Chapter 9 Conclusions and Future scopes

In this last chapter, we lay out the concise description of our work covering all the main points, its conclusion and the future scope of the present investigation.

9.1 Summary and conclusion

The application of multiferroic materials are enormous, but for its successful usage, the functional device should be operatable at room temperature. Up until now, most of the observed multiferroics exhibits weak ME coupling near RT which restricts it for multifunctional device applications. So, to remove this difficulty, the present thesis work is given in the investigation of enhanced ME coupling and multifunctional properties of BFO based materials. In this research work, we have systemically studied the role of different substituted materials such as Ti, Al, andCo at Fe – site and their composite BFO-TMO. The crystal structure, temperature dependent Raman spectra, XAS and XMCD analysis, magnetic and dielectric properties have been studied of the desired sample. The outcomes have been drawn below.

When nonmagnetic ion Ti is substituted at Mn- site of $Bi_{0.5}La_{0.5}Fe_{0.5}Mn_{0.5}O_3$multiferroics, it modifies the magnetic, dielectric and MD response of the sample. Substitution of 5% Ti at Mn-site enhanced the remnant magnetization and coercivity at 2K. Similar to the Al-doped$Bi_{0.5}La_{0.5}Fe_{0.5}Mn_{0.5}O_3$sample, Rietveld refinement and Raman analysis revealed that systems crystallize in the orthorhombic phase with *Pnma* space group. Dielectric study on $Bi_{0.5}La_{0.5}Fe_{0.5}Mn_{0.40}Al_{0.1}O_3$ indicates that ε' increases sharply and shows a high dielectric constant with weak-temperature dependence. Dielectric constant of the system enhances sharply from $\sim 8.5\times10^3$ for $Bi_{0.5}La_{0.5}Fe_{0.5}Mn_{0.5}O_3$ to $\sim 1\times10^4$ for $Bi_{0.5}La_{0.5}Fe_{0.5}Mn_{0.40}Al_{0.10}O_3$ at room temperature. The interesting result is the presence of spontaneous exchange bias (SEB) which

demonstrates the existence of the anti-ferromagnetic functionality of the partially substituted Coat Fe-sites$Bi_{0.5}La_{0.5}Fe_{0.5}Mn_{0.5}O_3$sample. Magnetic field dependent measurement of dielectric constant at different temperature confirms the strong MD coupling in this material. Our quantitative measurement of MD coupling shows maximum 9% increase in MD at 250K in the presence of the field 1.4T.

Besides this, we also have synthesized the magneto-electric multiferroic BFO-TMO composite in bulk by solid state reaction method. This composite exhibits substantial EB effect varying between 5-1155 Oe but persists up to room temperature reaching its maximum near a spin reorientation transition temperature, observed from magnetization vs. temperature measurement in Zero-field-cooled (ZFC), and Field cooled (FC) modes. Isothermal remnant magnetization measurements at room temperature indicate the presence of an interfacial layer of 2-dimensional dilute antiferromagnet in a field (2D DAFF).

X-ray Magnetic Circular Dichroism (XMCD) confirms the presence of charge transfer between different transition metal ions and different magnetically coupled layers which play a vital role in getting the exchange bias. Temperature-dependent Raman spectra measurement indicates anomalous softening of the phonon modes at ~ 210 K near the spin reorientation transition temperature (T*) which is a result of spin-phonon coupling in the lattice. Relaxor type ferroelectric behavior was observed in the temperature dependent dielectric measurements where the relaxation was found near T*. The frequency dependent dielectric study and the impedance spectroscopy revealed that the dielectric properties are a mixture of intrinsic Debye relaxation and Maxwell-Wagner relaxation arising from the space charge polarization at the interface of the two materials. A significant positive MD coupling was found near the relaxation temperature

which can be reasoned to be originated as a result of the magneto-structural coupling in the system.

9.2 Future scope of research work

1. We have studied the morphotrophic phase analysis, the evolution of EB phenomena, and ME coupling analysis in a different composition of BFO-TMO composite.
2. Novel techniques methods, for example, auto-combustion method for nanocomposite and pulse laser deposition (PLD) method to get epitaxial thin film can be used to synthesize the desired sample.
3. We have planned to work on some other multiferroic system which exhibits large exchange bias and ME coupling at room temperature and study its underlying physics.