Transport Phenomena in PAN-based Carbon Fibers with Different Mechanical Characteristics

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Introduction

Carbon fibers are usually classified in accordance with mechanical properties, especially the tensile strength and elastic modulus. However, electronic properties have been scarcely discussed so far.

In the present study, we have investigated transport properties in relation to the electronic structure of the PAN-based carbon fibers with different mechanical chracteristics.

Specimens and Experiments

Specimens examined are commercial PAN-based fibers manufactured by Toray Co. Ltd. Table 1 shows their mechanical properties and densities. T-type specimens have high strength, and M-type specimens have high modulus. Measurements of the electrical resistivity(ρ) was conducted by using the four-probes method for a single yarn of fiber, whose size was determined with a scanning electron microscope.

Result and Discussion

Figure 1 shows the temperature dependence of ρ. M-type specimens indicate the semiconductor-like temperature dependence all over the temperature range examined, and ρ increases with decreasing elastic modulus. On the contrary, T-type specimens exhibit a peak around 35 K (Fig.2). It should be noted that metallic like temperature dependence is observed in spite of their perfections of crystallite less than M-type fibers. This anomalous dependence can be explained by considering the Rayleigh wave phonon whose sound velocity is so small that a number of phonons are excited even at liquid helium temperature. In such a disordered fiber, the carrier system is wholly degenerated; and hence the negative coefficient above 35 K is not due to the carrier excitation. Then we assume a mixture model of the band conduction and 2D variable range hopping conduction as following.

$$\sigma = A\exp\left\{-\left(\frac{T_0}{T}\right)^{1/3}\right\} + \frac{1}{\rho_0 + BT} \qquad (1)$$

where A and B are constants, T_0 a quantity related to the hopping distance and ρ_0 the residual resistivity. The observed data is satisfactorily reproduced by the curve fitting based on this mixture model.

Figures 3 and 4 show the temperature dependence of the thermoelectric power(S) of M- and T-type specimens. The signs of S of the M-type specimens are positive, and absolute values decrease with decreasing modulus. Holes are scatterd rather strongly by charged defects than electrons, resulting in smaller S of low modulus fibers smaller than S of high modulus. Figure 4 shows similar temperature dependence to Fig.2; it implies that the Raighly wave phonons also affect S.

Table 1 Mechanical properties of specimens.

sample	strength [kg/mm²]	modulus of elasticity [t/mm²]	specific gravity
T800H	564	30.2	1.802
T1000G	646	30.3	1.807
M40J	456	38.6	1.774
M46J	395	44.7	1.844
M50J	429	49.0	1.874
M60J	424	60.2	1.920

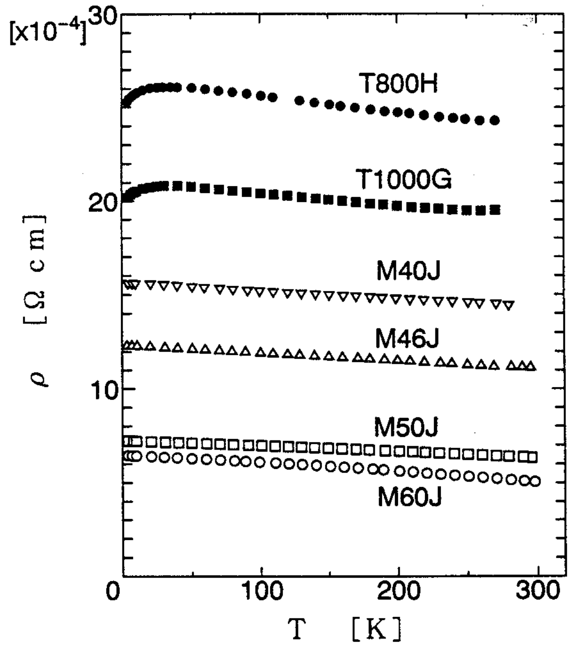

Fig.1 Temperature dependence of ρ of M-type specimens.

