Electron Transport in GIC's with ICl

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In succession to the preliminary work[1] presented in CARBONE 84 held in Bordeaux, a number of experiments have been done repeatedly and are still being conducted to obtain stable and reproducible results on electronic properties of low-stage GIC's with ICl. In view of the facts that the ICl compounds of graphite are generally fragile for cooling and heating cycle even at relatively low temperatures and exhibit a phase transition not much above room temperature, cares were taken of procedures of the sample preparation and handling.

Fig. 1 shows a reliable set of the in-plane resistivity vs. temperature plots for stage-1 and stage-2 compounds both prepared by the two-bulb method from HOPG. Nature of the stage-1 compound is just the same as previously reported in Bordeaux[1]. The stage-2 sample indicates much lower resistivity values all over the temperature range examined; the residual resistance seems to come down far below 10^{-6} ohm-cm, though the whole data can be reproduced by an empirical formula as those for the stage-1. No discontinuity is found of the latter at 260 K, implying that ICl layers in the stage-2 structure are more stable and have higher transition temperature than those in the stage-1[2].

Fig. 2 reveals that the Hall coefficient of the stage-2 compound is about 3/2 times that of the stage-1 in the magnitude, but quite alike in showing a weak dependence on the magnetic field intensity. The temperature dependence has been separately confirmed to be almost neglegible for the both. Therefore, one can look upon them as simple hole metals in a rough approximation, though the stage-2 is expected to have four bands[3]. The density of carriers (positive holes) thereby estimated is 8×10^{20} cm^{-3} for the stage-1 and 5.5×10^{20} cm^{-3} for the stage-2. On these bases, the Hall mobility of carriers has been calculated as in Fig. 3. The stage-2 sample has much higher values than those of the stage-1 reported before[1], amounting up to about 4,000 at 260 K, 16,000 at 40 K and possibly more than 20,000 at 4.2 K in laboratory unit.

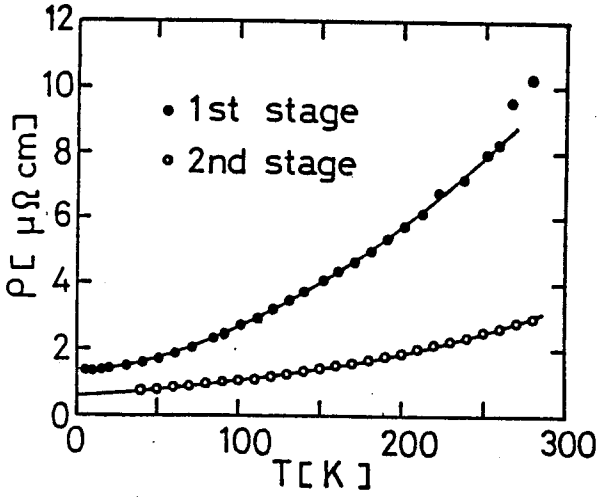

Fig. 1. In-plane resistivity vs. temperature

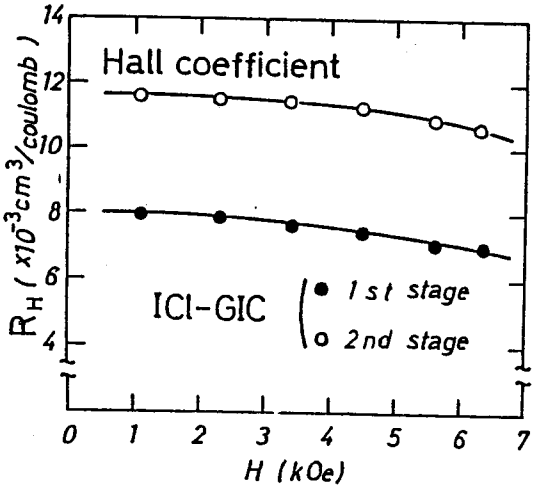

Fig. 2. Hall coefficient vs. magnetic field intensity

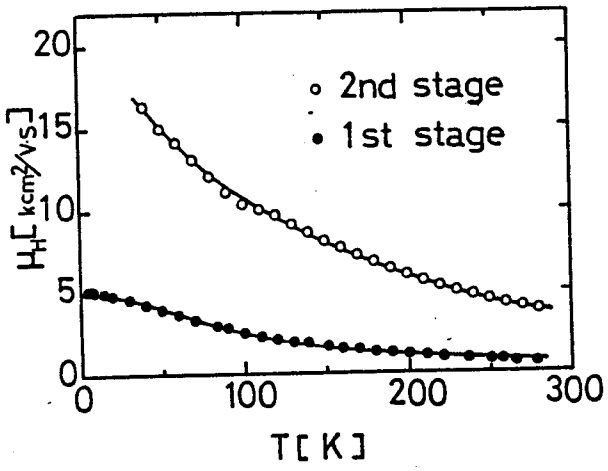

Fig. 3. Hall mobility vs. temperature

Hereupon, it may be noted that among the data for all stage-2 specimens so far examined, the resistivity shown in Fig. 1 is the lowest one but the Hall coefficient is common with the others'; viz., there is no difference in the carrier (positive hole) density, and hence also in the chemical composition. Therefore, the high mobility values of the stage-2 sample seem to reflect that the careful handling stabilizes the ordered alignment of intercalated ICl molecules so as to reduce the defect scattering of carriers in this specimen. The reason why the carrier density is not much affected by such a difference in the structural order can be connected undoubtedly with the low ionization efficiency (hole production rate) not exceeding 12%[1].

Finally, Fig. 4 reproduces the c-axis resistivity also as a function of temperature. The abrupt rise-up around 300 K is due to the order-disorder transition presented elsewhere[2]; the transition point of the stage-2 compound is actually found to be a little higher than that of the stage-1, but there is observed no discontinuity at 260 K even for the stage-1. As compared with the previous results[1], the thermal hysteresis is eliminated this time, and further the resistivity becomes more than one order less and shows steep temperature dependence for the both compounds. Careful handling seems to prevent the formation

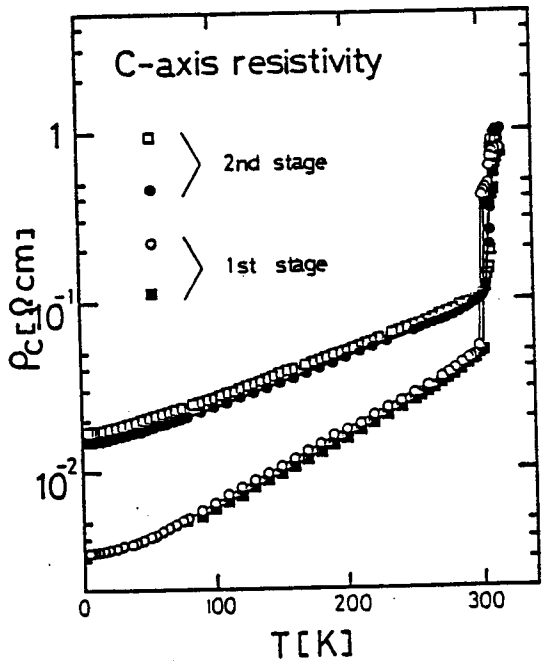

Fig. 4. C-axis resistivity vs. temperature

of microcracks which may disturb the interlayer transport of carriers.

In consequence, the resistance anisotropy ratio is so high as $2\sim3 \times 10^4$ for the stage-2 between room and liquid helium temperatures, whereas it ranges $2\sim3 \times 10^3$ for the stage-1. This is qualitatively consistent with the impurity-assisted hopping mechanism proposed by Sugihara[4].

References

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