MAGNETIC FIELD DEPENDENCE OF GALVANOMAGNETIC EFFECT OF VERY THIN GRAPHITE CRYSTALS

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Introduction

In the previous work, we have measured the temperature dependence of electrical resistivity of thin graphite crystals from liquid helium temperature to room temperature [1]. The film thicknesses were ranging from around 29 to 111nm. The experimental results could be expressed by a simple two band model and the Sugihara's theory for lattice vibration in thin-carbon films, and the overlap energy E_0 of conduction and valence bands for the thin graphite films were estimated. Consquently, it was found that as the film thickness decreased, the values of the band overlap energy E_0 decreased gradually and seemed to have a small value at the thickness thinner than about 50nm.

In this study, we focused our attention on the graphite films thinner than 50nm, and measured the magnetic field dependences of the Hall coefficient R_H and the transverse magnetoresistance $\Delta\rho/\rho_0$ at the temperatures between 1.8 and 100 K to obtain the more detailed characteristics.

Experimental

All the specimens of graphite films in this study, were made of the same bulk crystal of kish graphite KG as that used in the previous work, and the method of the sample preparation was also the same as that described in the previous work [1]. For the measurements of R_H and $\Delta\rho/\rho_0$, van der Pauw's method was used. Because this method is available to measure R_H and $\Delta\rho/\rho_0$ of a flat sample of arbitrary shape. We prepared four specimens of the graphite films, the thicknesses of which were 18, 23, 35 and 45 nm, respectively. The magnetic field was applied perpendicular to the film surface up to 5T at the temperatures of 1.8, 4.2, 10, 50 and 100K, respectively.

Results and Discussion

Typical examples of our results of R_H and $\Delta\rho/\rho_0$ versus magnetic field characteristics of graphite films at liquid helium temperature are shown in Fig.1 and Fig.2 corresponding to the film thickness of 18, 23, 35 and 45nm, respectively. Shubnikov de-Haas oscillation are observed in R_H and $\Delta\rho/\rho_0$ for all of these specimens especially more clearly in R_H. This observation means that these graphite films should have high quality of the crystallinity.

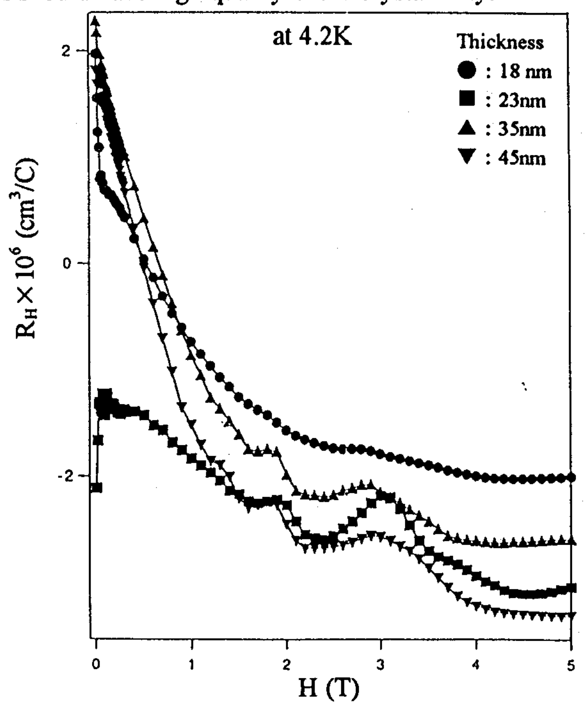

Figure1. Hall coefficient R_H as a function of magmetic field H for various KG film thicknesses at 4.2K.

In order to estimate the field dependence of the exponent n in the common relationship $\Delta\rho/\rho_0 \propto H^n$ at various temperatures, log($\Delta\rho/\rho_0$) against log H plots were made. For instance, Figs.3(a) and (b) show them, corresponding to the specimens with thickness 18 and 45nm. The slope of each curve corresponds to the exponent n. Our results for each specimen, showed different n values above and below critical field H of about 1T.

Temperature dependence of n in each specimen was plotted in Fig.4. As shown in this figure, the magnitude of n is much smaller than unity at high fields and did not depend on temperature for whole specimens in this experiment.

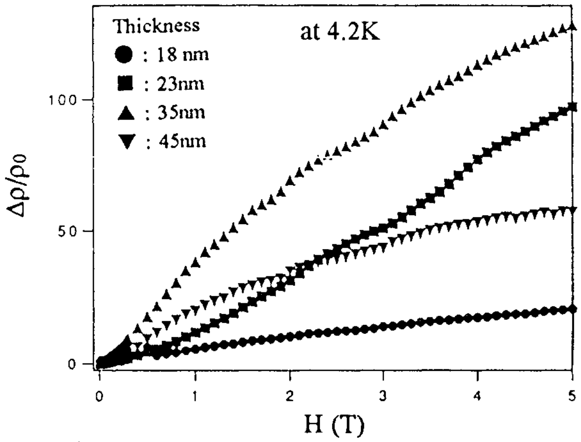

Figure 2. Transverse magnetoresistance $\Delta\rho/\rho_0$ as a function of magnetic field H for various KG film thicknesses at 4.2K.

