ANOMALOUS CONDUCTION WITH THE PHASE TRANSITIONS IN $SbCl_5$ GICs

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INTRODUCTION

The in-plane structure of the intercalant layers in $SbCl_5$ GICs is composed of two segregated molecular species, $SbCl_3$ and $SbCl_6^-$ islands. The majority species $SbCl_6^-$ form a close packed $\sqrt{7} \times \sqrt{7}$ structure. On the other hand a nearly commensurate $\sqrt{39} \times \sqrt{39}$ structure is established below T_0=230K in the $SbCl_3$ islands with 100 - 200 Å in size for stage n≥3. This unusual structure originates from the dimer formation of $SbCl_3$ pair with antiparallel dipole moments [1].

The c-axis resistivity ρ_c of stage -3 to 9 exhibits an anomalous thermal hysteresis between 180 and 250K as shown in Figs.1 and 2 [2,3]. In the following it will be shown that this anomaly can be explained in terms of the same model given by [1].

THEORETICAL CONSIDERATION ON THE C-AXIS CONDUCTION

We assume that ρ_c for stage n≥3 is given by the following series resistance model:

$$\rho_c \cong \{d_I \rho_c(GIG) + d_G(n-1)\rho_c(GG)\}/I_c,$$
$$\rho_c(GG) = \sum_{i=1}^{n-1} \rho_{GG}(i, i+1)/(n-1), \qquad (1)$$

where n is the stage number, $I_c = d_I + (n-1)d_G$ the repeat distance, $\rho_c(GIG)$ is the partial resistivity related to graphite-intercalant-graphite sandwich layer and $\rho_{GG}(i, i+1)$ corresponds to the resistivity associated with $i \leftrightarrow i+1$ transition without intervening intercalant layers. $\rho_{GG}(i, i+1)$ related to the inter-interior layer transition makes a bottleneck in the conduction process along the c-axis, and plays an important role in the longitudinal magnetoresistance $\Delta\rho_c/\rho_0$ and in the stage dependence of ρ_c vs T curve [4].

Carriers in the π-band spend most of the time in diffusive motion along the basal plane and occasionally make transition to adjacent layers. Let consider the behavior of stage-4 as a typical example in the intermediate stage compounds (see Figs.2 and 3). A distinct minimum of ρ_c around 200K in the heating process is ascribed to the inter-interior layer transition term in Eq. (1). Namely, $\rho_{GG}(i, i+1)^{-1} = \sigma_{GG}(i, i+1)$ increases with T for $T<T_{min}$ because the long-range dipolar field fluctuation enhances the transition $i \leftrightarrow i+1$ along the c-axis. The anomaly remains finite above T_0 since the molecular rearrangement associated with the order-disorder transition is not accomplished for a finite value of the temperature variation $\Delta T/\Delta t$. Consequently, the depth of the minimum of ρ_c vs T curve becomes large $\Delta T/\Delta t \to 0$ [3]. The behaviors of ρ_c in the process of decreasing T is also explained similarly.

Magnetic field along the c-axis affects the diffusion motion of carriers in the basal plane. This is the reason why a finite longitudinal magnetoresistance $\Delta\rho_c/\rho_0$ (positive or negative) is observed. $\Delta\rho_c/\rho_0$ for stage-4 is positive from helium temperature to room temperature for H>1kOe in contrast with the case in $MoCl_5$ GICs [2]. Figure 3 shows a clear minimum of $\Delta\rho_c/\rho_0$ vs T curves around T=200K for H>5kOe. This anomaly comes from the scattering enhancement of carriers in the basal plane since the critical fluctuation of the long-range correlated dipolar field strongly scatters carriers.

Figure 4 illustrates the basal plane resistivity ρ_a versus T curve of stage-4 compound. It should be noted that ρ_a does not show any minimum around 200K in contrast with the case in ρ_c. Most important contribution to ρ_a comes from the bounding layer since $\rho_a^{-1} = \sigma_a = \sum_{i=1}^{n} \sigma_a^{(i)}$, where i denotes the layer index. This situation explains the increase of ρ_a above 200K, where the critical scattering due to the long-range dipolar fluctuation enhances the scattering process in the basal plane.

