Abstract

Multiferroic Bismuth ferrite $BiFeO_3$ (BFO) is one of the rare compounds which gained huge attention of researchers in last few years due to the coexistence of magnetism and ferroelectricity at room temperature. Its both antiferromagnetic and ferroelectric transition temperatures at well above the room temperature which makes it a more potential candidate for device applications. In device applications, both bulk and thin films studies have great importance.

In current research work, BFO materials have been investigated in both forms (bulk and thin films). The work has been divided into three parts: The first part which is very important is based on the successful synthesis of pure BFO phase and rare earth (Ho and Dy) doped BFO ceramic by solid state reaction method; The second part is the fabrication of Ho doped thin films using the pulsed laser deposition technique; In the third and the last part, different types of ions (heavy, paramagnetic, ferromagnetic and diamagnetic) are implanted on pure and Dy doped BFO ceramic.

Pure and rare-earth doped (Ho and Dy) $BiFeO_3$ have been prepared by conventional solid state reaction method using Bi_2O_3, Fe_2O_3, Ho_2O_3 and Dy_2O_3 powders as starting precursor. All oxides have been mixed with an appropriate stoichiometric ratio and then grounded well in acetone medium and calcined. The calcined powder was pressed into pellets of 2.54 cm diameter and 3-4 mm thickness using PVA as a binder with the help of a hydraulic pelletizer at an applied pressure of 98 kPa. Finally, the pellets were sintered at 850 °C for 2 hours. These pellets have been used for the thin films fabrication and are used as a target for ion implantation.

The thin films of $Bi_{1-x}Ho_xFeO_3$ (with x=0, 0.05, 0.10, 0.15 and 0.20) have been successfully grown on Si (100) substrates using pulsed laser deposition and the effect of Ho doping on the crystal structure, dielectric and magnetic properties are studied by X-ray diffraction, field emission scanning electron microscopy (FE-SEM), atomic force microscopy (AFM), X-ray photoemission spectroscopy (XPS), impedance analyzer and Vibrating sample magnetometer (VSM). The structural change and enhanced magnetic properties have been observed after Ho doping in BFO thin films. Ho doped thin films have also shown good dielectric behavior as compared to un-doped $BiFeO_3$. The enhancement of these properties due to Ho doping is discussed along with their relevance in designing multiferroic materials based on $Bi_{1-x}Ho_xFeO_3$ films for magnetic field sensors, multiple-state memories and spintronic elements. Implantation of diamagnetic (Au^+, As^+, Ge^+), paramagnetic (Y^+) and ferromagnetic (Co^+) ions induced modification in structural and multiferroic properties of pure phase $BiFeO_3$ (BFO) ceramics. BFO samples are implanted by 500 keV ions of Au^+, As^+, Ge^+, Y^+ and Co^+ at constant ion fluence 3×10^{12} ions/cm^2. The nuclear and electronic energy losses at 500 keV Au^+, As^+, Ge^+, Y^+ and Co^+ ions on target BFO have been calculated by software STOPPING RANGE OF IONS IN MATTER (SRIM). Effect of different ions implantation is explained in terms of structural change coupled with amorphization/ recrystallization due to ion implantation probed through XRD, SEM, EDX and XPS. XRD patterns show broad diffuse contributions due to amorphization in implanted samples. The Rietveld refinement results indicate the phase distortion in irradiated samples and phase transition from space group R3c to R3m by the As^+ ions implantation, which is revealed by Rietveld refinement. X-ray photoemission spectroscopy was used to identify the chemical bonding, valence band and core levels of implanted BFO samples. The ferroelectric behavior of BFO ceramics varies with different implanted ions which might be understood in terms of oxygen vacancy, the displacement of Fe^{3+} ions, lattice distortion and lattice phase transition. Room temperature M–H hysteresis measurements reveal that magnetization varied due to the structural distortion and partial destruction of a spin cycloid, which is caused by ion implantation in $BiFeO_3$ ceramics. Furthermore, Y^+ ions beam of 500 keV energy irradiated on $Bi_{1-x}Dy_xFeO_3$

(xDBFO) where (x= 0.00, 0.05, 0.10, 0.15 and 0.20) at a constant fluence 3×10^{12} ions/cm^2 have been investigated. Study of basic crystal parameters using the X-ray diffraction technique of the irradiated samples suggests that all the materials are polycrystalline and indexed in the distorted-perovskite (rhombohedral) structure which was supplemented and supported by Rietveld refinement. The scanning electron micrograph of the compounds showed (i) the uniform distribution of grains on the sample surface with high density and (ii) reduction in grain size on increasing Dy^{3+} content and Y^+ ions irradiation in $BiFeO_3$ (BFO). Ferroelectric and ferromagnetic loops have been observed in the Y^+ implanted xDBFO (x=0.00, 0.05, 0.10, 0.15 and 0.20) samples at room temperature which indicate that ferroelectric and ferromagnetic ordering coexist in the ceramics at room temperature. The polarization Ps is increased up to 10.50 μC/cm^2 by increasing Dy contents at x=0.15. The Ms value is also enhanced up to 2.329 emu/g by 15% doping of Dy in BFO.