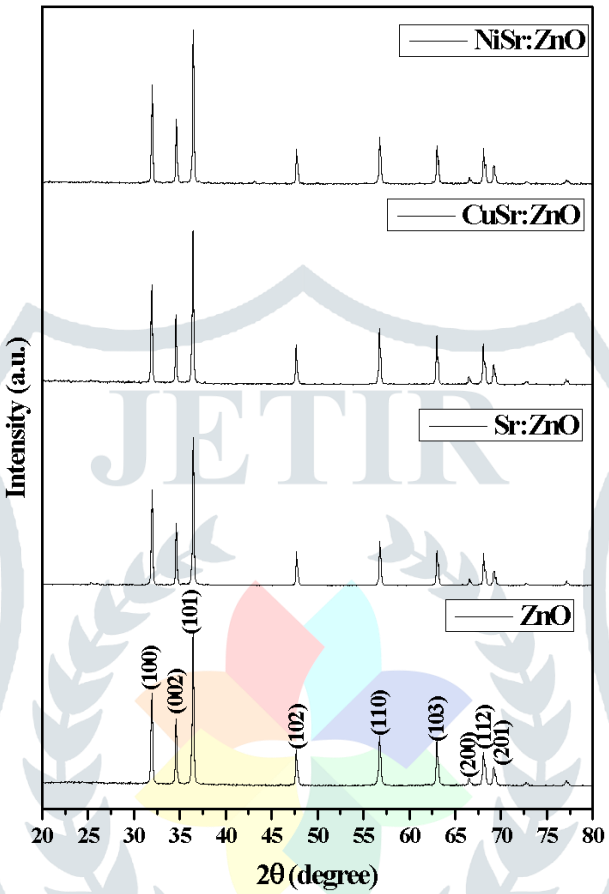

Figure 1 X-ray diffraction pattern of ZnO, Sr : ZnO, SrCu :ZnO and SrNi :ZnO NPs

Morphological and chemical composition analysis

From the FESEM image of synthesized ZnO, Sr : ZnO, SrCu :ZnO and SrNi :ZnO NPs are shown in the Fig. 2(a-d). FESEM image clearly display the synthesized nanoparticle are formed spherical, spherical, spherical and trigonal structure for ZnO, Sr : ZnO, SrCu :ZnO and SrNi :ZnO NPs respectively and average particles size range 50-100 nm for synthesized nanoparticles. The elements are identified using EDAX spectra are shown in Fig. 3(a-d). EDAX spectra show only Zn, Sr, Cu and O are present in the synthesized samples and there is no impurity phase observed for ZnO, Sr : ZnO, SrCu :ZnO and SrNi :ZnO NPs.

