Exchange interaction in $CoFe_2O_4$-$SrFe_{12}O_{19}$ nanocomposites

Kalyani Dhabekar [1], P. S. Anil Kumar [2] and K. Mohan Kant [1,#]

[1]Department of Physics, Visvesvaraya National Institute of Technology, Nagpur-440010.
[2]Department of Physics, Indian Institute of Science, Bangalore-560012, India.
#Email: k.mohankant@gmail.com

Abstract: In recent years, exchange spring systems have attracted much attention due to the prediction in the enhancement of the magnetic energy product *(BH)*$_{max}$ [1-3]. In order to increase the energy product, the saturation magnetization and coercivity is tailored by synthesizing magnetic composite consisting of hard and soft magnetic materials. The advantage of utilizing the high saturation magnetization of the soft phase and large coercivity of the hard phase leads to enhanced *(BH)*$_{max}$ in nanocomposites.

In the present work, chemical co-precipitation route was employed to synthesize $CoFe_2O_4$ and $SrFe_{12}O_{19}$ nanoparticles. Cobalt (II) chloride hexahydrate [$CoCl_2$. $6H_2O$)], Strontium (II) chloride hexahydrate [$SrCl_2$. $6H_2O$)], Iron (III) chloride hexahydrate [$FeCl_3$. $6H_2O$)], and sodium hydroxide (NaOH) were used to synthesize the nanoparticles. All the reagents used in the experiments were commercially available (> 99.9% purity, Sigma Aldrich). For synthesis of $CoFe_2O_4$ nanoparticles, a precursor solution was obtained by mixing $CoCl_2$ $6H_2O$ and $FeCl_3$ $6H_2O$ (Fe^{+3}/Co^{+2} = 2:1) in distilled water. NaOH solution (6M) was added drop wise into the precursor solution under constant stirring at 80 until the solution attains pH of 12. The reaction was continued for 30 min. The obtained precipitate was washed with distilled water and ethanol, and dried at 80 ^{o}C.

In case of $SrFe_{12}O_{19}$ nanoparticles, the precursor solution consists of $SrCl_2$ $6H_2O$ and $FeCl_3$ $6H_2O$ (Fe^{+3}/Sr^{+2} = 10:1) mixed in distilled water. After addition of NaOH solution (4M) at 80 , the reaction was continued for 2 hours. The precipitate obtained was dried at the synthesis temperature and later annealed at 850 for 4 hours to obtain pure hexaferrite phase.

Nanocomposites in the weight ratios of 1:1, 1:2, 1:4, 1:8 and 1:16 ($CoFe_2O_4$:$SrFe_{12}O_{19}$) were synthesized from $CoFe_2O_4$ and $SrFe_{12}O_{19}$ nanoparticles by grinding. After grinding the samples were annealed in air at 850 for 3 hours and grinded. The sample 1:1 is labeled as S/H-1/1, which represents the composite with soft/hard ratio of 1:1. Similarly, the other composites are labeled as S/H-1/2, S/H-1/4, S/H-1/8 and S/H-1/16.

X-ray diffraction patterns of the nanocomposites confirm the existence of independent major phases. The average crystallite size of pristine $SrFe_{12}O_{19}$ and $CoFe_2O_4$ is found to be 42 nm and 17 nm respectively. From the diffraction patterns (Fig. 1(a)-(c)), individual peaks corresponding to both $CoFe_2O_4$ and $SrFe_{12}O_{19}$ nanoparticles were observed. Exchange coupling in the nanocomposites was confirmed from room temperature M-H curves. Saturation magnetization (M_s) values for $CoFe_2O_4$ and $SrFe_{12}O_{19}$ nanoparticles are observed to be 52 emu/g and 25 emu/g respectively (Fig. 2(a)).

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The M_s values of the nanocomposites lie between the soft and hard phase. Single hysteresis loop observed for nanocomposites, confirms the existence of exchange interaction.

In this research work, we will discuss the role of First order reversal curve (FORC) measurements (Fig. 2(b)-(f)) in further confirmation of the exchange behavior in the prepared composites will be discussed in detail.

