Original Research Paper | Physics | Volume : 08 | Issue : 02 | Feb 2023 | e-ISSN : 2456-5040

TO STUDY THE MAGNETIC PROPERTIES OF SAMARIUM IRON GARNET DUE TO AL DOPING

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ABSTRACT

This study explores the magnetic properties of Samarium Iron Garnet (SmIG) when doped with aluminum (Al). SmIG displays complex magnetic behavior due to the interaction between rare earth and transition metal ions, making it a promising candidate for advanced magnetic applications. By replacing some of the Fe ions with Al in the SmIG structure, we aim to understand how Al doping affects the material's magnetic characteristics. We conducted detailed magnetic measurements, including magnetization, coercivity, and Curie temperature, on samples with varying Al concentrations.

1. INTRODUCTION

Samarium Iron Garnet (SmIG), a material from the rare earth iron garnet family, has garnered significant attention due to its intriguing magnetic properties and potential applications in magnetic and magneto-optical devices. The magnetic behaviour of SmIG arises from the complex interplay between samarium (Sm) and iron (Fe) ions, which results in high magnetic anisotropy, low magnetic losses, and substantial Faraday rotation. These characteristics make SmIG a promising candidate for various technological applications, including magnetic sensors, memory devices, and magneto-optical components [1,4-6].

One effective method for tailoring the properties of magnetic materials is doping, which involves the intentional introduction of impurity ions into the host lattice. Aluminium (Al) doping, in particular, has been shown to significantly influence the magnetic characteristics of garnet materials. By substituting Fe ions with Al in the SmIG structure, the local magnetic environment is altered, leading to modifications in the material's overall magnetic behaviour [2,7-8]. Previous studies have demonstrated that Al doping can affect parameters such as magnetization, coercivity, and Curie temperature in garnet systems, thereby offering a means to optimize their performance for specific applications [3,9-10].

The magnetic ordering in $Sm_3Fe_5O_{12}$ arise due to the super exchange interaction between the Sm^{3+}-Fe^{3+} ions and also between the Fe^{3+} ions in the tetrahedral and octahedral voids [11]. This strong ferrimagnetic ordering is found to dominate above ~150 K and is also responsible for its high Curie temperature ~573 K [12]. Due to this strong magnetic ordering and higher Curie point samarium iron garnet is one of the ready choices.

This study focuses on a systematic investigation of the magnetic properties of Al-doped SmIG. we aim to elucidate the impact of this doping on key magnetic parameters. Detailed magnetic measurements, including magnetization is conducted on samples to understand the underlying mechanisms driving these changes.

The outcomes of this research will provide valuable insights into the tunability of SmIG's magnetic properties through Al doping. These findings have the potential to contribute to the development of customized materials for specific technological applications, advancing both the fundamental understanding of doped garnet systems and their practical implementations.

2. EXPERIMENTAL

Magnetization versus applied magnetic field (M–H) data of the samples was recorded at different temperature with maximum applied field of 30 kOe in a Quantum Design make VSM.

Static magnetic properties

To investigate the static magnetic property of the garnet nanoparticles, magnetic hysteresis loop of the samples was recorded at room temperature (RT) and at 50 K. The maximum applied field used for the measurement of magnetisation with the variation of applied magnetic field (M-H loops) here was ~ 3T. The observed M-H loops of the samples are shown in the Figure 1 Values of different magnetic parameter viz.

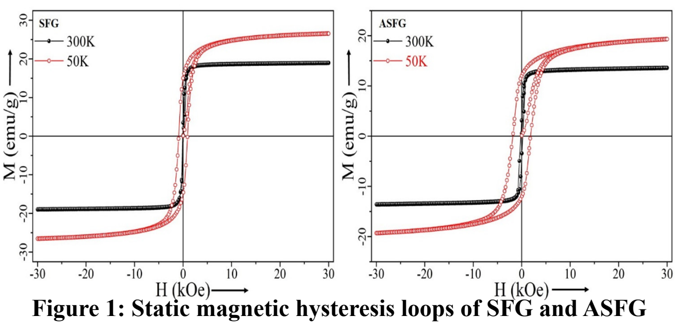

Figure 1: Static magnetic hysteresis loops of SFG and ASFG observed at 300 K and 50 K.

maximum magnetization (Mmax), remanent magnetization (MR) and coercive field (Hc) of the samples are extracted from M-H loops and tabulated in Table 1. From the Fig. 1 we see that, both the samples show saturated and symmetric hysteresis loops around zero at both the temperature of observation. This

Volume : 08 | Issue : 02 | Feb 2023 | e-ISSN : 2456-5040

type of M-H loops is consistent with that of the ferrimagnetic samples. The magnetic nature of rare earth iron garnet can be explained through Néel's sub lattice model. In case of samarium iron garnet, the magnetic sub lattices of samarium ion are found to be coupled antiparallel to the magnetic sub lattices of iron ion through super exchange interactions. Thus, the magnetization observed arises from the resultant magnetic moments of these two sub lattices. The maximum magnetization as observed in case of SFG, ASFG nanoparticles are respectively ~18.5 emu/g, ~13.4 emu/g at RT and ~26.4 emu/g, ~19.0 emu/g at 50 K. In both cases of RT and 50 K, the magnetization of ASFG is found to be lower than that of SFG. This is due

Sample	Measurement Temperature (K)	M_{max} (emu/g)	M_r (emu/g)	H_c (kOe)	M_{max} / M_r
SFG	300	19.39	3.25	0.07	5.96
	50	26.35	15.20	0.92	1.73
ASFG	300	13.42	3.60	0.21	3.73
	50	18.89	12.00	1.81	1.57

Table 1: Detail Results of Static Magnetic Measurements

To the introduction of aluminium ion replacing samarium in the garnet lattice. As aluminium is a non-magnetic ion it breaks the long-range interactions between the sub lattices of samarium and iron. This tends to introduce misalignments between the magnetic moments, which results in a decrease in the magnetization value. However, from the Table 1, we see that H_c value is found to increase in case of doped sample. From the hysteresis loops we also observe that the magnetization data continues to increase slowly with increase in magnetic field in the high field region. This type of effect can be observed due to the presence of high anisotropy in the sample which require higher magnetic field to align the magnetic moments along the direction of the field. Another probable reason behind this type of behaviour in M-H loops is the presence of single domain particle in the prepared sample. These single domain particles show super paramagnetic (SPM) behaviour which restricts the magnetic moment to get aligned with the magnetic field at lower field region. At present we can't confirm the actual reason behind this phenomenon because of lack of information available in present case. To confirm the reason behind this observation we need to study the variation in magnetization with change in temperature of these samples under zero field cooled (ZFC) and field cooled (FC) conditions. This we will try to include in future study.

3. CONCLUSION

Nanoparticles of $Sm_3Fe_5O_{12}$ and $Sm_{2.7}Al_{0.3}Fe_5O_{12}$ were successfully prepared using wet chemical method through sol-gel technique. Magnetic property like magnetization, shape of hysteresis loops etc. of the sample shows ferrimagnetic ordering together with high magnetization value even at RT. The observed magnetic ordering of the samples will be very much useful for practical applications. We also observe small linear increase in magnetization value in the high field region. This magnetic enhancement may be due to the presence of SPM particles and/or high anisotropy of the samples. Although the detail reason behind this observation is not discussed in the present dissertation. In future we will also try to investigate the detail nature of temperature variation of the magnetization. This will give a detail idea about the magnetic nature of the sample. We will also try to study the dielectric behaviour of the sample to have clear idea about the physical properties of rare earth iron garnets which will be beneficiary to have practical applications of these materials.

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