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Room temperature ferromagnetism in $Zn_{1-x}Ni_xO$ nanostructures synthesized by chemical precipitation method

Levna Chacko[1], K M Shafeeq[1], R Anjana[2], M K Jayaraj[2] and P M Aneesh[1]

[1] Department of Physics, Central University of Kerala, Kasaragod, Kerala 671314, India
[2] Centre for Advanced Materials, Department of Physics, Cochin University of Science and Technology, Kochi, Kerala 682022, India

E-mail: aneeshpm@cukerala.ac.in

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Abstract

ZnO nanomaterials have drawn considerable research interest as a multifunctional semiconductor material due to its unique thermal, electrical, optical and optoelectronic properties and also a suitable candidate for the transparent conducting oxide (TCO) layer in optoelectronic devices. The present work deals with the co-precipitation synthesis of ZnO nanostructures with Ni dopants. The structure and phase identification, morphology, optical and magnetic response of the prepared $Zn_{1-x}Ni_xO$ nanostructures have been investigated by employing x-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), energy dispersive x-ray spectroscopy (EDAX), Raman analysis, UV–Vis–NIR and fluorescence spectrophotometer and vibrating sample magnetometer (VSM) measurements. Structural studies reveal the hexagonal wurtzite structure of ZnO nanostructures with a slight decrease in the particle size with Ni doping. The incorporation Ni in the ZnO host lattice is confirmed by EDAX measurements. Optical studies confirm the observance of blue shift and violet photoluminescence emission for $Zn_{1-x}Ni_xO$ nanostructures. Vibrating sample magnetometer (VSM) measurements of $Zn_{1-x}Ni_xO$ nanostructures shows hysteresis loop at room temperature confirming the ferromagnetic behaviour of the samples.

Introduction

Nanosized particles of semiconductor materials exhibit versatile novel properties and scientific applications due to their smaller size and large surface to volume ratio. In the last few decades, zinc oxide (ZnO) has gained substantial attention due to their wide applications in the field of transparent electronics [1], piezoelectric devices [2], diluted magnetic semiconductors (DMS) for spintronics [3], sensors [4], lasing devices, field emitters and light emitting diodes [5] etc. Above all metal oxides, ZnO unveil multifarious properties such as excellent optical transparency, high voltage–current nonlinearity, high thermal and electrical conductivity, piezoelectricity and pyroelectricity. Meanwhile, the wide and direct band gap of 3.34 eV with a relative large exciton binding energy of 60 meV at room temperature makes it a promising II–VI semiconductor material [6]. The key parameter for many of these fascinating properties and methodical applications is the doping of ZnO with various elements for enhancing and modulating its electrical, optical and magnetic performance [7, 8]. Among these, the diluted magnetic semiconductors (DMS) exhibiting distinctive magnetic as well as semiconducting properties because of the strong spin-dependent coupling along with the phenomenon of charge transport that can be manipulated for future applications of spintronics. Spintronics is a technology exploiting both the intrinsic spin of the electron and its associated magnetic moment in addition to its fundamental electronic charge, in solid-state devices. In these diluted magnetic semiconductors, a small part of the cations host lattice is substituted by magnetic atoms such as Fe, Ni, Co, Cu, Mn, Cr etc [3, 7, 9–15]. The co-existence of magnetic, semiconducting, and optical functionalities increase the potential of transition metal-doped ZnO (ZnO:TM) to be a multifunctional material. It might have potential applications in the new emerging field of optoelectronics, magnetic tunnel junctions, photovoltaics, sensors, spin polarized light emitting diodes and spintronics devices [16]. ZnO crystallizes in either cubic zinc blende or hexagonal wurtzite structure where each anion is surrounded by four cations which