REFERENCES

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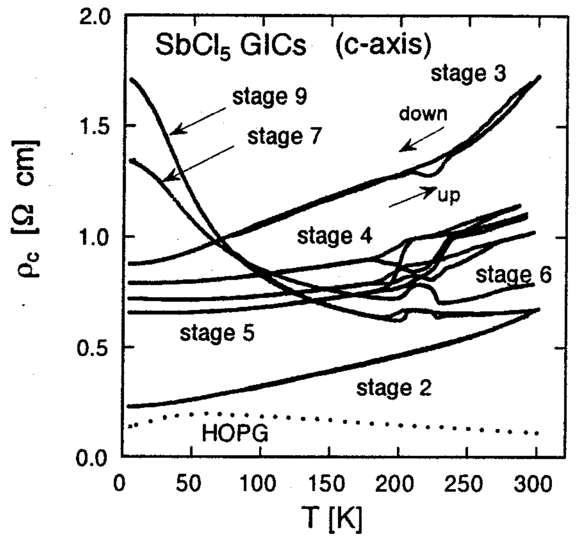

Figure1 c-axis resistivity ρ_c versus T curve for various stage of $SbCl_5$ GICs and HOPG.

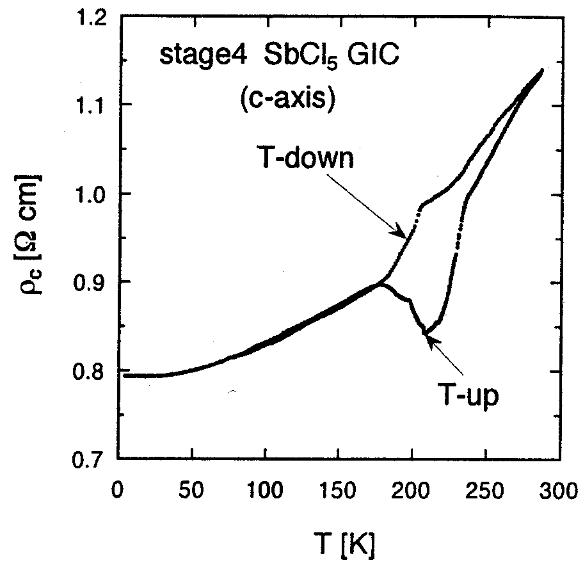

Figure 2 c-axis resistivity ρ_c versus T curve for stage4 $SbCl_5$ GIC.

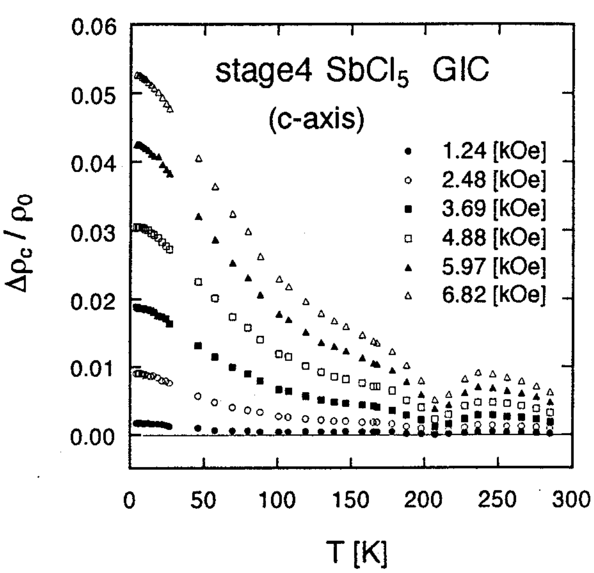

Figure 3 c-axis magnetoresistance versus T curves for stage-4 $SbCl_5$ GIC as a parameter of magnetic field intensity.

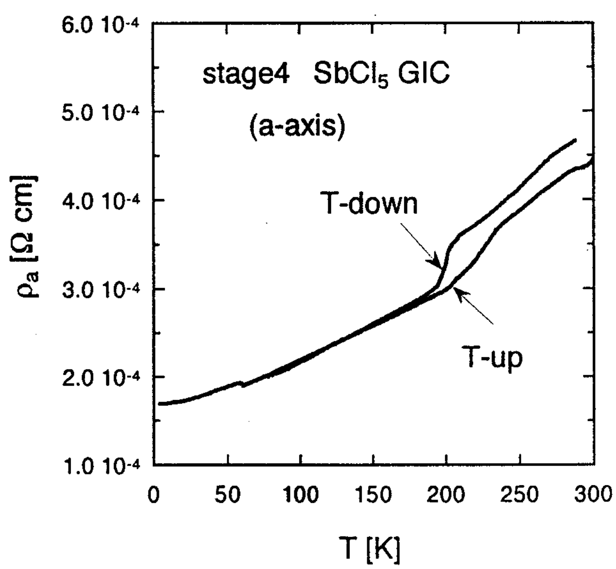

Figure 4 In plane resistivity ρ_a versus T curve for stage-4 $SbCl_5$ GIC.