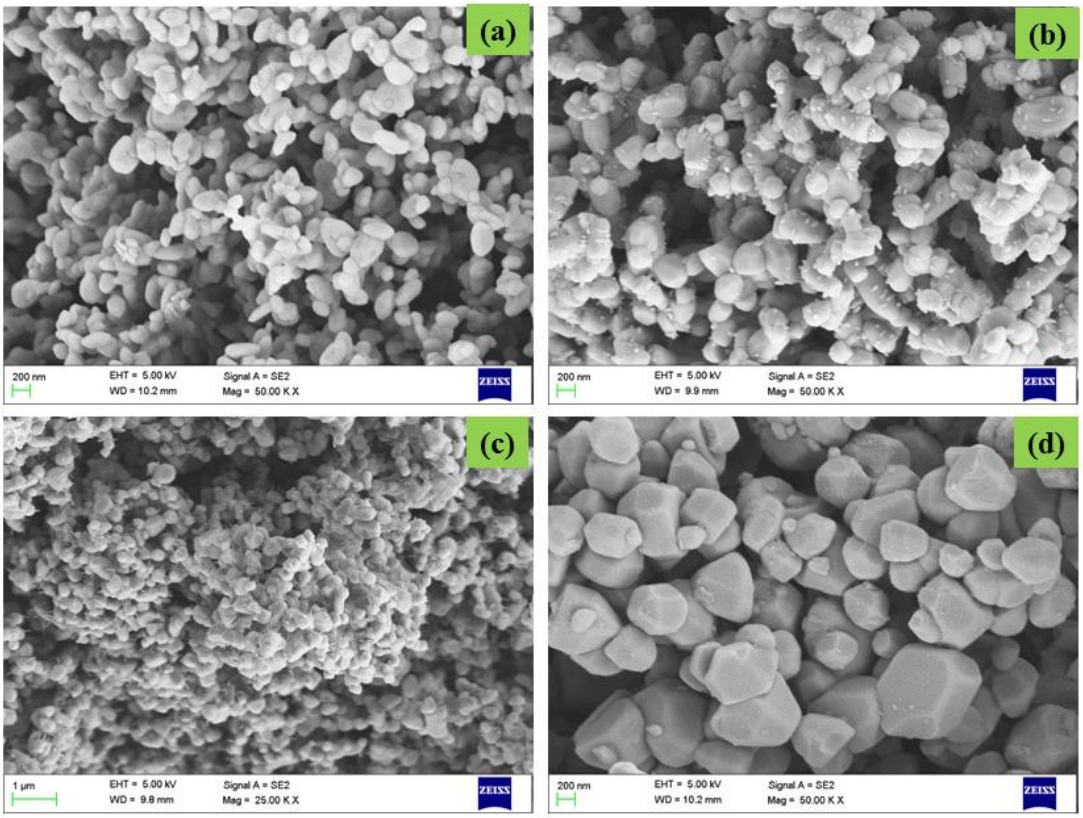

Figure 2 (a-d) FESEM image of ZnO, Sr : ZnO, SrCu :ZnO and SrNi :ZnO NPs

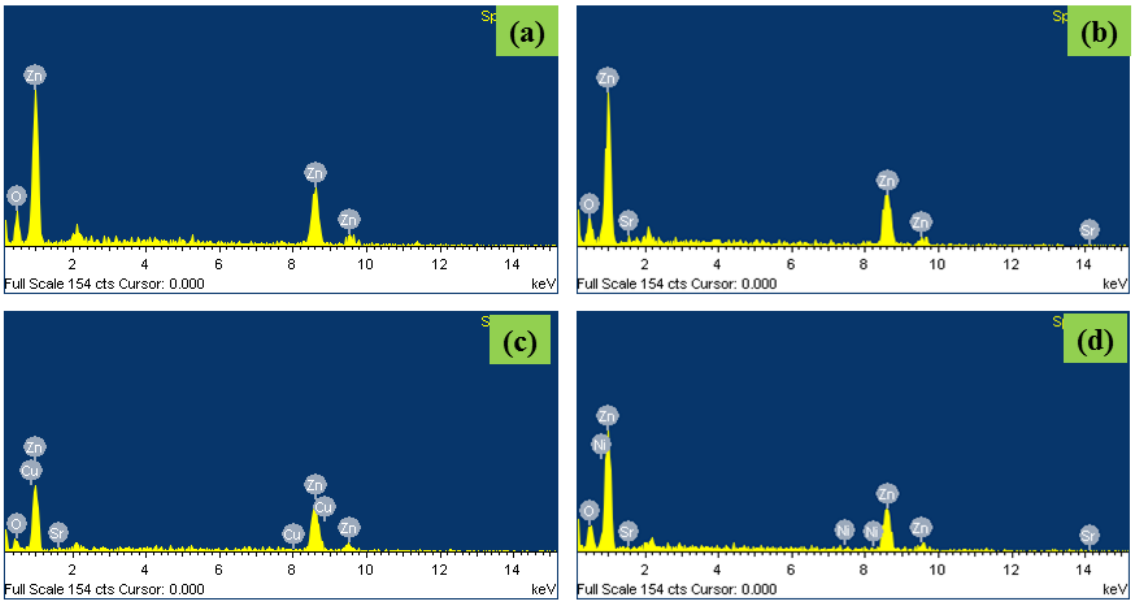

Figure 3 (a-d) EDAX spectra of ZnO, Sr : ZnO, SrCu :ZnO and SrNi :ZnO NPs.

VSM studies

Figure 4 shows Vibrating sample magnetometer of synthesized ZnO, Sr : ZnO, SrCu :ZnO and SrNi :ZnO NPs. The magnetic hysteresis M-H loop ZnO, Sr : ZnO, SrCu :ZnO and SrNi :ZnO NPs observed at 300 K with an applied magnetic field range from 0 to ±15 kOe. In the case of ZnO NPs exhibits diamagnetic behaviours [7]. However, Sr:ZnO, SrCu : ZnO and SrNi : ZnO NPs clearly indicate the existence of

ferromagnetic behaviours. The magnetization values observed at 100.06 E^{-6} emu/g, 422.14 E^{-6} emu/g, 406.49 E^{-6} emu/g and 359.13 E^{-6} emu/g for ZnO, Sr:ZnO, SrCu : ZnO and SrNi : ZnO NPs respectively. Magnetization values of Sr:ZnO, SrCu co-doped ZnO and SrNi co-doped ZnO NPs are increased as compared to the pure ZnO NPs, due to the exchange interaction between localized spin moments resulting from the oxygen vacancies at the surface of nanoparticles [8].

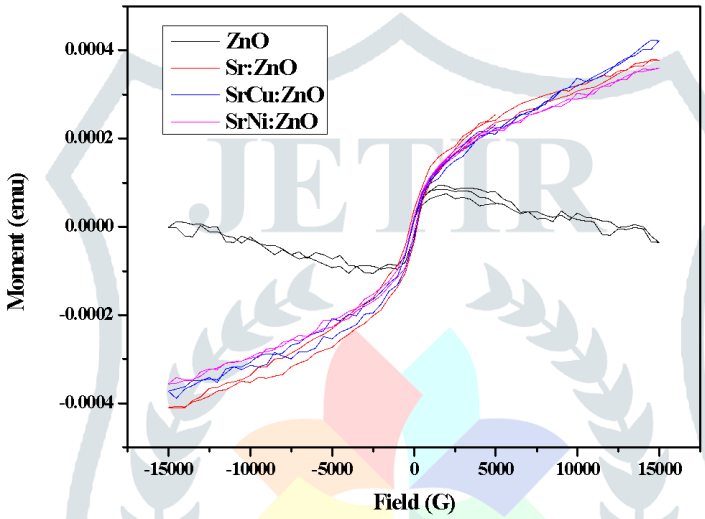

Figure 4 VSM analysis of ZnO, Sr : ZnO, SrCu :ZnO and SrNi :ZnO NPs

Conclusions

In the summary, ZnO, Sr : ZnO, SrCu :ZnO and SrNi :ZnO NPs were synthesized by co-precipitation method. From the X-ray diffraction of synthesized ZnO NPs exhibits hexagonal wurtzite structure. FESEM image clearly showed that synthesized nanoparticle were formed spherical, spherical, spherical and trigonal structure for ZnO, Sr : ZnO, SrCu :ZnO and SrNi :ZnO NPs respectively. Elemental composition was identified by EDAX spectra. Thus, Sr:ZnO, SrCu : ZnO and SrNi : ZnO NPs exhibiting room temperature ferromagnetism. This materials is suitable material for spintronic applications.

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