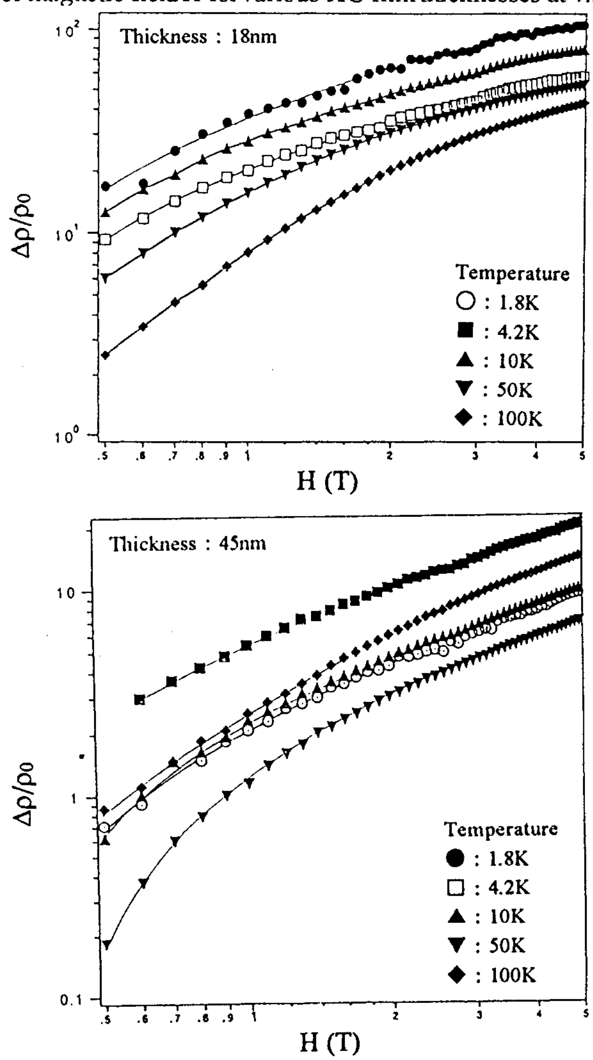

Figure 3. Transverse magnetoresistance $\Delta\rho/\rho_0$ as a function of magnetic field H for two KG films at various temperatures. (a): KG thickness is 18nm. (b): KG thickness is 45nm.

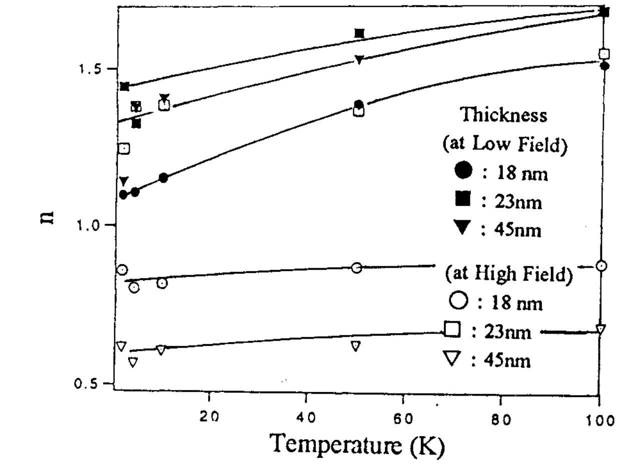

Figure 4. Temperature and magnetic field dependences of n value for various film thickness.

On the other hand, the magnitude of n increases as the temperature increases at low fields. R_H of each specimen shows the positive value at low magnetic fields, while R_H changes from positive to negative at high fields as shown in Fig.1. That is similar to those of bulk graphite crystals with large rrr value. On the contrary, the fact that the exponent n in $\Delta\rho/\rho_0 \propto H^n$ is smaller than 1.0 at high fields, should be a feature of graphite crystals with small rrr values [2]. Consequently, all the present experimental results seems to be peculiar to thin graphite films, and not to bulk crystals of graphite.

Conclusion

Magnetic field dependences of the Hall coefficient R_H and the transverse magnetoresistance $\Delta\rho/\rho_0$ were measured for the graphite films with the thickness, 18, 23, 35 and 45nm at 1.8, 4.2, 10, 50, and 100 K. Whole experimental results for the present specimens suggest that there should be any evaluation criteria other than rrr for thin graphite films.

References

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2. Y. Kaburagi and Y. Hishiyama, Carbon, 33, (1995) 1505-1506.

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