

**Title of the Thesis: EFFECT OF FERROMAGNETIC AND FERROELECTRIC PHASES ON THE MAGNETIC AND TRANSPORT PROPERTIES OF  $x\text{Li}_{0.1}\text{Ni}_{0.2}\text{Mn}_{0.6}\text{Fe}_{2.1}\text{O}_4 + (1-x)\text{Bi}_{1-y}\text{R}_y\text{FeO}_3$  MULTIFERROIC COMPOSITES**

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**Session: October/2014**

**ABSTRACT**

Various multiferroic composites  $x\text{Li}_{0.1}\text{Mn}_{0.6}\text{Ni}_{0.2}\text{Fe}_{2.1}\text{O}_4 + (1-x)\text{Bi}_{1-y}\text{R}_y\text{FeO}_3$ , (where, R = Y and Dy; x = 0.00, 0.10, 0.20, 0.30, 0.40, 0.50 and 1.00; y = 0.0 and 0.2) have been synthesized by the standard solid state reaction technique. The structural, complex initial permeability, dielectric properties, ac conductivity, impedance spectroscopy, *M-H* hysteresis loop and magnetoelectric coefficient of the composites have been investigated thoroughly. The X-ray diffraction analysis has confirmed that the composites are composed of a mixture of ferrite and ferroelectric phases. The ferrite phase  $\text{Li}_{0.1}\text{Mn}_{0.6}\text{Ni}_{0.2}\text{Fe}_{2.1}\text{O}_4$  (LNMFO) forms cubic spinel structure. On the other hand, ferroelectric phases  $\text{BiFeO}_3$  (BFO) and  $\text{Bi}_{0.8}\text{Y}_{0.2}\text{FeO}_3$  (BYFO) show distorted rhombohedral crystal structure, but  $\text{Bi}_{0.8}\text{Dy}_{0.2}\text{FeO}_3$  (BDFO) shows the orthorhombic crystal structure. In the composites, there is a small change in the lattice parameters of both ferrite and ferroelectric phases, due to the stress exerted on each other. The theoretical density and bulk density decreases linearly with ferrite content for all composites. The average grain diameter ( $\bar{D}$ ) decreases for  $x\text{LNMFO} + (1-x)\text{BFO}$  composites, but for  $x\text{LNMFO} + (1-x)\text{BDFO}$  and  $x\text{LNMFO} + (1-x)\text{BYFO}$  composites, the  $\bar{D}$  slightly decreases with ferrite part upto  $x = 0.1$  and for further increase it has increased. The real part of initial permeability has increased with ferrite content for all composites. However,  $x\text{LNMFO} + (1-x)\text{BYFO}$  composites show relatively higher initial permeability compared to other composites. The real part of dielectric constant ( $\epsilon'$ ) for all composites exhibit usual dielectric dispersion due to Maxwell-Wagner type interfacial polarization. For all composites, the  $\epsilon'$  and dielectric loss ( $\tan\delta_E$ ) decreases with ferrite content. The  $x\text{LNMFO} + (1-x)\text{BDFO}$  shows maximum  $\epsilon'$  and minimum  $\tan\delta_E$ . The ac conductivity of composites follows the Jonscher's power law and increases with frequency, indicating that the conduction is due to small polaron hopping. Impedance spectroscopy studies indicated that both the grain and grain boundary perform to the conduction mechanism. The saturation magnetization, remanent magnetization and coercivity have been obtained from the magnetic hysteresis loops. The magnetoelectric voltage coefficient for all composites decreases with ferrite content for  $x \geq 0.1$  and maximum value ( $182 \times 10^3 \text{ Vm}^{-1}\text{T}^{-1}$ ) is found for 0.1LNMFO + 0.9BYFO composite.

## List of Publications

The following contributions are based on this thesis

### i) Journals:

1. **A.A. Momin**, Roksana Parvin and A.K.M. Akther Hossain, “**Structural, morphological and magnetic properties variation of nickel-manganese ferrites with lithium substitution**”, Journal of Magnetism and Magnetic Materials, 423, pp.124-132, 2017.
2. **A.A. Momin**, M.A. Zubair, Md. Fakhru Islam, A. K. M. Akther Hossain., “**Enhance magnetoelectric coupling in  $x\text{Li}_{0.1}\text{Ni}_{0.2}\text{Mn}_{0.6}\text{Fe}_{2.1}\text{O}_4 + (1-x)\text{BiFeO}_3$  multiferroic composites**”, Journal of Materials Science: Materials in Electronics, vol. 30(14), pp.13033-13046, 2019.
3. **A.A. Momin**, Roksana Parvin, Md Fakhru Islam and A.K.M. Akther Hossain, “**Synthesis and characterization of  $0.2\text{Li}_{0.1}\text{Ni}_{0.2}\text{Mn}_{0.6}\text{Fe}_{2.1}\text{O}_4 + 0.8\text{BiFeO}_3$  Multiferroic composite**” Jagannath University Journal of Science, Vol. 6, pp. 36-46, 2019.
4. **A.A. Momin**, M. Shahjahan, Md. Fakhru Islam, Hidekazu Tanaka, Roksana Parvin, A. K. M. Akther Hossain, “**Interplay between the ferrimagnetic and ferroelectric phases on the large magnetoelectric coupling of  $x\text{Li}_{0.1}\text{Ni}_{0.2}\text{Mn}_{0.6}\text{Fe}_{2.1}\text{O}_4 - (1-x)\text{Bi}_{0.8}\text{Dy}_{0.2}\text{FeO}_3$  composites**”, Journal of Materials Science: Materials in Electronics, Vol. 31(1), pp. 511-525, 2020.

