SHUBNIKOV - DE HAAS EFFECT OF VERY THIN GRAPHITE CRYSTALS

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1.Introduction

Recently, the magnetic field dependence of the transverse magnetoresistance $\Delta\rho/\rho_0$ and the Hall coefficient R_H was measured for the graphite films of various thickness ranging from around 20 to 110 nm at temperatures between 4.2K and 300K. High quality of the crystallinity of these graphite films prepared by cleaving could be confirmed from the observation of Shubnikov-de Haas oscillation in R_H. The saturation tendency revealed in the resistivity ρ versus magnetic field B characteristics for graphite films thinner than about 50 nm in the strong magnetic field region at low temperature, while as for all graphite films in this study, ρ varied in proportion to B^n (n >1) in the strong magnetic field region at high temperature. According to the simple two-carrier system of conductors in the strong magnetic field region, this saturation tendency should be due to the difference between electron and hole densities. It may be caused by some change of energy band structure in thin films[1].

In this study we measured the magnetic field dependence of the Hall coefficient R_H for the graphite films of various thickness ranging from around 20 to 100 nm at 1.8K to obtain the more detailed feature of Shubnikov - de Haas oscillation .

2. Experimental

All of the specimens of graphite films measured in this study were made of the same bulk crystal of kish graphite as that used in the previous works[1, 2] , the residual resistivity ratio (rrr) value of which was 32.3. The methods of the sample preparation by cleaving and of measurement were also the same as those described in the previous work[2], respectively. The magnetic field was applied perpendicular to the film surface at the low temperature of 1.8K.

3. Results and discussion

The magnetic field dependence of the Hall coefficient R_H of graphite films at 1.8K is shown in Fig.1(a) and (b). Shubnikov - de Haas oscillation was observed for all of these specimens of various film thickness. It was found that the period of Shubnikov - de Haas oscillation in the R_H versus magnetic field B characteristic depends on the film thickness. Each period of maximums and minimums of the oscillation should be caused by electrons and holes, respectively. It means that the largest cross section of

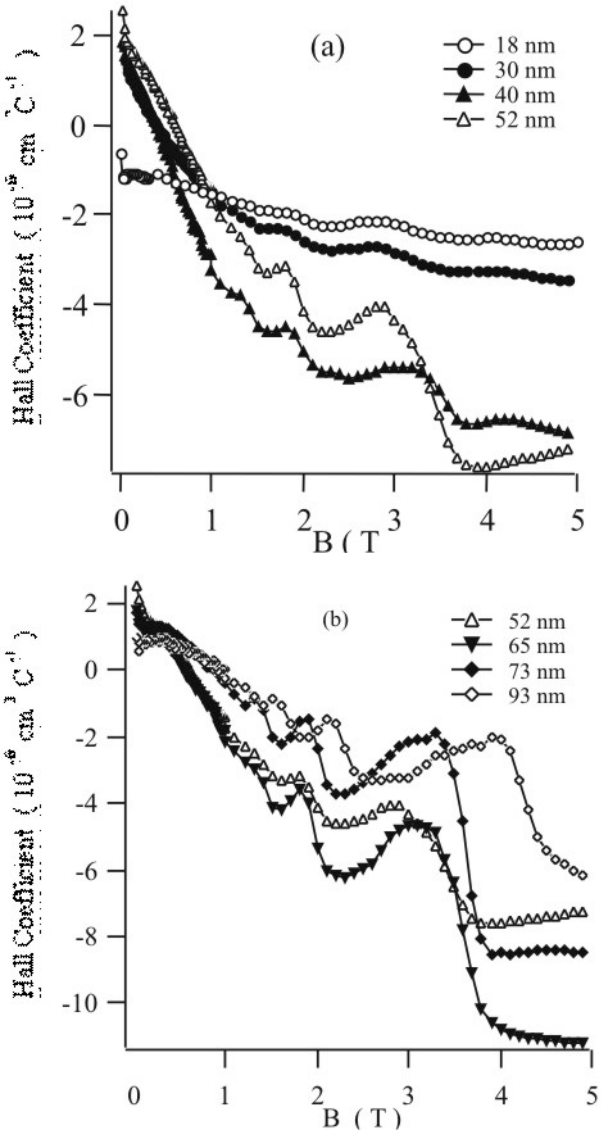


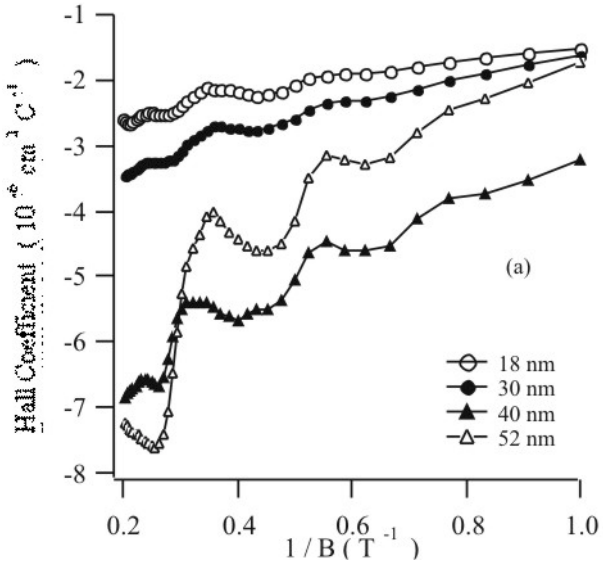
Fig.1. Magnetic field dependence of Hall coefficient R_H

at 1.8K for graphite films with various thickness, (a) thinner than around 50 nm, (b) thicker than around 50 nm.

