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Raman scattering in Me-doped ZnO nanorods (Me = Mn, Co, Cu and Ni) prepared by thermal diffusion

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Abstract

We have investigated normal and resonant Raman scattering in Me-doped ZnO nanorods (Me = Mn, Co, Cu and Ni) prepared by thermal diffusion. Experimental results show that the normal Raman spectra consist of the conventional modes associated with wurtzite ZnO and impurity-related additional modes. Under resonant conditions, only longitudinal optical (LO) phonon scattering and its overtones are observed. The number of LO phonon lines and their relative intensity depend on the doping element and level. For the nanorods doped with Cu and Ni, we have observed LO phonon overtones up to eleventh order. This situation does not happen for the Mn-doped nanorods, which show only five LO phonon modes. By co-doping Mn and Co into the ZnO host lattice, however, the LO phonon overtones up to eleventh order are observed again. The nature of this phenomenon is explained by means of the study of XRD, TEM and photoluminescence.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

Zinc oxide (ZnO) is a transparent wide bandgap semiconductor compound (E_g = 3.37 eV) with a direct electronic transition and has a large exciton binding energy (60 meV) that ensures high luminescence efficiency at room temperature. Similar to GaN [1–3], ZnO is considered as a promising material for photonic devices working in the ultraviolet and blue spectral regions [4–7]. Recent studies have shown that ZnO exhibits many novel nanoscale structures, such as nanorods, nanowires, nanotubes, nanoneedles, nanocombs and so forth [4–12], which open up new prospects for applications in micro-optoelectronic devices.

In addition, theoretical calculations have predicted that transition-metal-doped ZnO materials may exhibit room-temperature ferromagnetism [13, 14]. This offers opportunities for developing spintronic devices combining standard microelectronics with spin-dependent effects. Such spin-based devices are multifunctional and have very high integration density, ultra-fast data processing speed and low electrical power consumption. However, to realize this idea, a thorough knowledge of the role of impurities and interaction mechanisms taking place in doped ZnO materials is essential.

Micro-Raman spectroscopy is used widely to study structural changes, lattice defects, grain size and secondary phases present in doped ZnO materials [15], where the Raman scattering (RS) signal is dependent on the electron–phonon interaction. Earlier Raman studies of ZnO materials have revealed a strong dependence of the spectral features on the nature and concentration of impurities present in the ZnO host lattice [16–23]. For normal RS spectra, besides conventional modes characteristic of wurtzite ZnO [24], there are some impurity-related additional modes [16, 17, 19–23].

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