Structural, Dielectric and Magnetic Studies of Mn doped Y type Barium Hexaferrite ($Ba_2Mg_2Fe_{12}O_{22}$)

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Abstract

The polycrystalline single phase $Ba_2Mg_2Fe_{12}O_{22}$ (BMF) and $Ba_2Mg_2Fe_{11.52}Mn_{0.48}O_{22}$ (BMFM) were prepared using conventional solid state reaction route. We report the modification in structural, dielectric and magnetic properties of BMF due to 4% Mn doping at Fe site. Phase purity of both sample are confirmed by the Reitveld refinement of XRD data. Temperature dependent dielectric study shows decrease in dielectric constant (ε′) and dielectric loss (tan δ) due to 4% Mn doping in parent sample. The ferrimagnetic to paramagnetic transition temperature (T_c) in doped sample decreases from 277°C to 150°C. Room temperature magnetization measurement shows ferrimagnetic behavior for both the samples. We have fitted the saturation magnetization data at 300°C by using least square method which confirms the enhancement of saturation magnetization and magnetic anisotropy constant in doped sample.

Introduction

- In recent years, interesting research has focused on hexaferrites due to its potential electrical, dielectric and Magneto-electric coupling (MEC) properties at room temperature [1, 2].
- According to chemical formula and structure, hexaferrites are classified into six types namely M, W, Y, Z, X and U.
- $Ba_2Mg_2Fe_{12}O_{22}$ (BMF)belongs to the family of Y-type hexaferrites in which effect of doping on structural, magnetic, dielectric and magnetoelectric properties are least investigated.
- BMF is reported to show three magnetic phase transitions: T<20 K (longitudinal conical spin), 20K<T<260K (proper screw spin) and 260K<T<550K (ferrimagnetic spin) [3, 4].
- Spin current model explains the magnetoelectric origin in BMF due to noncolinear arrangement of spins and the polarization is being quantified as $\vec{P} = A\vec{e_{ij}} \times (\vec{S_i} \times \vec{S_j})$ [5,6].
- It also reported that in $Ba_{0.5}Sr_{1.5}Zn_2Fe_{12}O_{22}$ magnetic field induced electrical polarization drastically reduces the critical field by partial substitution of Fe with Al [7].
- The present works focuses on the modifications in structural, dielectric and magnetic properties of $Ba_2Mg_2Fe_{12}O_{22}$ (BMF) due 4% Mn doping at magnetic Fe site .

