Negative Magnetoresistance and Thermoelectric Power of Pyrocarbon

Keiko Matsubara, Yuuich Sakurai, Kiyoshi Kawamura and Takuro Tsuzuku
Colllege of Science and technology, Nihon University
1-8 Kanda-Surugadai Chiyoda-ku Tokyo 101, Japan
Ko Sugihara
College of Pharmacy, Nihon University 7-7-1
Narashinodai Funabashi-shi Chiba 204, Japan

Introduction

In-plane(a-axis) transport phenomena in pyrocarbons which contain lots stacking disorder have been measured by many authors, and were mostly analyzed on the basis of band model. In the last decades, the weak localization theory has newly been developed to explain electronic processes in defective solids, successfully reproducing their negative magnetoresistance as a function of magnetic field intensity at low temperatures.

In the present study, we have investigated the a-axis resistivity, transverse and longitudinal magnetoresistance in the presence of a magnetic field perpendicular to the deposit plane, and thermoelectricity of various pyrocarbons between room and liquid helium temperatures. Qualitative discussion is given in connection with the weak localizaition theory.

Experimental

Pyrocarbon specimens examined were deposited at 2100°C from methane, and heat treated stepwise at temperatures 2300, 2400, 2600 and 2800°C for 30 minutes, respectively. The resistivity and magnetoresistance measurements were conducted by means of the four probe method, and the thermoelectric power by using two Au+0.07%Fe vs. normal Ag themocouples.

Result and Discussion

Figure 1 shows temperature(T) dependence of the a-axis resistivity(ρ_a). Gradients of the plots for PG2100, 2400 and 2600 are wholly negative; ρ_a still goes up leftward even at 4.2 K where the carrier system is undoubtedly degenerated. This comes from the weak localization in such disordered carbon solids, owing to the elastic scattering of carriers by defects dominant at low T. In Fig. 2 is shown T dependence of the transverse magnetoresistance($\frac{\Delta\rho_a}{\rho_{a0}}$) at field intensity of H=6.8 kG. The negative magnetoresistance observed except for PG-2600 tends to increase its magnitude with lowering heat treatment temperature. The peak around 50 K for PG2600 seems to be a result of competition between positive and negative components. Figure 3 shows T dependence of the longitudinal magnetoresistancec $\frac{\Delta\rho_z}{\rho_{z0}}$ in the direction vertical to the deposit plane behaves in a manner considerably different from in Fig.2; e.g., $\frac{\Delta\rho_a}{\rho_{a0}}$ changes its sign from negative to positive at 100 K. For instance, $\frac{\Delta\rho_{z0}}{\rho_{z0}}$ of PG2100 exhibits negative magnetoresistance all over the T range exmined, while $\frac{\Delta\rho_{a0}}{\rho_{z0}}$ changes its sign from negative to positive at 100 K. If all the basal planes are aligned in complete parallel, the current flow in the c-direction is not affected by the magnetic field parallel to it, and no magnetoresistance is produced. However, since pyrocarbons have the so-called mosaic spread, $\frac{\Delta\rho_{z0}}{\rho_{z0}}$ is inevitably correlated to the in-plane current passing through the misaligned crystallites, and to the transverse $\frac{\Delta\rho_a}{\rho_{a0}}$ accordingly.

In order to explain the difference between the T-dependnce of $\frac{\Delta\rho_a}{\rho_{a0}}$ and $\frac{\Delta\rho_z}{\rho_{z0}}$, we introduce the effective magnetic field defined as $\mathbf{H}_{eff} = \mathbf{H}\cos\theta$, where θ denotes the angle between the external field and the c-aixs of each crystallite. On this basis, a qualitative expression of $\frac{\Delta\rho_z}{\rho_{z0}}$ is given as a sum of the positive term $\propto (H\cos\theta)^2$ and the negative term nearly $\propto \ln(H\cos\theta)$.

The in-plane current responsible for the finite $\frac{\Delta\rho_z}{\rho_{z0}}$ flows more dominantly in crystallites with larger θ, where $\mathbf{H}_{eff}$ is rather smaller however. Thence, the positive term $(H\cos\theta)^2$ becomes less than the negative term $\ln(H\cos\theta)$ in such a situation, making $\frac{\Delta\rho_c}{\rho_{c0}} < 0$ at temperatures higher than those at which $\frac{\Delta\rho_a}{\rho_a} < 0$.

Figure 4 represents the temperature dependence of the thermoelectric power. The phonon drag dip

around 35 K characteristic of the graphite band is observed for PG2800, 2600 and 2400. The weak localization effect is not clearly indicated in the plots other than the steep change in the low T range.

