a- AND c-AXES RESISTIVITY AND MAGNETORESISTANCE OF STAGE2-9 $SbCl_5$ GICs

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INTRODUCTION

It is well known that temperature(T) dependence of electrical resistivity of antimony pentachloride graphite intercalation compounds ($SbCl_5$ GIC) exhibits an anomaly due to the order-disorder phase transition around T=230K [1,2]. This transition is attributed to the growth of the $(\sqrt{39} \times \sqrt{39})$ $R \pm 16.1°$ commensurate structure of $SbCl_3$ molecule, resulting from the intercalation process of $SbCl_5$ in graphite. Although there have been several works concerning the T-dependence of resistivity for $SbCl_5$ GICs, little attention has been paid to the correlation between a- and c-axis conduction and systematic study on their stage dependence. In the present work we report experimental results of the a-axis resistivity (ρ_a), a-axis transverse magnetoresistance($\Delta\rho_a/\rho_0$), c-axis resistivity (ρ_c) and c-axis longitudinal magnetoresistance ($\Delta\rho_c/\rho_0$) of stage2- to 7 and stage9 $SbCl_5$ GICs and give a qualitative explanation for the conduction mechanism in relation to a long-range fluctuation of the dipolar field of $SbCl_3$ molecules.

EXPERIMENTAL

$SbCl_5$ GIC samples were synthesized using a two-zone furnace. The measurements of resistivity were carried out by the usual four probe method, and magnetoresistance was measured in the presence of a magnetic field (H) changing stepwise 0 to 6.8kOe at T between 4.2 and 300K. In order to study the kinetics of ordering in phase transition, ρ_c was measured under the various heating and cooling rate (dT/dt).

RESULTS AND DISCUSSION

Figure 1 shows the T-dependence of ρ_c for $SbCl_5$ GICs and host material HOPG. The features of Fig.1 are summarized as follows; (i) the thermal hysteresis in the T range between 190 and 240K is observed except for stage2, (ii) the value of ρ_c decreases with increasing stage number (n) at room T except for stage2 , (iii) the T-dependence of ρ_c changes continuously from metallic-like to semiconductor-like with increasing n. The feature (ii) and (iii) are almost the same as those of the $MoCl_5$ GICs [3]. We have reported that c-axis conduction of $MoCl_5$ GIC is a hopping process correlated to the a-axis relaxation time τ_a, and this concept also can be applied to $SbCl_5$ GICs. Observed ρ_c is given by the series connection of G-I-G (G: graphite layer, I: intercalated layer) and G-G layer resistivity. The contribution of ρ_c(GIG) becomes dominant with increasing n, leading to the change of T-dependence from metallic-like to semiconductor-like.

Figure 2 shows the T-dependence of ρ_a for stage 2- to 6 samples. The derivative $d\rho_a/dT$ is almost independent of n in contrast with $d\rho_c/dT$ except for stage 6, indicating the T-dependence of τ_a for stage 2- to 5 $SbCl_5$ GICs is nearly the same.

Figure 3 shows ρ_a vs T plots around the transition temperature, ρ_c vs T is shown in the inset. In the heating process ρ_c has a local minimum at 209K, on the contrary ρ_a monotonically increases with increasing T. The decrease of ρ_c between 180K and 209K is a result of the increase of scattering to the c-direction caused by the long-range fluctuation of the dipole moment of $SbCl_3$ molecules. In the case of ρ_a this effect does not contribute to the conduction mechanism.

Rolla et al. reported that linewidth of ESR spectrum for stage4 $SbCl_5$ GIC depends on cooling rate [4]. We also measured ρ_c of stage5 $SbCl_5$ GIC under various heating and cooling rate (Fig.4). As dT/dt decreases, the difference between ρ_c(T-down) and ρ_c(T-up) becomes large. This trend is remarkable for the intermediate stage.

Figures 5 and 6 show the field dependence of $\Delta\rho_c/\rho_0$ and $\Delta\rho_a/\rho_0$ at T=4.2K. Absolute values of $\Delta\rho_c/\rho_0$ and $\Delta\rho_a/\rho_0$ are nearly the same. However for intermediate stage, $\Delta\rho_a/\rho_0$ increases with increasing H, while $\Delta\rho_c/\rho_0$ is nearly zero at H<1kOe. This implies the existence of small negative magnetoresistance component due to two dimensional (2D) weak localization effect. In the intermediate stage, the density of stages of the interior G layer is small as compared to that of the bounding G layer, then the condition of 2D localization is satisfied. Therefore resistivity corresponding to the inter-interior layer transition makes a bottleneck in the conduction process. Since $\Delta\rho_c/\rho_0$ is expressed by the series resistance of contributions of each G layer, the component of negative magnetoresistance is larger than that of $\Delta\rho_a/\rho_0$ given by parallel connection.