Solid State Reaction Route

$4BaCo_3 + 4MgO + 12(1\text{-}x)Fe_2O_3 + 12XMn_2O_3$

Mixing and Grinding

Calcined at 1000°C for 10 h

Reground and Pelletized

Sintered at 1200a°C for 16 h

$2Ba_2Mg_2(Fe_{(1-x)}Mn_x)_{12}O_{22}(X= 0,0.04)$

Acknowledgment

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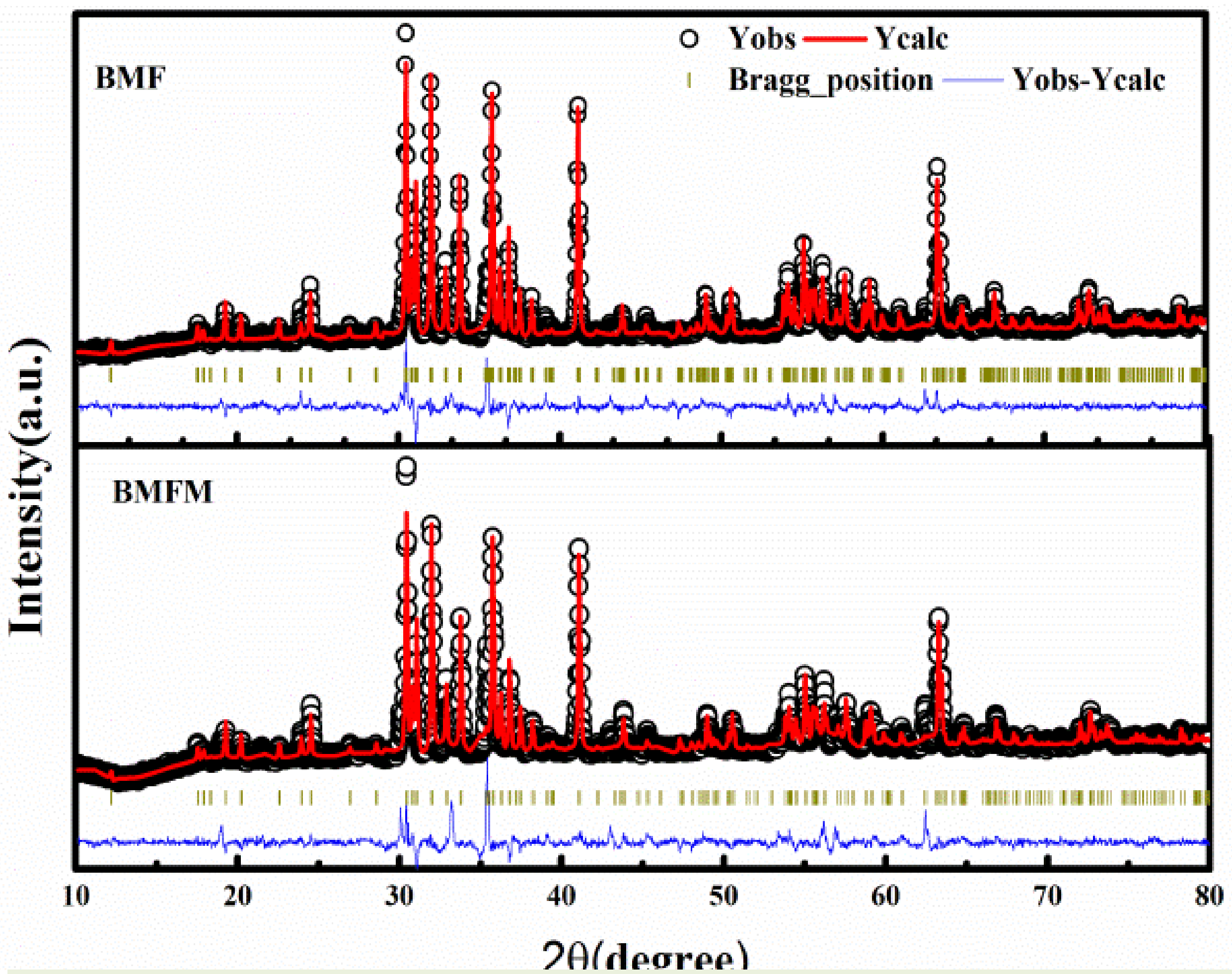
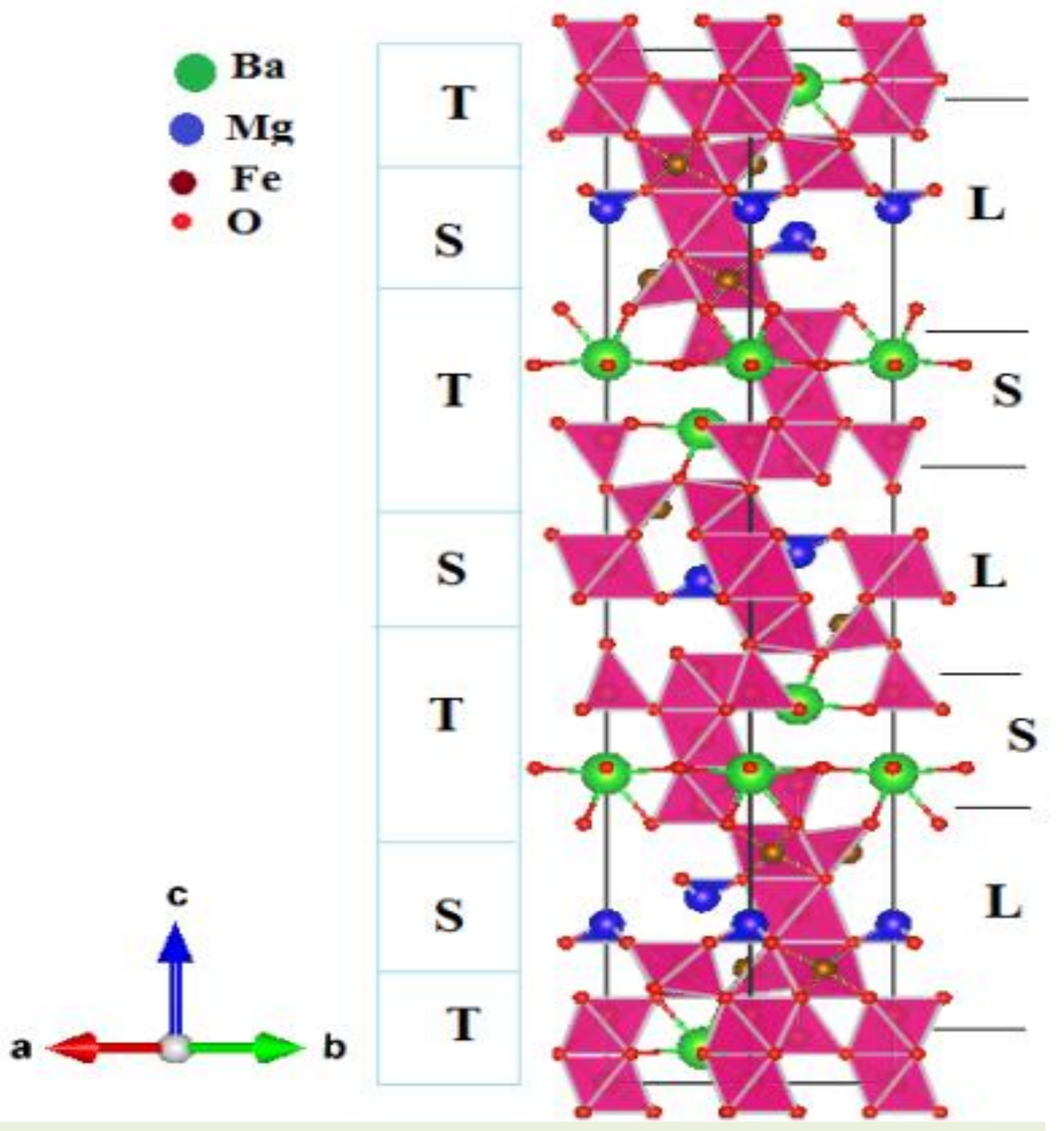
Experimental Results