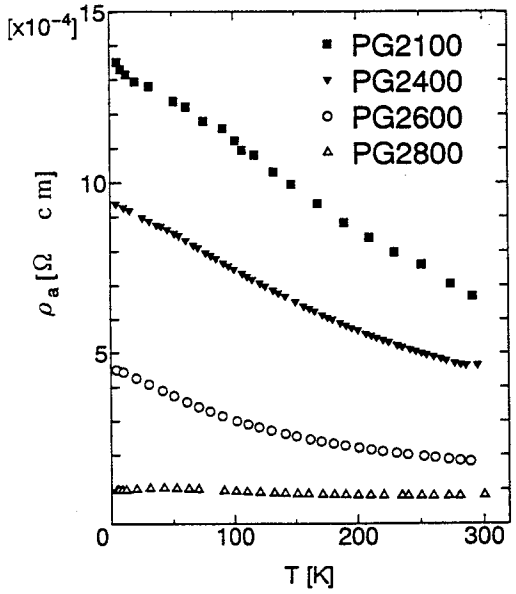

Fig.1 Temperature dependence of in-plane resistivity of pyrocarbons.

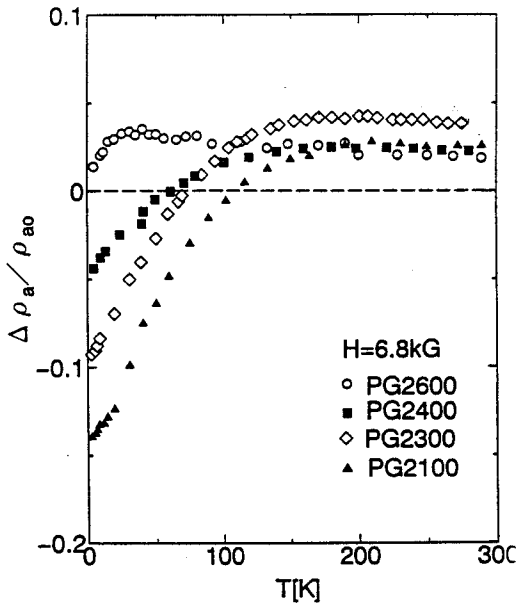

Fig.2 Temperature dependence of the transverse magnetoresistance $\Delta\rho_a/\rho_{a0}$ at field intensity of H=6.8 kG.

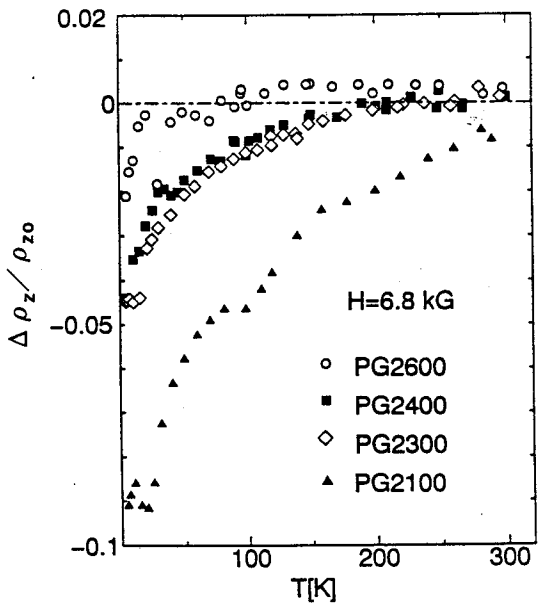

Fig.3 Temperature dependence of the longitudinal magnetoresistance $\Delta\rho_z/\rho_{z0}$ at H =6.8 kG.

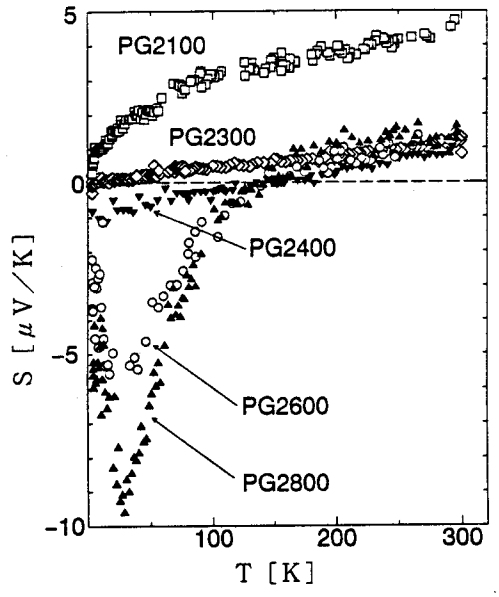

Fig.4 Plot of the thermoelectric power vs temperature.