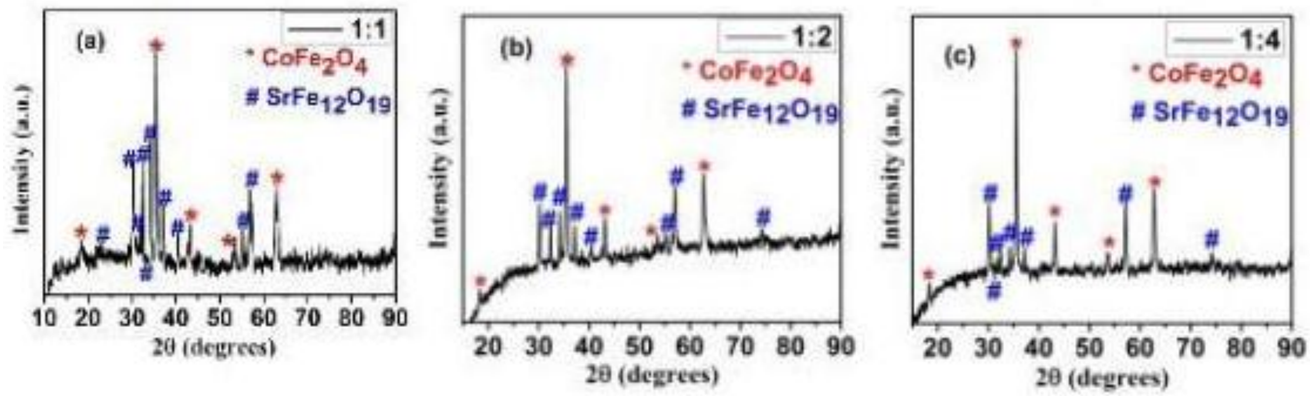
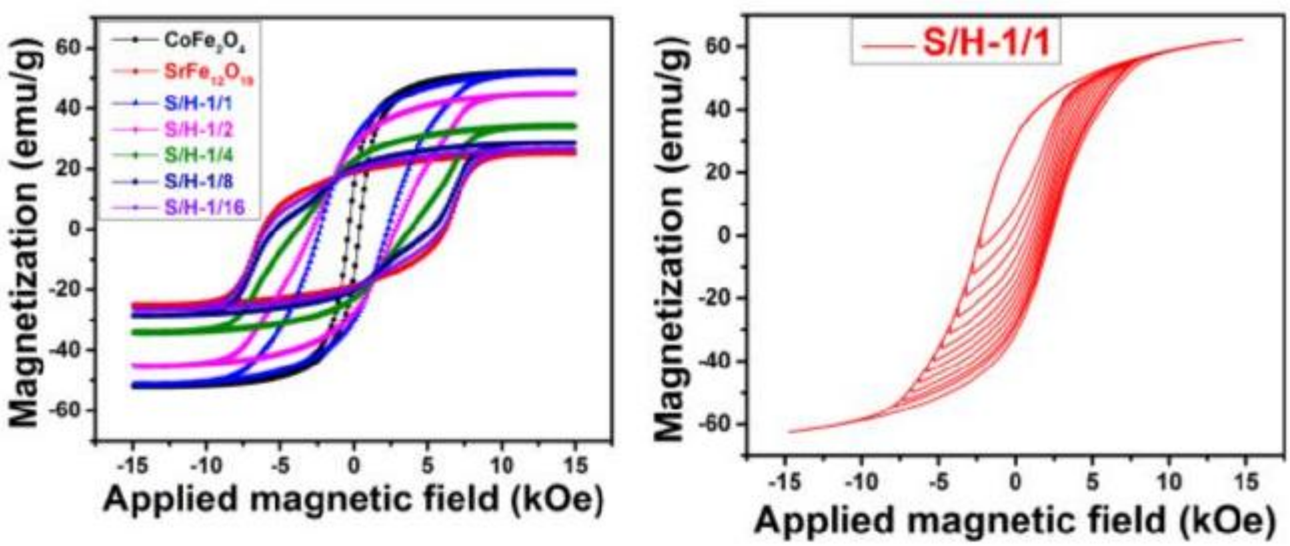


Figure 1: X-ray diffractograms of (a) S/H-1/1, (b) S/H-1/2 and (c) S/H-1/4.