Fermi surface should depend on the film thickness. Because, the cross section of Fermi surface can be expressed as a function of the period of Shubnikov - de Haas oscillation as follows:

$$\frac{1}{B_i} - \frac{1}{B_{i+1}} = \frac{4\pi^2 e}{h A(\varepsilon)}, \qquad (1)$$

where B_i and B_{i+1} (i: integer) indicate magnetic fields corresponding to the fields where R_H reveals the adjacent maximum values for electrons and minimum values for holes, respectively, e is electron or hole charge, h is Plank's constant, and $A(\varepsilon)$ is the maximum value of the cross section at the Fermi surface. In order to estimate $A(\varepsilon)$ in equation (1) for each specimens, Hall coefficient R_H as a function of the reciprocal of the magnetic field B was plotted in Fig.2(a) and (b).



Consequently, it was found that $A(\varepsilon)$ varies with the film thickness of graphite films as shown in Fig.3.

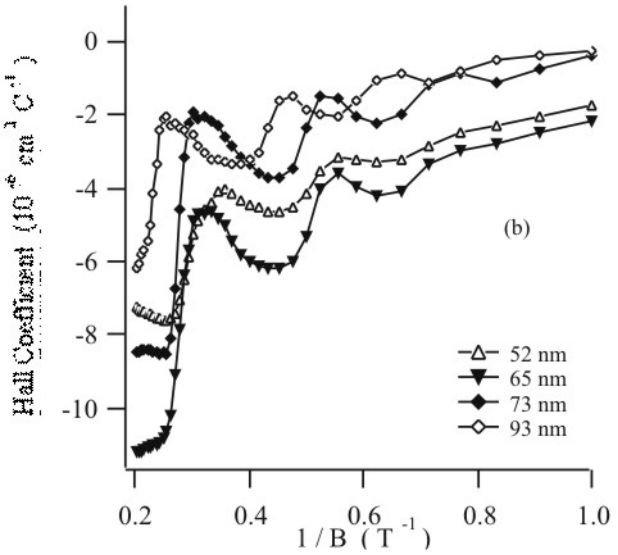


Fig.2. Hall coefficient R_H of graphite films of various thickness as a function of the reciprocal of the magnetic field B at 1.8K, (a) films thinner than about 50 nm, (b) films thicker than about 50 nm.

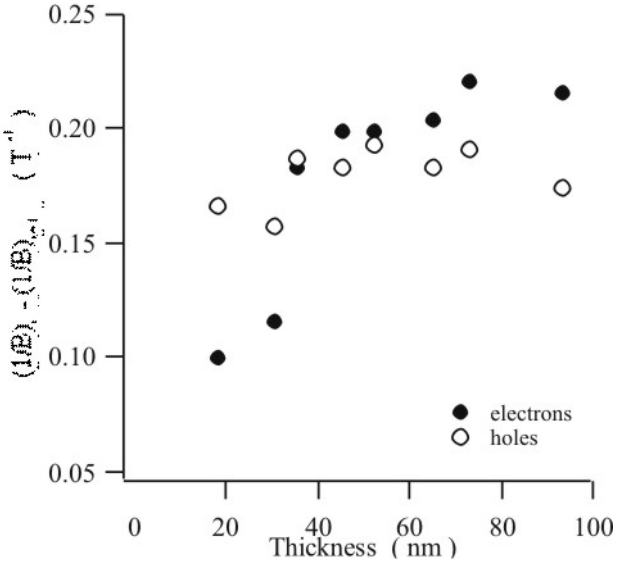


Fig.3. Film thickness dependence of the period of Shubnikov - de Haas oscillation.

According to eq. (1), $A(\varepsilon)$ of thin films thinner than about 40 nm should be larger than that of bulk graphite. It suggests that these results may be due to some change in Fermi surface of thin graphite films, though the origin

of the change in Fermi surface should be investigated hereafter .

4. Summary

R_H versus B characteristics of graphite films of various thickness at temperature of 1.8K. Shubnikov-de Haas oscillation was observed for all of the specimens in this study. The period of Shubnikov-de Haas oscillation depends on the film thickness. The cross-sectional areas of electron- and hole- Fermi surface of graphite films are larger than that of bulk graphite.

Acknowledgement

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Reference

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2) Y.Ohashi, T.Hironaka, T.Kubo and K.Shiiki, *TANSO*, 2000 [No.195] 410-413.