NEGATIVE MAGNETORESITANCE ALONG THE c- AND a-AXES OF PYROCARBON -Theory-

Ko Sugihara
College of Pharmacy, Nihon University 7-7-1
Narashinodai Funabashi-shi Chiba 204, Japan

INTRODUCTION

Pyrocarbon exhibits a negative magnetoresistance along the a-axis[1]. With increasing the magnetic field intensity and temperatures $\Delta\rho_a/\rho_a$ changes its sign and becomes positive. Weak localization theory[2] has been successfully applied to explain the observed feature of the negative magnetoresistance in disordered carbons[3,4]. The similar negative magnetoresistance was observed along the c-axis in some pyrocarbons[3,4]. Figure 1 and 2 represent our measurement for $\Delta\rho_a/\rho_a$ and $\Delta\rho_z/\rho_z$ of PG2100 sample, where z is parallel to the applied magnetic field.

It is worthy of note that (i) the sign change of $\Delta\rho_a/\rho_a$ takes place at nearly same temperature irrespective of the field intensity and (ii) $\Delta\rho_z/\rho_z$ remains to be negative over 4.2 K $\sim$ 300 K. We focus our attention to explain these features in consideration of the turbostratic structure of pyrocarbon.

a-AXIS MAGNETORESISTANCE

In the presence of a magnetic field the weak localization theory provides an expression for the two-dimensional magnetoresistance as follows[2]:

$$\frac{\Delta\rho_a}{\rho_a} \cong (\omega_c\tau)^2 + \frac{1}{\bar{c}\sigma_B(0,T)}\left[\frac{e^2}{2\pi^2\hbar}F(z)\right], \qquad (1)$$

where

$$\left.\begin{array}{ll} F(Z) & = \log Z - \psi(\frac{1}{2}+Z) \\ Z & = (\frac{L_H}{L_{in}})^2 \propto \frac{T}{H} \\ L_H & = \sqrt{\hbar c/4eH} \\ L_{in} & = \sqrt{D\tau_{in}} \\ \tau_{in} & : \text{inelastic relaxation time} \\ \sigma_B & : \text{conductivity given by Drude formula} \\ \omega_c & : \text{cyclotron frequency.} \end{array}\right\} \qquad (2)$$

D is the 2D-diffusion constant controlled by the relaxation time related to the elastic scattering and $\bar{c}$ is the mean interlayer distance.

The first term in (1) gives rise to the positive magnetoresistance, while the second term is related to the negative magnetoresistance. Figure 3 shows the qualitative feature of $-F(Z)$vsZ^2 curve. In the region of $F(Z) \propto Z^{-2} \propto (H/T)^2$, $\Delta\rho_a/\rho_a$ changes its sign at $T \cong T_0$, where T_0 is insensitive to the field intensity.

Since the masaic spread for pyrocarbon heat treated at $\sim 2000°$C ranges over $30° \sim 40°$, each crystallite feels a different efective field $\mathbf{H}_{eff} = \mathbf{H}\cos\theta$ and then (1) should be read as an aveage over θ.

c-Axis MAGNETORESISTANCE

Figure 2 clearly indicates that the in-plane conduction plays an essential role in the negative magnetoresistance along the z-axis, becaulse σ_a is strongly depdendent on H, while σ_c is H-independent.

In-plane conduction along the graphane planes with large θ makes a dominant contribution to ρ_z, where θ is the angle between $\mathbf{H}(\| z)$ and crystallite plane. On the other hand, the conduction along the crystallites with small θ is important in $\Delta\rho_a/\rho_a$. The expression for $\Delta\rho_z/\rho_z$ takes the similar form:

$$\frac{\Delta\rho_z}{\rho_z} \cong G(\theta_0) \times \text{eq.(1)}, \qquad G(\theta_0) \sim O(1)$$

where $\mathbf{H}_{eff} = \mathbf{H}\cos\theta_0$, ($\theta_0$: mosaic spread). Since eq.(1)$\propto \mathbf{H}^m_{eff}$ ($2 \geq m > 1$), carriers feel rather weak field intensity. This is the reason why $\Delta\rho_z/\rho_z$ remaing to be positive at high temperatures.

