L.9: Enhancement of magnetic properties of $BiFeO_3$ epitaxial thin films by co-doping of La and Nd

Multiferroic materials are receiving attention because of the coupled nature of ferroelectric and ferromagnetic order in these is of considerable scientific interest and also these materials are attractive for potential applications. Among the various known multiferroic materials, $BiFeO_3$ (BFO) is of particular interest as it shows magnetoelectric (ME) coupling at room temperature. A lot of R&D has been carried out on this material to find ways to improve its resistivity, which limits maximum value of electric field that can be used and also enhance its weak ferromagnetism. One approach has been to use suitable dopants to suppress the space modulated spin structure in BFO to result in larger magnetization and also modify the resistive behavior due to local structural distortions. Our earlier studies, reported in J. Appl.Phys. 106, (2009)114105, on the effect of Nd and La co substitution in bulk BFO had shown enhancement of magnetic properties.

Since improved mutiferroic behavior is observed in BFO thin films, we have investigated the effect of Nd and La co substitution on the magnetic and ferroelectric properties of these films. Pure BFO as well as co doped $Ba_{0.8}La_{0.1}Nd_{0.1}FeO_3$ (BLNFO) epitaxial films were deposited on $SrRuO_3$ buffered $SrTiO_3$ substrate by using pulsed laser deposition. Due to Nd and La co substitution, the crystal structure has been transformed from rhombohedral to monoclinic in BLNFO films. The magnetic measurements, made on the films with the magnetic field applied parallel to the film plane, are shown in Fig. L.9.1.

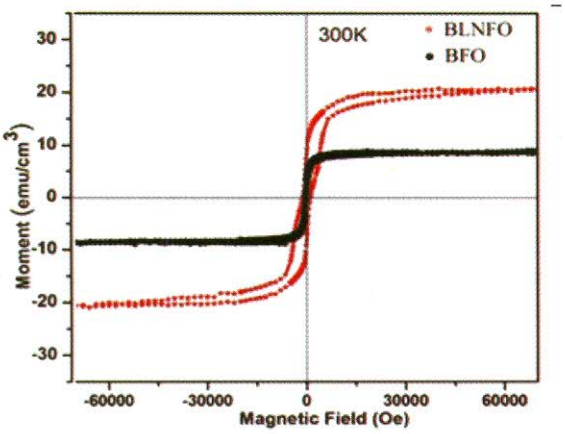

Fig. L.9.1: Curves of magnetization vs hysteresis for BFO ($BiFeO_3$) and BLNFO ($Ba_{0.8}La_{0.1}Nd_{0.1}FeO_3$) films at room temperature.

The saturation magnetization of the BLNFO films (20 emu/cm^3) was found to be larger by a factor of 2.5 compared to the value for BFO films. The improved magnetic properties observed in doped films might be due to the suppression of spatially non uniform spin structure.

Raman spectroscopic studies have also been carried out to understand the correlation between structural distortions and magnetoelectric coupling in BFO. The lattice distortions and modified magnetic structure of BFO was seen to get reflected in phonon behavior. The temperature dependent Raman studies for BFO and BLNFO (Fig. L.9.2) shows phonon anomalies in the vicinity of magnetic ordering temperature (T_N~375°C) owing to the spin phonon coupling. Doped films (BLNFO) exhibit strong anomalies in the line widths of Raman bands around T_N revealing presence of strong spin-lattice coupling.

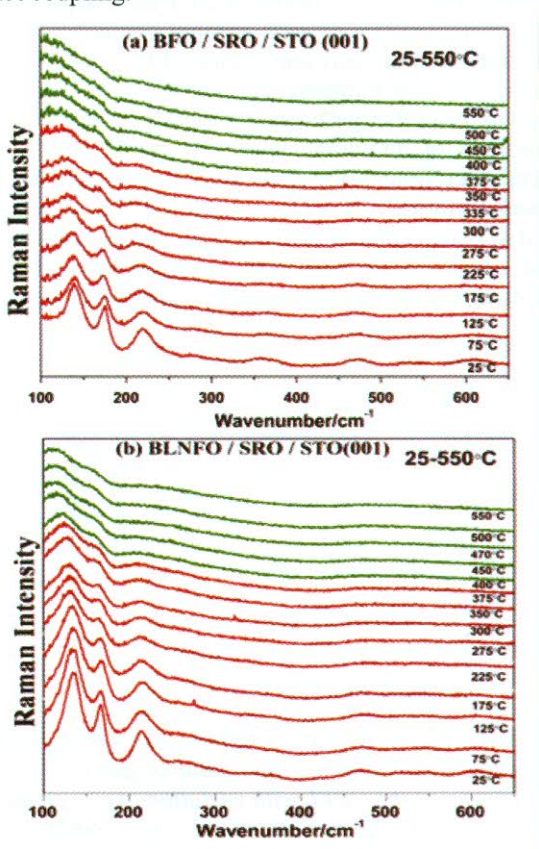

Fig. L.9.2:Temperature dependent Raman spectra for BFO (a) and BLNFO (b) films.

Temperature dependent Raman studies provided evidence of strong spin phonon coupling in BLNFO films which possibly leads to the stronger ME coupling observed in the doped films. For more details, please refer to Anju Ahlawat et al., J.Raman Spectroscopy 45,958 (2014).

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