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Anisotropic Spin-fluctuations In SmCoPO: ^{31}P NMR Study

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Abstract. ^{31}P NMR has been done in the paramagnetic state of SmCoPO. H_{iso}^{hf}, H_{ax}^{hf} are 13.4 and -5.19 kOe/μ_B respectively have been estimated which indicates the nature of hybridization between P 2p orbitals with Co 3d orbitals. Anisotropic spin-lattice relaxation rate has been observed. In plane spin-correlations are 2D FM and out of plane spin correlations are AFM type.

Keywords: Itinerant magnetism, Nuclear Manetic Resonance, Spin-lattice relaxation rate.
PACS: 71.27.+a, 76.60.Es, 75.40.Gb

INTRODUCTION

The discovery of iron based (grouped in several families) superconductors has drawn immense attention because of the presence of strongly correlated electrons that are responsible for diverse electronic and magnetic properties shown by these materials. The non-superconducting parent compounds which show spin density wave (SDW) transition, structural phase transition, itinerant ferromagnetism etc. show superconductivity (SC) upon carrier doping. In 1111 and 122 family, superconductivity is also achieved by Co doping in place of iron. It is presumed that the study of Co based non superconducting members would provide important information about the key factor that determines the ground state.

In *L*CoAsO (*L* = rare earth) series La, Ce, and Pr show paramagnetic (PM) to ferromagnetic (FM) transition, whereas Sm, Nd, and Gd show PM → FM → AFM transition. The FM transition temperature (T_C) increases from La to Ce and for Pr, Nd, Sm it is almost same. *L*CoPO family also shows similar behavior with important difference that the T_C increases progressively as we go down the series from La to Sm. In both the series, the lattice volume decreases as one goes from La to Sm. In general, with the application of chemical or physical pressure, T_C decreases due to the increment of density of state (DOS) at Fermi level (magneto-volume effect). However, due to the lattice size decrement, the three dimensionality of the magnetic interaction may enhance causing an increment of T_C. Thus competing phenomena are playing active role in determining T_C.

Our earlier ^{31}P and ^{139}La NMR [2,3] measurements in LaCoPO (quasi 2D Fermi surface) reveal dominant 2D spin fluctuation of 3d electrons in PM state with non negligible 3D part and in the FM state spin fluctuation is 3D in nature. Since SmCoPO has the minimum unit cell volume in the series, we intend to study the paramagnetic state to probe the interplay between increasing interlayer interaction due to three dimensionality of the Fermi surface (causes increment of T_C) and magneto-volume effect (causes decrement of T_C). Probing dynamic spin susceptibility, the spin-lattice relaxation rate provides microscopic information on the dimensionality of spin-fluctuations.

RESULTS AND DISCUSSIONS

Figure 1. shows typical ^{31}P NMR spectrum in polycrystalline SmCoPO, which corresponds to the powder pattern for a spin 1/2 nucleus with axially symmetric local magnetic field, as expected for tetragonal symmetry. The step in the low-frequency side corresponds to H ∥ c ($\theta = 0^\circ$) and the peak in high frequency corresponds to H ⊥ c ($\theta = 90^\circ$). The shift of the step with respect to the reference position (ν_R), corresponds to K_c and that of the peak corresponds to K_{ab}. Figure 2. shows temperature dependence of K_{iso} and K_{ax} in the temperature range 300 -140K. Where $K_{iso} = (2/3)K_{ab} + (1/3)K_c$ and $K_{ax} = (1/3)(K_c - K_{ab})$. At room temperature K_{iso} and K_{ax} are almost same for LaCoPO and SmCoPO, but below room

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temperature K_{iso} and K_{ax} for SmCoPO increases rapidly than LaCoPO. Measured shift can be written as $K = K_0 + K(T)$, where $K(T) = (H^{hf}/N\mu_B)\chi(T)$. H^{hf} is the fine hyper

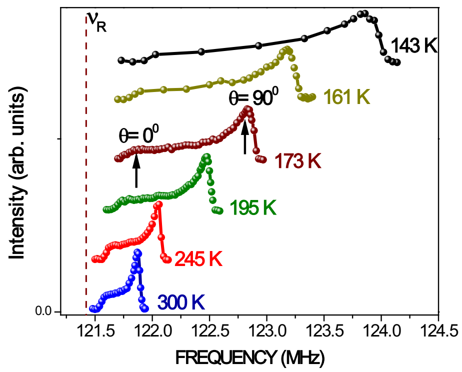

FIGURE 1. ^{31}P NMR spectra for SmCoPO.

