Investigation of spin driven multiferrocity in corundum Cr_{2-X}-Fe_XO_3 thin films

Abstract

Processing of information using logic devices which are in use currently demand high power and release a significant amount of heat. Manipulating the magnetic information by electric field can be efficient to overcome the power demand because manipulating the spin requires lesser energy compared to that of charge. Multiferroics are one of the most promising families of materials for controlling magnetisation by an electric field. However, most of the single-phase materials exhibit multiferroicity at cryogenic temperature and only a few materials exhibit multiferroicity at room temperature. Cr_2O_3 is a room temperature linear magnetoelectric (ME) material. To increase the Neel temperature of Cr_2O_3 researchers have carried out the synthesis of bulk by hydrostatic pressure or introducing chemical pressure through dopants in crystal structure. Conical spin structure is known in lower doping concentrations of $(1-x)Cr_2O_3$-xFe_2O_3 ($0 \leq x \leq 0.5$). In this thesis, Cr_2O_3 - Fe_2O_3 solid solutions was explored for possible electric polarization. The multifunctional properties of Cr_{2-X}-Fe_XO_3 in bulk, nanoparticles and thin films were explored. We wanted to explore composition having conical spin structure and 1:1 cation ratio composition for multiferroic property. We have prepared Cr_2O_3 - Fe_2O_3 solid solutions in bulk and nanoparticles and studied the structural, magnetic, optical and dielectric properties and compared with the literature. The $CrFeO_3$ (CFO) shows corundum structure with R-3c space group. The AFM spin arrangement of Fe/Cr ions along the *a*-axis with propagation vector k=0, implying identical chemical and magnetic unit cell. The magnetic field dependent impedance is attributed to extrinsic origin of grain boundary tunnelling. Epitaxial CFO films fabricated using PLD also showed no electric polarization from PFM studies. AFM spin structure of CFO is similar to antiferromagnetic FeF_2 and MnF_2 which show positive exchange bias effect below their Neel temperature (<70 K). We have fabricated the exchange coupled heterostructures of CFO with the Metglas CoFeSiB and demonstrated conventional, positive and spontaneous exchange bias effects. Finally, neutron diffraction of $Cr_{1.7}Fe_{0.3}O_3$ composition in bulk showed incommensurate phase of conical spin with a propagation vector K= (0, 0.143,0) in this spin is pointing along the *c*-axis. However, this transition in the bulk is well below 300 K. An epitaxial thin film of this sample has shown domain structure and switching of the polarization at room temperature. The electric polarization ~1 μC/cm2 at room temperature and epitaxial strain of the films seem to play a role in enhancing the effect to room temperature.