Application Possibility of $Mn_{0.04}Cu_{0.05}Zn_{0.91}O$ in Electronic and Magnetic Devices

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***Abstract*— In this literature, we have investigated the magnetic properties and Schottky device-based charge transport properties of hydrothermally derived $Mn_{0.04}Cu_{0.05}Zn_{0.91}O$ nanorod. The doping of 3-D transitional metals, Mn and Cu, within ZnO makes it potentially applicable in spin-based electronics, whereas its temperature-dependent conductivity (of the order of 10^{-3} in C.G.S.) makes it suitable for semiconductor-based devices. The observation of intrinsic ferromagnetism of the synthesized composite and its variation of magnetization with magnetic field and temperature exhibited the suitability of spin-based electronic application. To check the applicability in optoelectronic devices, metal–semiconductor ($Al/Mn_{0.04}Cu_{0.05}Zn_{0.91}O$) junction was fabricated and analyzed. The current–voltage characteristic represented the rectifying behavior of the junction with on/off current ratio 4.3 at ±1 V in dark and potential barrier height 0.61 eV. The significant change in rectification due to the influence of incident radiation makes this material suitable for photosensing electronic device application.**

***Index Terms*— Current–voltage (I–V) characteristics, magnetic semiconductors, magnetic susceptibility, magnetization, nanostructured materials, Schottky diodes, thin films.**

I. Introduction

SEMICONDUCTOR devices generally take advantage of the charge of carriers, whereas magnetic materials are used for recording information involving electron spin. To make use of both the electrical and magnetic behavior of electrons in semiconductors, a certain concentration of magnetic elements can be introduced in nonmagnetic semiconductors. Actually, when electronic functionalities evolve from both the charge and spin degrees of freedom in a single system, the system's (or may be the device's) utility will be enhanced manifold. The minute amount doping of magnetic element (transition metal) into nonmagnetic semiconductor develops the intrinsic (development of any secondary magnetic phase related to transition metal or its any kind of oxide phases are prohibited) ferromagnetism. This originates the dilute magnetic semiconductor (DMS). In this paper, one of the most promising II-VI semiconductors, namely, ZnO has been simultaneously doped with transition metals Mn and Cu. The motive of this paper is to develop a simple photosensitive Schottky device utilizing the electrical property of Mn- and Cu-codoped ZnO. Simultaneously, due to the codoping of Mn and Cu, if intrinsic ferromagnetism is generated in this system then the sample can be used for the purpose of magnetic storage device (utilizing its spin degrees of freedom).

Zinc oxide (ZnO) is a wide bandgap (3.7 eV) semiconductor material. There are many literatures based on its intrinsic properties and potential credibility in the device application, such as transistors, sensors, diodes, and solar cells [1], [2]. Nowadays, the nontoxic behavior, ecofriendly, easiest synthesis procedure of ZnO nanomaterial developed a huge curiosity to the scientists and researchers. Starting from the last few years, the scientists and researchers had shown their interest to optimize the bandgap of ZnO nanomaterial by varying the synthesis procedure [3], [4]. Since the morphological changes in size and shape have an effect on the energy absorption, an immense effort has been given to change the growth of the nanomaterials during the synthesis. It was investigated that the bandgap of ZnO can be reduced significantly by varying the concentration of doping element [5]–[9]. To improve the absorption, the energy bandgap of ZnO was reduced by introducing Cd, Se, F, etc [10]. It has also been doped with Mn. Mn doping reduces the absorption of ZnO, still there had been a lot of interest in doping 3-D transition metal ions with ZnO because of its potential application in spin-based electronics (spintronics). Dietl *et al.* [11] predicted that Mn-doped ZnO would be ferromagnetic at room temperature. It is generally believed that the origin of ferromagnetism in such transition-metal-doped ZnO is induced carrier. No ferromagnetic ordering has been observed for Cu-doped ZnO nanoparticles [12]. But, ZnO which is simultaneously doped with Mn and Cu may be an interesting DMS. Although there are several studies on transition metals (e.g., Mn, Co, Ni, Fe, and Cu) doped ZnO, there are very few studies on

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