field, N is the avogadro number and μ_B is the Bohr magneton. Inset of figure 2 shows K_{iso} and K_{ax} are linear with M/H (χ) plot where M has been measured at 7 Tesla, the same field where NMR has been done. The hypefine coupling constants H_{iso}^{hf}, H_{ax}^{hf} are 13.4 and -5.19 kOe/μ_B respectively. The axial part of hyperfine coupling constant indicates the extent hybridization between of P 2p orbitals with Co 3d orbitals. In case of LaCoPO, H_{ax}^{hf} = -4.24 kOe/μ_B. Thus P 2p orbitals are little more hybridized with Co 3d orbitals in SmCoPO. This may be due to the shrinkage of lattice volume.

$(1/T_1T)_{ab}$ and $(1/T_1T)_c$ versus T (Figure 3), shows that spin-lattice relaxation rate is anisotropic in nature. Continuous enhancement of $1/T_1$ below 300 K indicates the signature of the development of short range correlation among the Co-3d spins from temperature which is far above T_C. This is the characteristic of itinerant magnetism as predicted by Moriya. The ratio $1/T_1TK^2$ is proportional to the conduction electron density of states $n(E_F)$ at Fermi surface, indicating $n(E_F)_{SmCoPO} \gg n(E_F)_{LaCoPO}$, which reveals the less dominance of magneto-volume effect.

If Knight shift and nuclear relaxation process are governed by conduction electrons, then $1/T_1TK^2$ is constant, but if there is a exchange interaction between the electrons then using Stoner approximation and random phase approximation modified Korringa relation reduces to $S_0/T_1TK^2_{spin} = K(\alpha)$, $S_0 = 4\pi k_B\,(\gamma_e/\gamma_n)^2$. $K(\alpha) < 1$ means the spin-fluctuations are enhanced around q=0, leading to that the predominance of ferromagnetic correlations and $K(\alpha) > 1$ signfies that spin -fluctuations are enhanced away from q=0. Estimated $K(\alpha)_{ab} < 1$, but $K(\alpha)_c > 1$, which indicates that in SmCoPO in plane spin-correlations are FM and out of plane spin correlations are AFM type. According to the theory of weak itinerant ferromagnet if 3D (2D) spin-fluctuations are dominant then $1/T_1T \propto \chi^{1(3/2)}$. Inset offgure 3. depicts

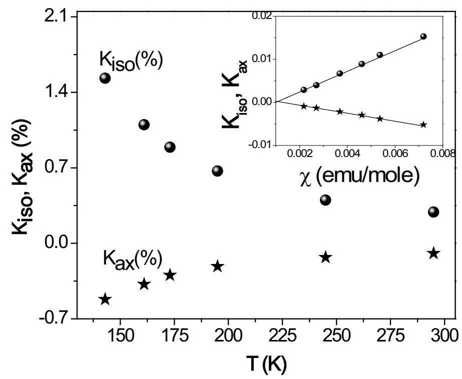

FIGURE 1. Variation of K_{iso}, K_{ax} (%) vs T, and inset: K_{iso} and K_{ax} vs susceptibility(χ) plot, fitted with straight line.

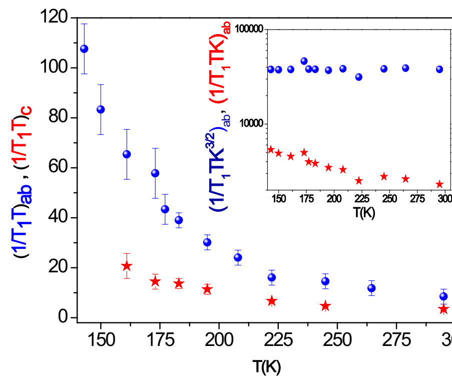

FIGURE 2. $(1/T_1T)_{ab}$ (circle) and $(1/T_1T)_c$ (star) vs T for SmCoPO; inset: $(1/T_1TK)_{ab}$ and $(1/T_1TK^{3/2})_{ab}$ vs T.

plot of $(1/T_1TK)_{ab}$ and $(1/T_1TK^{3/2})_{ab}$ against T showing dominant 2D FM spin-fluctuations in the ab plane.

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