Chapter 7

Summary and Future Scope

In the concluding section, we provide a summary of our study, including all of the important points, its conclusion, and the future scope of the current investigation.

7.1. SUMMARY

We have used the solid-state method in all the research articles for preparing all polycrystalline. In our first research i.e., $Bi_{0.8}Tb_{0.2}Fe_{0.8}Mn_{0.2}O_3$, we have used the co-substitution of Tb, and Mn in $BiFeO_3$ at A and B sites respectively. The value of the dielectric constant increases and the dielectric loss value decreases, large value of the dielectric constant suggests that these types of materials can be used for high dielectric applications. From XPS analysis, we found the mixed-valence state of Tb (+3, +4), Fe (+2, +3), and Mn (+3, +4) elements. There is the possibility of the different exchange interactions between all these mixed valence elements which can induce the exchange bias phenomenon in our system. The spontaneous exchange bias (H_{SEB}) value is approximately 468 Oe and 11.04 Oe, and Coercivity (H_C) value is 349 Oe and 38.04 Oe at 300 K and 5 K temperatures respectively. The finding of spontaneous exchange bias at ambient temperature in a BFO-based system is still unusual, thus classifying our system as a rare material.

In our second system, i.e., $Bi_{0.9}Tb_{0.1}Fe_{0.9}Mn_{0.1}O_{3.}$, from the UV-visible absorption spectra the band gap value found is 1.83 eV which is low for BFO based system. The decreased band gap energy values found could signify that our system can be used as a photoactive agent. The increment dielectric constant and decrement in tanδ value compared to the pure BFO system suggest an enhancement in the dielectric property. We found weak ferromagnetic behavior at room temperature as measured by magnetic (M-H curve). Whereas, in the magnetization measurement, we found that the Neel temperature of our system is 568 K.

From our third system i.e., $Bi_{0.5}La_{0.5}Fe_{0.4}Al_{0.1}Mn_{0.5}O_3$ we have found that the dielectric constant value enhanced many folds which can be used in many applications proposed, and spin glass behavior is found which can be used in the memory device. In our fourth research, we worked on $GaFeO_3$ multiferroic material, the M-H curve shows a pinched-type behavior at 2.2 and 10 K, because of the presence of two different magnetic phases (i.e., hard and soft magnetic phases). From

dielectric measurement, we have found the Debye-like dipolar relaxation phenomenon.

System name	$Bi_{0.8}Tb_{0.2}Fe_{0.8}Mn_{0.2}O_3$ (20% Tb and Mn doping A and B site respectively)	$Bi_{0.9}Tb_{0.1}Fe_{0.9}Mn_{0.1}O_3$(10% Tb and Mn doping A and B site respectively)	$Bi_{0.5}La_{0.5}Fe_{0.4}Al_{0.1}Mn_{0.5}O_3$ (50% La doping at A site) and (10%Al and 40% Mn) doping at B site	$Ga_{0.75}Er_{0.25}FeO_3$ (25% Er doping at A site on Ga)
Structural study (XRD and NPD)	Orthorhombic phase with two space group $Pn2_1a$ + Pnma and magnetic phase (P-1)	Rhombohedral and orthorhombic phase with two space group R3c +$Pn2_1a$ and magnetic phase (P-1)	Orthorhombic phase with Pnma space group	Cubic (Space group: Ia3d) + Rhombohedral (Space group: R-3c)
Dielectric study	Dielectric constant(ε') value is 3400 which is high and the loss value is ~1.2	Dielectric constant (ε') value is 3100 which is high and loss value is ~1.2	Dielectric constant (ε') value is 11500 which is very high and loss value is ~ 2	The dielectric constant(ε') value is 560 and low loss value is ~ 0.7
Magnetic study	T_C = 521 K (643 K for pure BFO), M value increase M=2 μB (NPD), H_{SEB} = 468 Oe and H_C=349 Oe, weak FM behavior at RT	T_C = 568 K (643 K for pure BFO) , M value increase M=0.5 μB (NPD), weak FM magnetic ordering at RT	T_C= 147 K (643 K for pure BFO) , both spin glass (47 K) and FM magnetic ordering present	T_C = 293 K and wasp-waisted hysteresis behaviour

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7.2 FUTURE SCOPE

- As we have observed the spontaneous exchange bias property along with the high dielectric constant value in the $Bi_{0.8}Tb_{0.2}Fe_{0.8}Mn_{0.2}O_3$ system. So, this material can be used for spintronic devices and high dielectric applications purposes in technology. Furthermore, the BFO-based system also shows interesting magnetic properties in the nano dimension. It would give some interesting properties if we make the thin of $Bi_{0.8}Tb_{0.2}Fe_{0.8}Mn_{0.2}O_3$ based system using epitaxial growth technique.
- In the $Bi_{0.9}Tb_{0.1}Fe_{0.9}Mn_{0.1}O_3$ system, we have found a low band gap value, so to further we will explore theoretical DFT calculations that can also be performed to clarify the exact origin of the observed band gap.
- Spin phonon coupling and a dielectric relaxor behavior were displayed by $Bi_{0.5}La_{0.5}Fe_{0.4}Al_{0.1}Mn_{0.5}O_3$. To further elucidate the precise cause of the observed spin

dynamics and electrical polarization, detailed structural and magnetic research using additional experiments such as Mossbauer spectroscopy, neutron diffraction, and theoretical DFT calculations can also be carried out.

- We will prepare some other GaFeO3-based multiferroic materials with different doping and will explore their magnetic and electrical properties.
- We propose to look into the underlying physics of another multiferroic system that displays high exchange bias and ME coupling at ambient temperature.