### ii) Proceeding:

**A.A. Momin**, Roksana Parvina and A.K.M. Akther Hossain, “**Magnetoelectric Coupling and Ferroelectric Behavior in  $0.5\text{Bi}_{0.8}\text{Dy}_{0.2}\text{FeO}_3 - 0.5\text{Li}_{0.1}\text{Ni}_{0.2}\text{Mn}_{0.6}\text{Fe}_{2.1}\text{O}_4$  Composite**”, 1<sup>st</sup> International Conference on Engineering Materials and Metallurgical Engineering (ICEMME), 22-24 December, 2016 (Full Paper).

### iii) Published Abstracts/Presentations:

1. **A.A. Momin**, Roksana Parvin and A.K.M. Akther Hossain, “**Preparation and Magnetoelectric Effect of  $0.6\text{Bi}_{0.8}\text{Dy}_{0.2}\text{FeO}_3 + 0.4\text{Li}_{0.1}\text{Ni}_{0.2}\text{Mn}_{0.6}\text{Fe}_{2.1}\text{O}_4$  Multiferroic Composite**”, 3<sup>rd</sup> Conference of Bangladesh Crystallographic Association, 1-2 December 2016.
2. **A.A. Momin** and A.K.M. Akther Hossain, “**Magnetoelectric Effects On Ferromagnetic and Ferroelectric Phases of  $(1-x)\text{Bi}_{0.8}\text{Dy}_{0.2}\text{FeO}_3 + x\text{Li}_{0.1}\text{Ni}_{0.2}\text{Mn}_{0.6}\text{Fe}_{2.1}\text{O}_4$  Composites**”, National conference on Physics organized by the Bangladesh Physical Society (BPS), 5-7 January, 2017.
3. **A. A. Momin**, Asma Azam, Mithun Kumar Das, Roksana Parvin, Md. Fakhru Islam and A. K. M. Akther Hossain, “**Preparation and Magnetoelectric Effect of Multiferroic  $x\text{Li}_{0.1}\text{Ni}_{0.2}\text{Mn}_{0.6}\text{Fe}_{2.1}\text{O}_4 + (1-x)\text{BiFeO}_3$  Composites**”, 2<sup>nd</sup> International conference on Physics for Sustainable Development & Technology, ICPSDT-2017, Organized by Department of Physics, Chittagong University of Engineering & Technology (CUET), 10-11 December, 2017.
4. **A. A. Momin** and A. K. M. Akther Hossain, “**Studies On Structural, Dielectric And Magnetic Properties Of  $x\text{Li}_{0.1}\text{Ni}_{0.2}\text{Mn}_{0.6}\text{Fe}_{2.1}\text{O}_4 + (1-x)\text{BiFeO}_3$  Magnetoelectric Composites**”, International Conference on Physics-2018, Organized by Department of Physics, Dhaka University, Dhaka, Bangladesh, 08-10 March 2018.
5. **A. A. Momin**, Roksana Parvin, Md. Fakhru Islam and A.K.M. Akther Hossain, “**Synthesis and characterization of  $0.2\text{Li}_{0.1}\text{Ni}_{0.2}\text{Mn}_{0.6}\text{Fe}_{2.1}\text{O}_4 + 0.8\text{BiFeO}_3$  multiferroic composite**”, National Conference on Physics-2019, Organized by Department of Physics, Dhaka University, Dhaka, Bangladesh, 7-9 February, 2019.
6. **A. A. Momin**, Md. Fakhru Islam and A.K.M. Akther Hossain, “**Investigations on electrical and magnetic properties of multiferroic  $x\text{Li}_{0.1}\text{Ni}_{0.2}\text{Mn}_{0.6}\text{Fe}_{2.1}\text{O}_4 - (1-x)\text{Bi}_{0.8}\text{Y}_{0.2}\text{FeO}_3$  composites**”, National Conference on Electronics and Informatics-2019, 4-5 December, 2019.