Inducing ferromagnetism in pyrochlore $\text{Eu}_2\text{Ti}_2\text{O}_7$ by Fe and Mn doping and establishing ferroelectricity in $\text{Eu}_2\text{Ti}_2\text{O}_7$

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Pyrochlore titanates $\text{R}_2\text{Ti}_2\text{O}_7$ have drawn remarkable attention for last 20 years due to its wealth of diverse properties. The magnetic spins sitting on the pyrochlore lattice cannot satisfy the anti-ferromagnetic spin orientation to reach its ground state at low temperature, as a consequence frustrated spins gives rise to various novel phenomena like spin liquid, spin ice, spin glass etc[1,2]. Pyrochlore $\text{Eu}_2\text{Ti}_2\text{O}_7$ has a cubic structure of Fd3m symmetry. The special electronic configuration $4f^6$ of rare earth Eu^{3+} ion has a major role in its magnetic and electrical properties. Polycrystalline samples of pure and doped sample of $\text{Eu}_{2-x}\text{M}_x\text{Ti}_2\text{O}_7$ ($\text{M}=\text{Fe}, \text{Mn}, \text{Ni}$) for $x=0$ and $x=0.1$ were prepared in conventional solid state reaction method. XRD study was done using Rigaku-Miniflex-II diffractometer and it confirmed that all the pure and doped samples are formed in single (cubic) phase, with lattice parameter $a=10.19 \text{ \AA}$. Magnetic measurement was done using "Quantum Design" MPMS system. M-T measurement was performed at a field of .01 Tesla for all doped and undoped samples and an additional M-T measurement at 1 Tesla of pure $\text{Eu}_2\text{Ti}_2\text{O}_7$ was done. With 5% doping of Mn and Fe, the magnetization increased sharply and the nature of the low temperature magnetic state of these(Fe,Mn) doped samples seems to be different from that of the pure sample (Figure 1). The clear shift observed in the " $1/\chi$ Vs T" plot of $\text{Eu}_2\text{Ti}_2\text{O}_7$ for .01T and 1T indicates existence of field dependent energy barrier in addition to the thermal excitation. Surprisingly for 5% Ni doped sample, the nature of the MT curve remained almost similar to that of the pure $\text{Eu}_2\text{Ti}_2\text{O}_7$. Magnetization Vs Magnetic field measurement also showed (Figure 2) the appreciable enhancement of magnetization for Mn and Fe doped samples, the nonlinear nature of the MH curve is an indication of weak ferromagnetism for the Fe and Mn doped samples. For Ni doped sample for MH curve again, the nature remained same as of the pure $\text{Eu}_2\text{Ti}_2\text{O}_7$ which is linear implying antiferromagnetic nature. In Susceptibility χ Vs Temperature plot for $\text{Eu}_2\text{Ti}_2\text{O}_7$, at 4.9 K there is a sudden antiferromagnetic increase in magnetization. However previous study on $\text{Eu}_2\text{Ti}_2\text{O}_7$ [2] showed that there is a dominating exchange interaction $J_{nn}=-.76$ and weak dipolar interaction $D_{nn}=0.0056$. The total magnetic moment of Eu^{3+} ion is lower than that of Fe^{3+} , that might enhance the dipolar interaction and thereby enhanced weak ferromagnetism. For

Mn^{4+} ion, the magnetic enhancement may be due the double exchange interaction.

Figure 1: M-T plot for $\text{Eu}_2\text{Ti}_2\text{O}_7$ and its doped sample (Inset of Figure 1 showing Zfc –Fc hysteresis for Mn doped sample)

Figure 2: Showing M-H plot for $\text{Eu}_2\text{Ti}_2\text{O}_7$ and its doped sample

Figure 3: Showing Pyroelectric current vs. temperature plot for pure $\text{Eu}_2\text{Ti}_2\text{O}_7$ sample.

Pyroelectric current measurement for pure $\text{Eu}_2\text{Ti}_2\text{O}_7$ sample showed appreciably large pyroelectric current (nA) (Figure 3) and the corresponding spontaneous polarization also is quite high which indicates the existence of ferroelectricity which was not reported earlier.

References

1. L.Balents, Nature. 464, 08917(2010)
2. J.S.Gardner, M.J.P.Gingras, J.E.Greedan, Rev. Mod. Phys. 82(2010)
3. P.Dasgupta, Y.M.Jana, J.Phy.Chem. Sold, 68,347(2007)