REFERECES

1. P.Delhaes, P.de Kepper and M.Uhlrich, Phys Mag. **29**, 1301(1974)
2. P.A.Lee and T.V. Ramakrishnan, Rev. Mod. Phys. **57**,287(1985)
3. V.Bayot, Thesis of Dr. of Applied Science (1991)
4. V.Bayot, J-P.Michenaud, J-P.Issi, M.Lelaurain and I.Rannou, 21th Conf. Carbon (1991), Extended Abstracts p.706

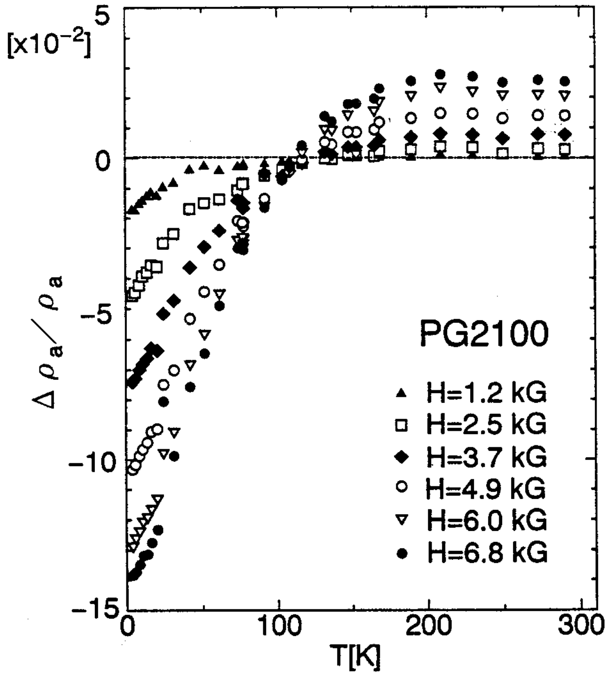

Fig.1 $\Delta\rho_a/\rho a$ versus T curve of pyrocarbon.

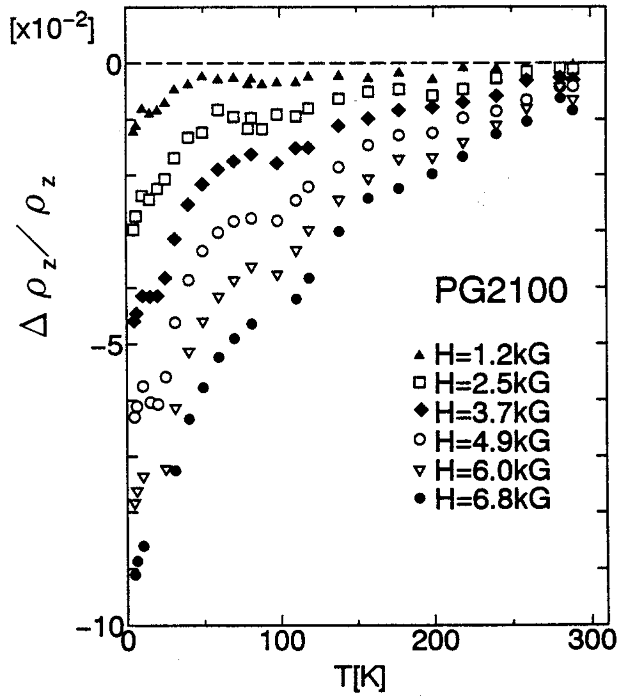

Fig.2 $\Delta\rho_z/\rho_z$ versus T curve of pyrocarbon.

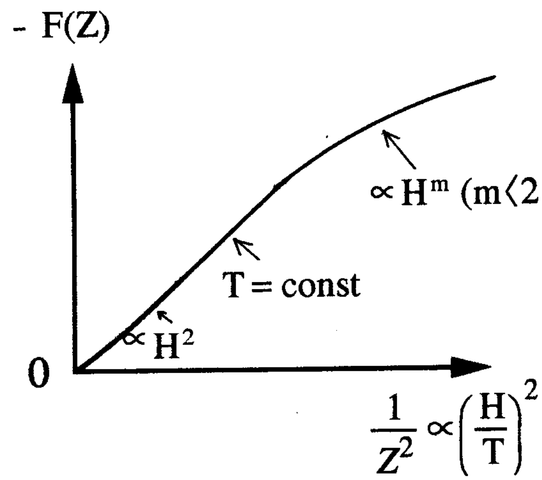

Fig.3 $-F(Z)$ *vs* $1/Z^2$ curve.