Room temperature ferromagnetism in Co-Cr and Fe-Cr co-doped ZnO nanoparticles

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The study focuses in particular on the effect of the transition metal (TM: Co-Cr and Fe-Cr) co-doping on the structural, optical and magnetic properties of ZnO. $Zn_{0.99-x}M_{0.01}Cr_xO$ (M=Co and Fe, $0 \leq x \leq 0.05$) nanoparticles were synthesized by the solution combustion method. Powder x-ray diffraction (XRD) analysis confirms all the samples has hexagonal wurtzite structures without any secondary phase present in the spectra. The average crystallite size (D) of $Zn_{0.99}Co_{0.01}O$ and $Zn_{0.99}Fe_{0.01}O$ was calculated using Scherrer's formula [1] and found to be 41±4 nm and 18±7 nm. In the case of $Zn_{0.94}Co_{0.01}Cr_{0.05}O$, D decreased to 23±7 nm, but for $Zn_{0.94}Fe_{0.01}Cr_{0.05}O$ it remains approximately unchanged at 16±7 nm. Transmission electron microscopy (TEM) images of the samples indicate that particles are in the nano-regime. It is found to be 50±1 nm for $Zn_{0.99}Co_{0.01}O$, but for other samples particles are agglomerated. Diffuse reflectance spectroscopy (DRS) analysis shows the optical band gap values are 3.302±0.005 eV and 3.293±0.006 eV for $Zn_{0.99}Co_{0.01}O$ and $Zn_{0.99}Fe_{0.01}O$, respectively, and slightly decreases (3.272±0.005 eV and 3.254±0.004 eV) with the increased Cr (0.05) ion doping concentration. A vibrating sample magnetometer (VSM) was used to obtain room temperature (RT) field-dependent magnetization (M - μ_oH) measurements. The M-H curves of all the samples are found to be hysteretic, which signifying RT ferromagnetism (RTFM). The RTFM is enhanced with Cr ion concentration which is antiferromagnetic in character. Maximum saturation magnetization, coercivities and remnant magnetization obtained for the samples are 0.665±0.01 emu.g^{-1}, 0.734±0.01 emu.g^{-1}, 142±2 Oe, 147±2 Oe and 0.103±0.01 emu.g^{-1}, 0.120±0.01 emu.g^{-1} for $Zn_{0.94}Co_{0.01}Cr_{0.05}O$ and $Zn_{0.94}Fe_{0.01}Cr_{0.05}O$, respectively. As compared to other TM co-doped ZnO such as Fe-Cu [2], Mn-Ni [3], Cu-Cr [4], the noticeable RTFM has achieved in the wurtzite structure of $Zn_{0.99-x}M_{0.01}Cr_xO$ (M=Co and Fe, $0 \leq x \leq 0.05$) nanoparticles. The correlation between structure and RTFM as a function co-doping concentration probed in these samples can helpful to manipulate the magnetic ordering in future diluted magnetic semiconductors studies.

References:

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