Structural Characterization

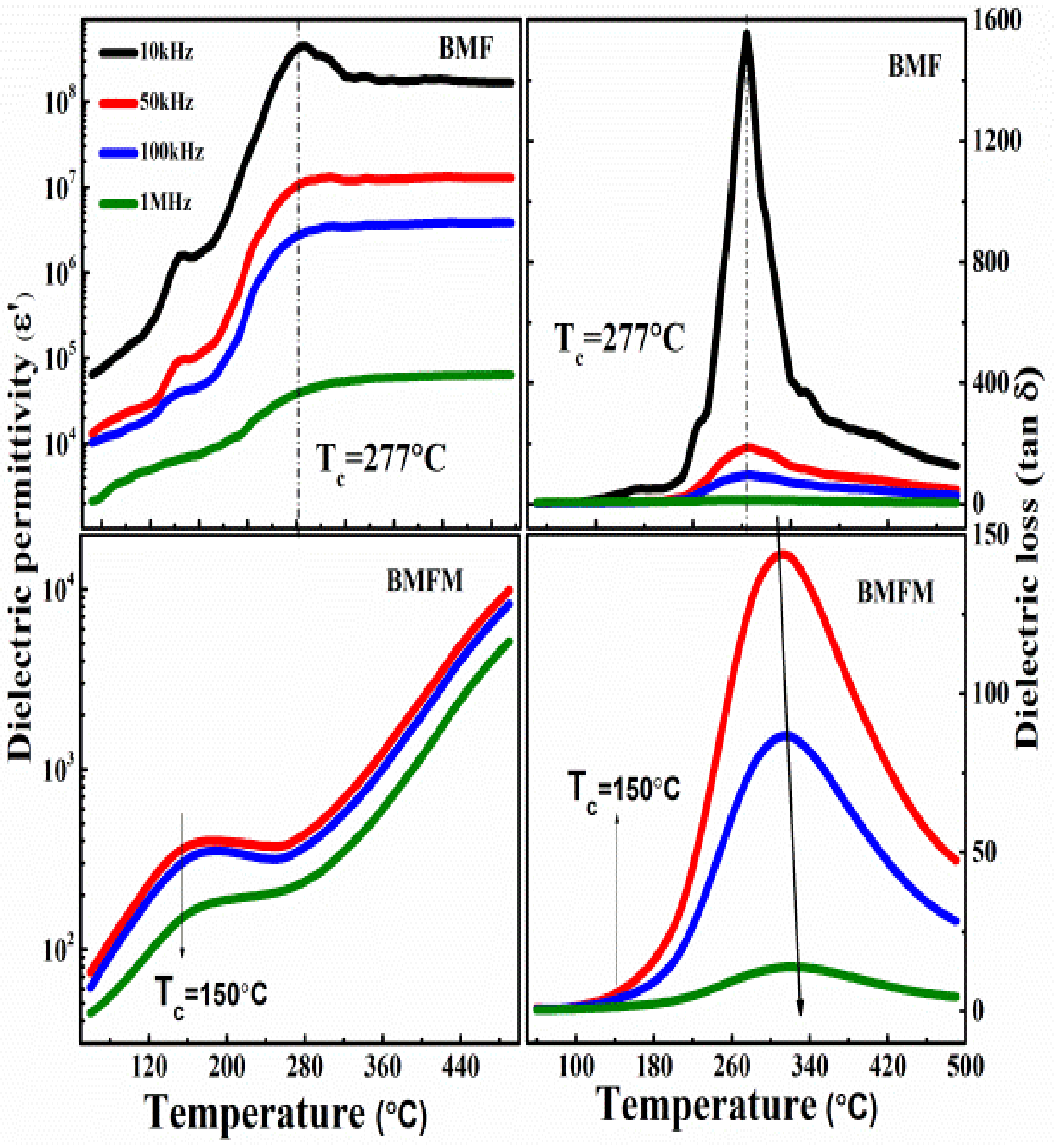




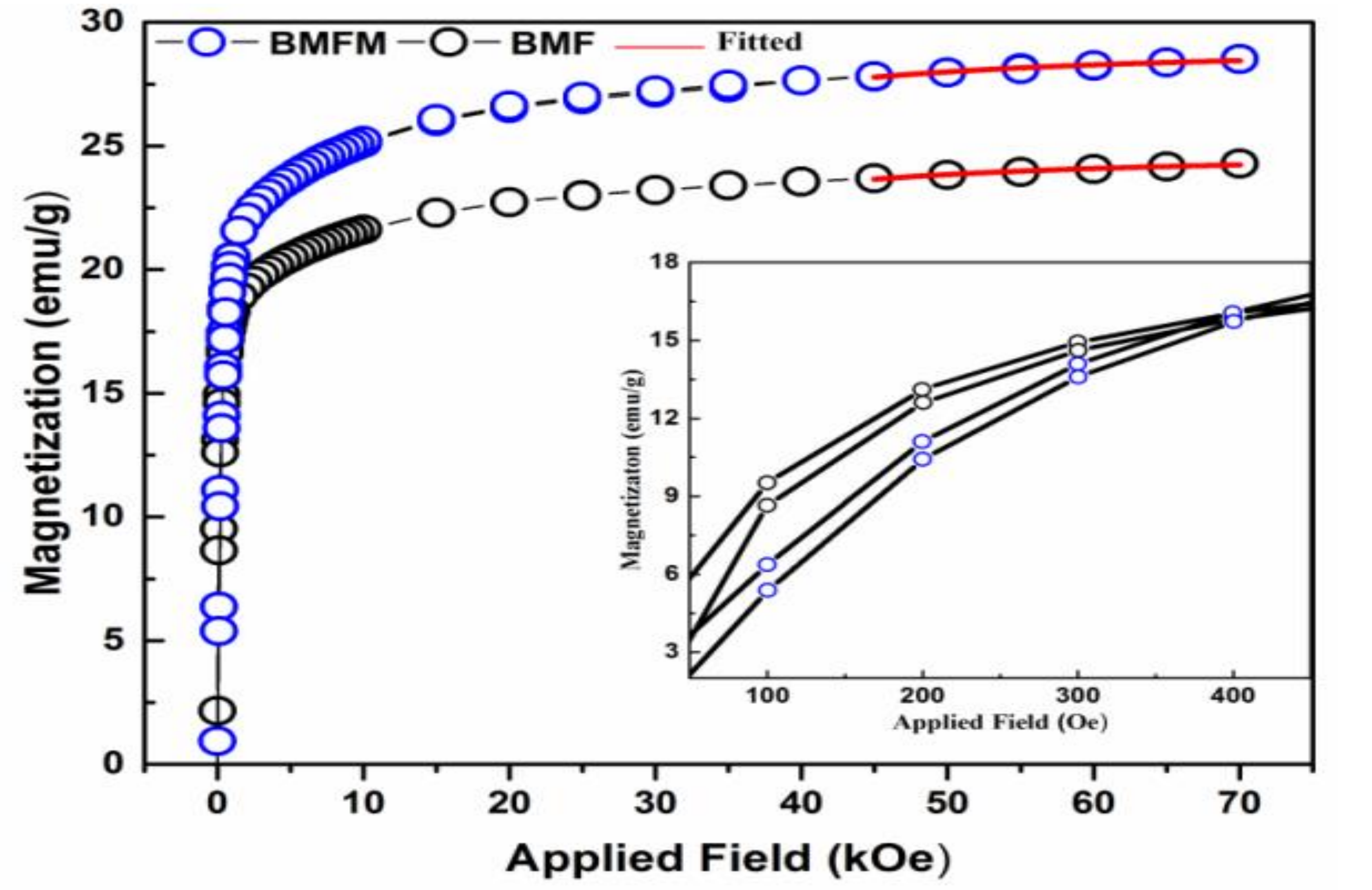
Materials	a(Å)	b(Å)	c(Å)	Vol(Å³)	χ^2	M_s(emu/gm)	K(erg/cm³)
BMF	5.866(5)	5.866(5)	43.499(7)	1296.384(3)	5.75	24.640	8.01×10^5
BMFM	5.873(6)	5.873(6)	43.543(4)	1301.037(3)	6.50	28.921	9.37×10^5

- XRD refinement confirms that both the sample are properly crystallize with space group R-3m.
- The structure shown can be considered as a staking of alternation $S(Mg_2Fe_4O_8)$ and $T(Ba_2Fe_8O_{14})$ blocks along c-axis of the unit cell.

Dielectric and Magnetic Characterizations.



- Broad peak at 277 °C in dielectric permittivity and sharp peak in dielectric loss which is related with the ferromagnetic to paramagnetic transition temperature (T_c) of parent sample.
- The transition temperature (Tc) of the doped sample have decreased to 150°C .
- The decreased in T_c can be correlated to the change in O-Fe-O bond angles due to substitution of Mn ions at Fe sites.
- The dielectric loss plot of 4% Mn doped sample has shown dielectric relaxation phenomena above 300°C which is indicated by the solid arrow line
- The correlation between Tc and bond angle can be understood by using expression: Tc= $JZS(S+1)\cos\theta$, where, J is exchange constant , S is the spin of Fe^{3+} (i.e. 5/2), Z is average number of linkage per Fe^{3+} ions and θ is the Fe-O-Fe bond angle[8].



- The law of approach to saturation is used to measure saturation magnetization by using least square method given by $M = Ms(1 - A/H - B/H2)$ where M_S is saturation magnetization , *A* represents inhomogeneity in the sample, *B* is proportional to the K^2 (K is anisotropy constant) [9,10].
- The monotonically increasing nature oh magnetic moment is observed at low field region

Conclusions

- The Reitveld refinement data of prepared sample are single phase rhombohedral with space group R-3 m.
- The lattice parameter and unit cell volume increases with 4% Mn doping in parent sample.
- The dielectric impedance analysis revels that both dielectric constant and dielectric loss decreases due to doping.
- The room temperature magnetization measurement (M-H) shows that up to 450Oe field magnetization increases monotonically and above this field magnetization almost saturated.
- The saturation magnetization and anisotropy constant of the doped sample increased in comparison to parent sample.