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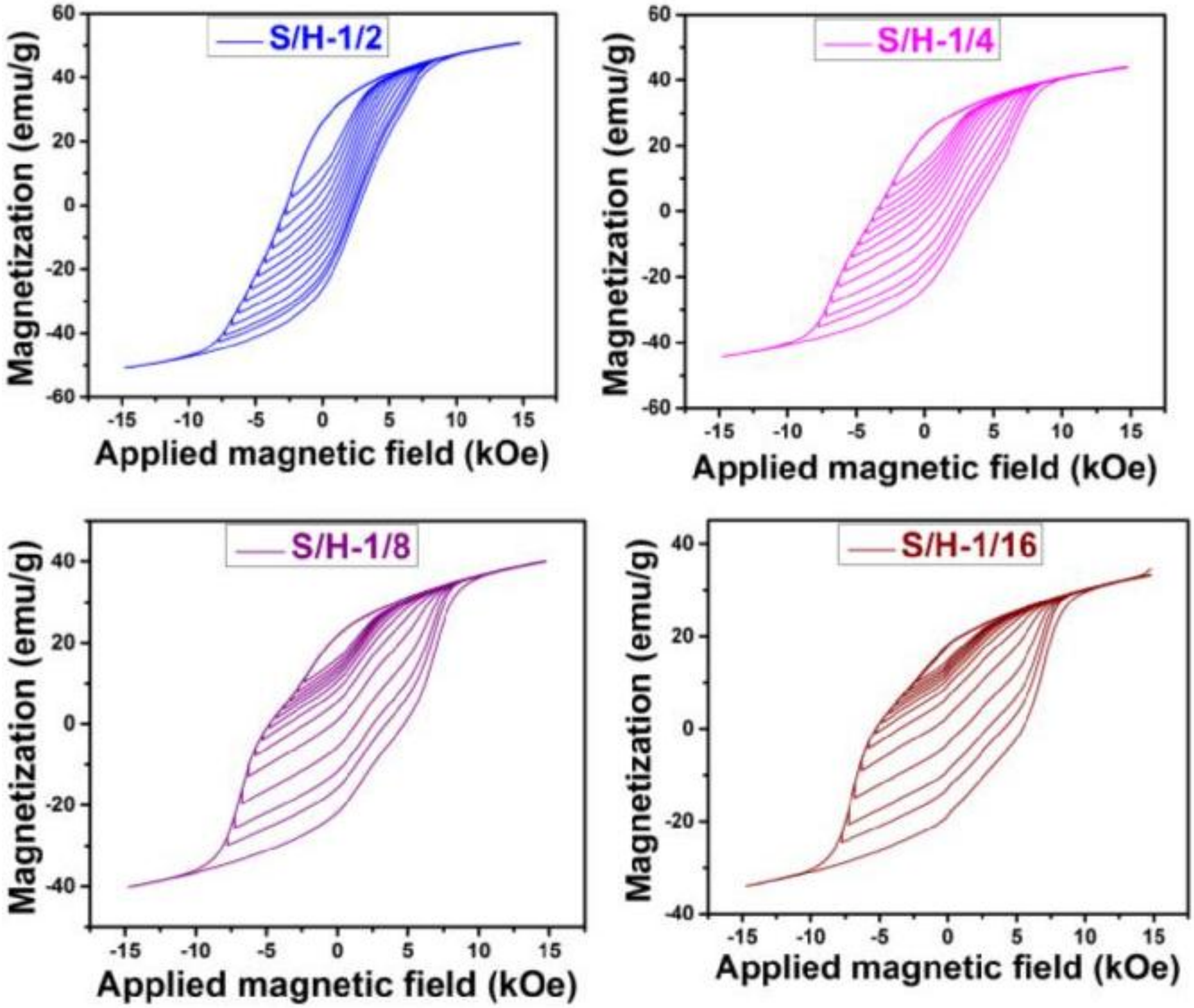

Figure 2: (a) M-H curves for $CoFe_2O_4$ nanoparticles, $SrFe_{12}O_{19}$ nanoparticles and the prepared composites. First order reversal curve (FORC) measurement of (b) S/H-1/1, (c) S/H-1/2, (d) S/H-1/4, (e) S/H-1/8 and (f) S/H-1/16.

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