MAGNETORESISTANCE OF DISORDERED CARBONS AT LOW TEMPERATURE

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Introduction

Several years ago, the transverse magnetoresistance was measured in soft carbon heat treated between 1000°C and 3200°C for temperatures at 1.7K and 4.2K[1,2]. One unusual behavior for the magnetoresistance was a positive magnetoresistance for disordered samples of low heat-treatments. This was also measured in anthrathene char heat treated between 800°C and 1200°C for temperature at 4.2K [3]. From the analysis of the temperature dependence of the electrical conductivity σ, the positive magnetoresistance was associated with the variable range of hopping conduction between localized states in amorphous material described by Mott[4] for which $\sigma \propto \exp[-(T_0/T)^{1/4}]$, T_0 being a constant. For more complete experimental understanding, a systematic study of the changes in the positive magnetoresistance at low heat-treatments has been undertaken for temperatures between 1.4K and 4.2K in the work presented in this paper.

Experimental

Samples were prepared from a bamboo char and raw petroleum cokes (samples B and C). Heat-treatment of the samples was carried out at temperatures between 900°C and 1500°C for three hours. The magnetoresistance has been measured by dc method up to 60 kG. The temperature dependence of the electrical resistance has also been studied for temperatures between 1.4 K and 4.2 K.

Results and Discussion

Electrical resistivity of the samples heat treated at 900°C exhibits the $T^{-1/4}$ dependence, which is evidence for the existence of localized states in these samples. Logarithms of the relative resistance $R_T/R_{4.2}$ are plotted against $T^{-1/4}$ in Fig. 1. The results of the magnetoresistance on these samples are shown for measuring temperature of 4.2K in Fig. 2. These results confirm those obtained previously.

The magnetoresistance of the bamboo char heat treated at 900°C is positive at all fields and at all temperatures investigated. No variation of the magnetoresistance against magnetic field direction is observed. The magnetoresistance increases with increasing magnetic field and with decreasing temperature. Log-log plots of the magnetoresistance value vs. magnetic field show that the magnetoresistance varies approximately as H^2 with decrease of exponent at high field. Decrease of exponent becomes appreciably with decreasing temperature.

The magnetoresistance of the cokes heat treated at 900°C shows complicated variations on both magnetic field and temperature. The magnetoresistance is positive at all fields, and varies weakly against magnetic field direction. The results of the sample B are shown in Fig. 3, where $(\Delta\rho/\rho)_{max}$ and $(\Delta\rho/\rho)_{min}$ are the maximum transverse magnetoresistance and the minimum at the same magnetic field. In this and other samples, maxima in the mean transverse magnetoresistance vs. temperature at constant magnetic field are observed. The mean transverse magnetoresistance is defined by the mean value of the maximum transverse magnetoresistance and the minimum. Temperature at the maximum is about 2K. This behavior is associated with the onset of the anisotropic negative component which is stronger at higher magnetic fields and lower temperatures

The anisotropic negative magnetoresistance can be attributed to characteristic of the growing graphitic crystallite, the region of the pseudo-metallic conductivity. Therefore, the results of the samples of cokes heat treated at 900 °C suggests a structural model of these samples involving regions of the pseudo-metallic conductivity connected by the variable range of hopping conduction, as the model proposed by Hamilton, Cross and Adkins for amorphous carbon films[5].

The pseudo-metallic conduction becomes dominant with increasing heat-treatment temperature. The $T^{-1/4}$ dependence of $\ln[R_T/R_{4.2}]$ is no longer observed for the samples of the cokes heat treated above 1100°C. The negative component of the magnetoresistance becomes remarkable with increasing heat-treatment temperature, which can be illustrated in Fig. 3 with the results obtained for the sample B heat treated at 1100°C.

For the samples of the cokes heat treated at 1500°C, the magnetoresistance is negative at all fields and at all temperatures. With increasing magnetic field, the mean transverse magnetoresistance decreases at first and then tends to saturate at constant temperature. It decreases with decreasing temperature at lower fields, while it increases at higher fields. This implies that the positive component due to hopping conduction superposes on the negative magnetoresistance of the graphitic layer plane. Therefore, amorphous regions still remain in these samples.

References

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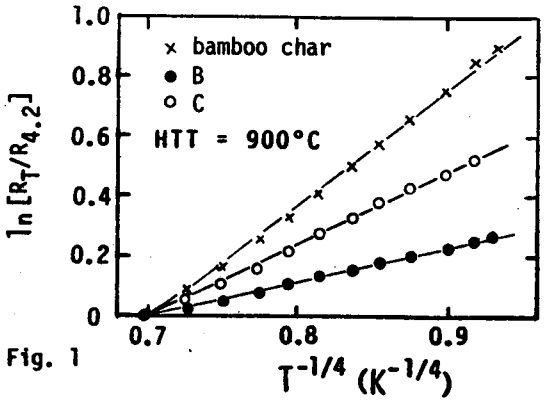