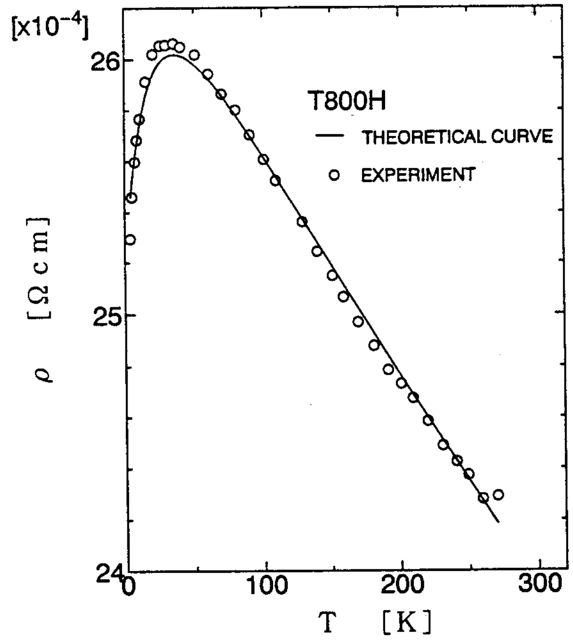

Fig.2 Resistivity vs temperature curve for T800H. Solid line represents the calculation.

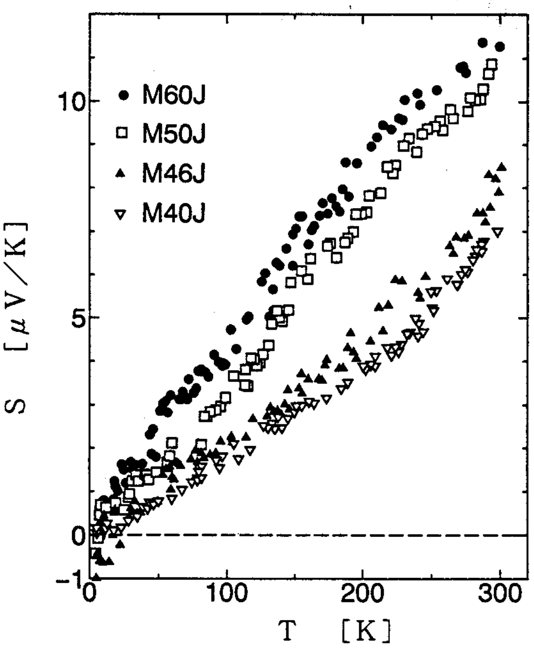

Fig.3 Temperature dependence of the thermoelectric power of M-type specimens.

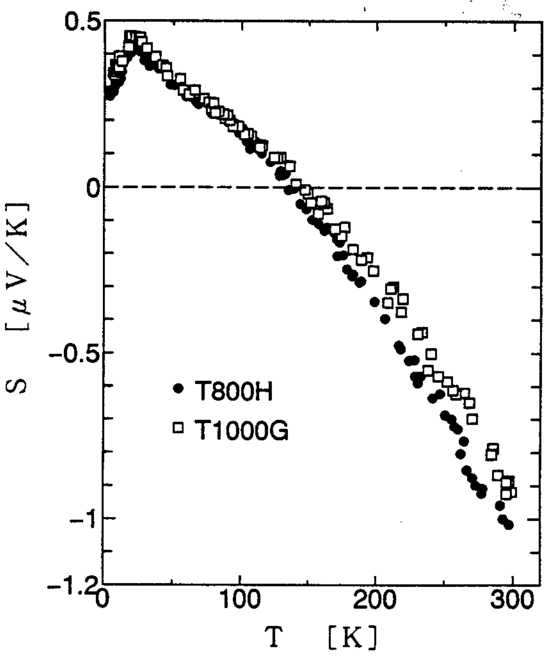

Fig.4 Plot of the thermoelectric power vs temperature for T-type specimens.