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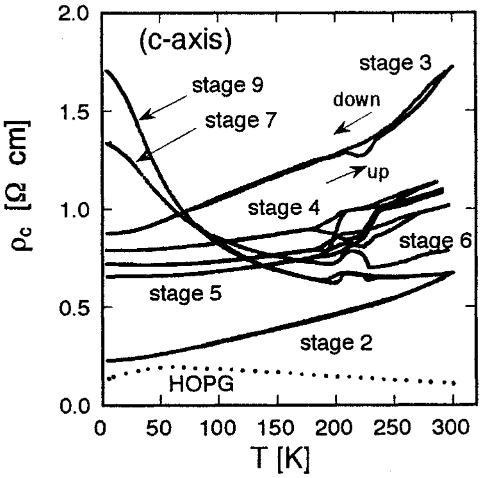

Figure1 Temperature dependence of c-axis resistivity (ρ_c) of $SbCl_5$ GIC's and HOPG.

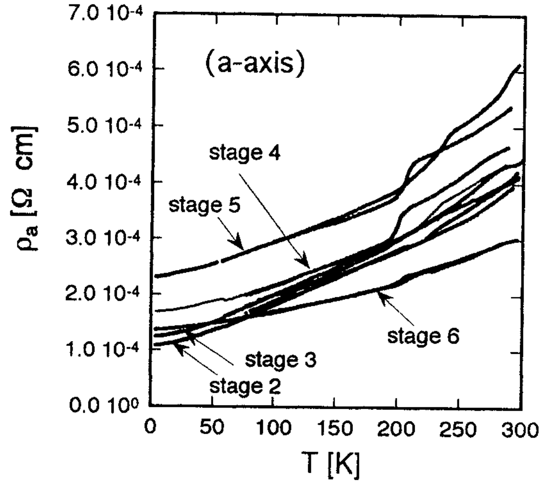

Figure 2 Temperature dependence of a-axis resistivity (ρ_a) of $SbCl_5$ GIC's.

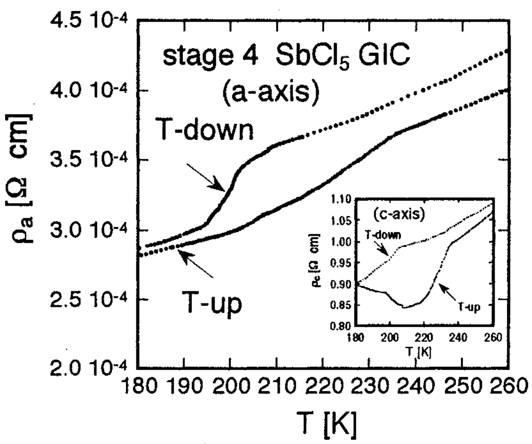

Figure 3 ρ_a vs T for stage 4 $SbCl_5$ GIC measured during the cooling and heating processes. In the inset ρ_c vs T is also shown.

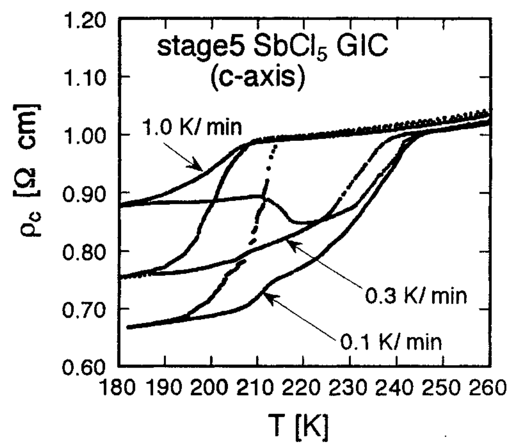

Figure 4 ρ_c vs T for stage 5 $SbCl_5$ GIC under various temperature change rates.

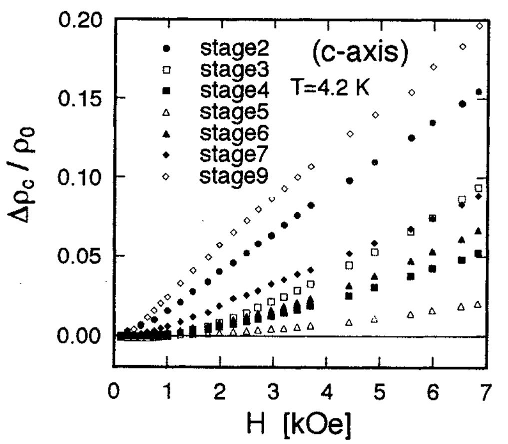

Figure 5 Field dependence of c-axis longitudinal magnetoresistance ($\Delta\rho_c / \rho_0$) of $SbCl_5$ GIC's

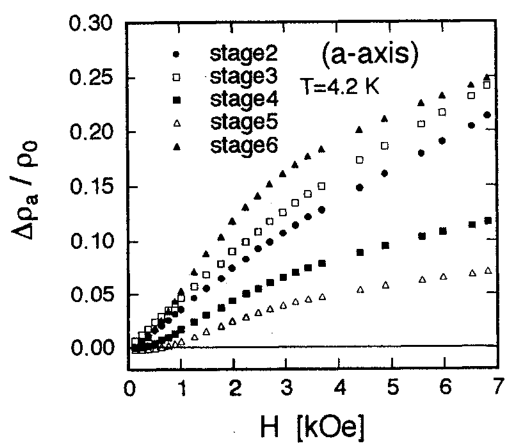

Figure 6 Field dependence of a-axis transverse magnetoresistance ($\Delta\rho_a / \rho_0$) of $SbCl_5$ GIC's.