Fig. 1

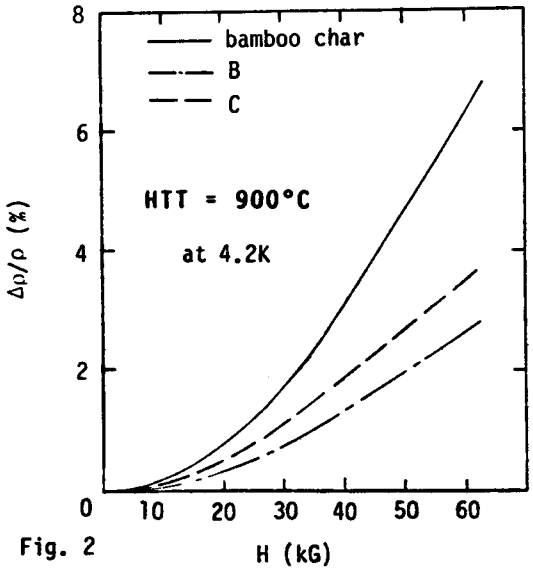

Fig. 2

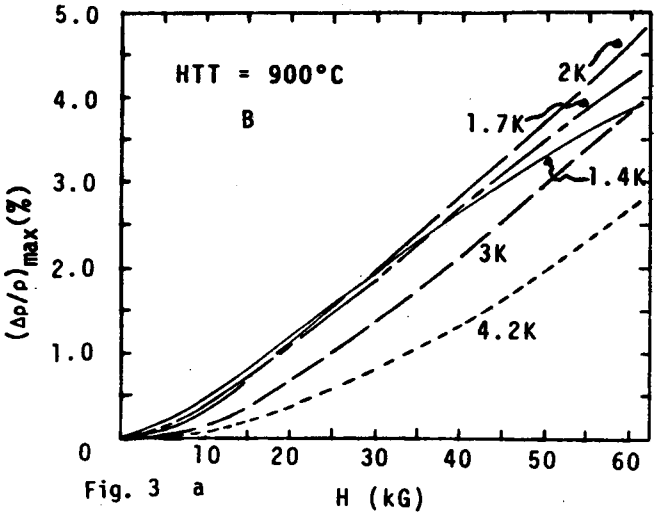

Fig. 3 a

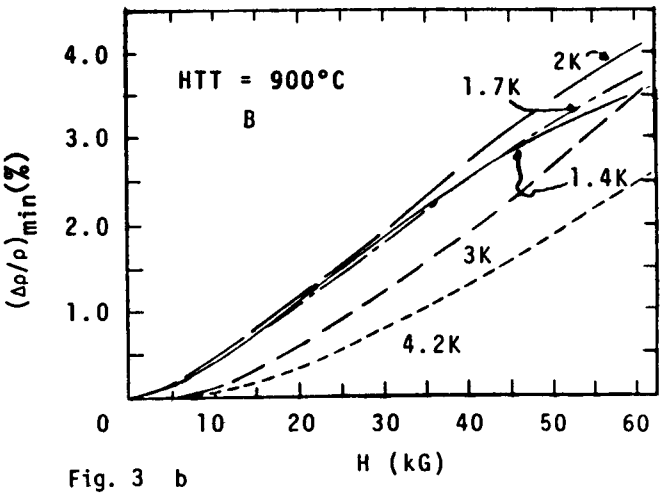

Fig. 3 b

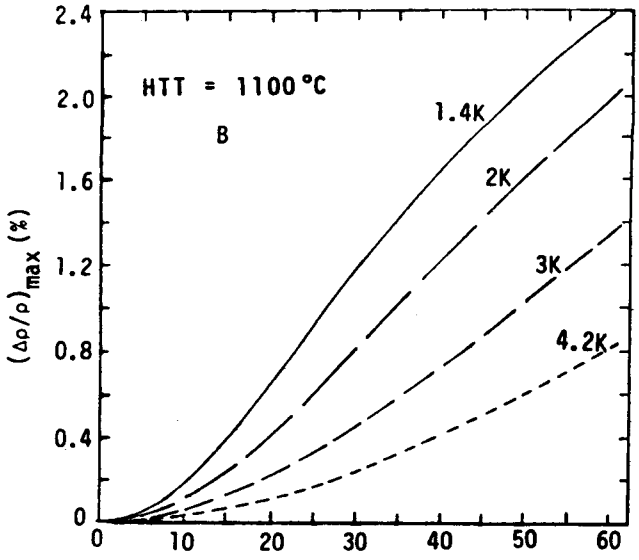

Fig. 4 a

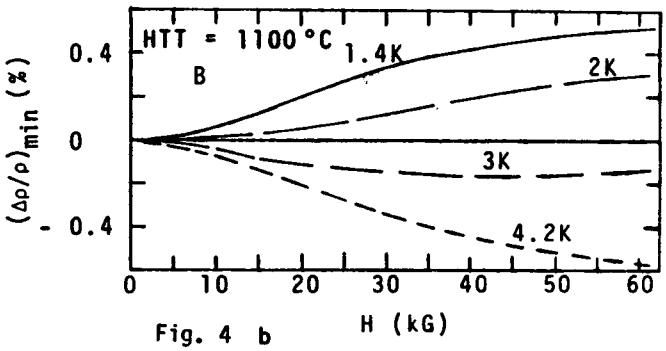

Fig. 4 b