TEMPERATURE AND FIELD DEPENDENCIES OF GALVANOMAGNETIC EFFECTS IN GRAPHITE

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At the twelfth biennial conference on carbon, we reported that highly oriented pyrolytic graphite (HOPG) had an anomolous temperature dependent magnetoresistivity.[1] In zero field, B, the electrical resistivity, $\rho_{xx}(0,T)$, decreased monotonically with decreasing temperature, T, becoming nearly constant below 4 Kelvin. However, in an applied field B_z the transverse resistivity component $\rho_{xx}(B_z,T)$ went through a maximum as a function of temperature at about 25 degrees Kelvin. We now have data on a single crystal (figure 1) which is very similar to the data for HOPG. That is, the resistivity in high field goes through a maximum as a function of temperature, the maximum is more pronounced at high B, and the maximum is at roughly the same temperature as for HOPG. The data in figure 1 are "modulated" by the presence of Shubnikov deHaas (SdH) oscillations which are more pronounced at lower temperatures. The last SdH oscillation as a function of field is near 8 tesla, so the data from 10 to 13.5 tesla in figure 1 illustrate the maximum, unmodulated by the SdH effect. Since we now find maxima for both HOPG and single crystal graphite, we must conclude that the effect is intrinsic to graphite.

As a second set of experiments, we measured the B dependence of $\rho_{xx}(B_z,T)$ at a series of fixed T's from 1 to 300°K. According to the simple two-band model for a compensated material

$$(1)\quad \frac{\Delta\rho}{\rho} = \frac{\rho_{xx}(B_z,T)-\rho_{xx}(0,T)}{\rho_{xx}(0,T)} = \overline{\mu(T)}^2 B_z^2 \text{, Where}$$

$\bar{\mu}(T)$ is a suitably defined average carrier mobility. However, we find, as have others,[2-5] that the exponent of B_z in equation (1) is generally less than two and is a function of temperature and field strength, indicating that the simple theory is inadequate. We present results which better define the temperature and field dependence of the exponent for several HOPG samples and a natural single crystal. We have determined an "effective" exponent, n(T), relating $\Delta\rho/\rho$ to $B_z^{n(T)}$ from plots of log ρ_{xx} vs. log B_z. We find, in HOPG for example, that at 1 Tesla $n \simeq 1.8$ at 300 Kelvin, decreases to 1.4 at 40 Kelvin, then drops rapidly to 1.2 at 4.2 Kelvin. The mobility, $\bar{\mu}(T)$, as estimated from plots of ρ_{xx} vs. B_z at low fields, is roughly constant at low temperatures, but decreases rapidly at higher temperatures. Qualitatively, then, the maximum in ρ_{xx} result because n(T) decreases at low temperatures while $\bar{\mu}(T)$ decreases at high temperatures, so the product goes through a maximum. However, since the data associated with $n<1.8$ are in or near the quantum limit regime, calculations including the effects of the quantization of electronic motion are needed.

We conclude that: 1) the maxima are present in both HOPG and natural single crystals, and, therefore, seem to be intrinsic to graphite; and 2) The maxima are related to the field dependence of ρ_{xx} at low temperatures; and 3) calculations are needed of the field dependence of $\sigma_{xx} \simeq 1/\rho_{xx}$ in graphite as a function of temperature just below and in the quantum limit for phonon and boundary scattering.

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2. John A. Woollam, Physics Letters 32A, 371 (1970).

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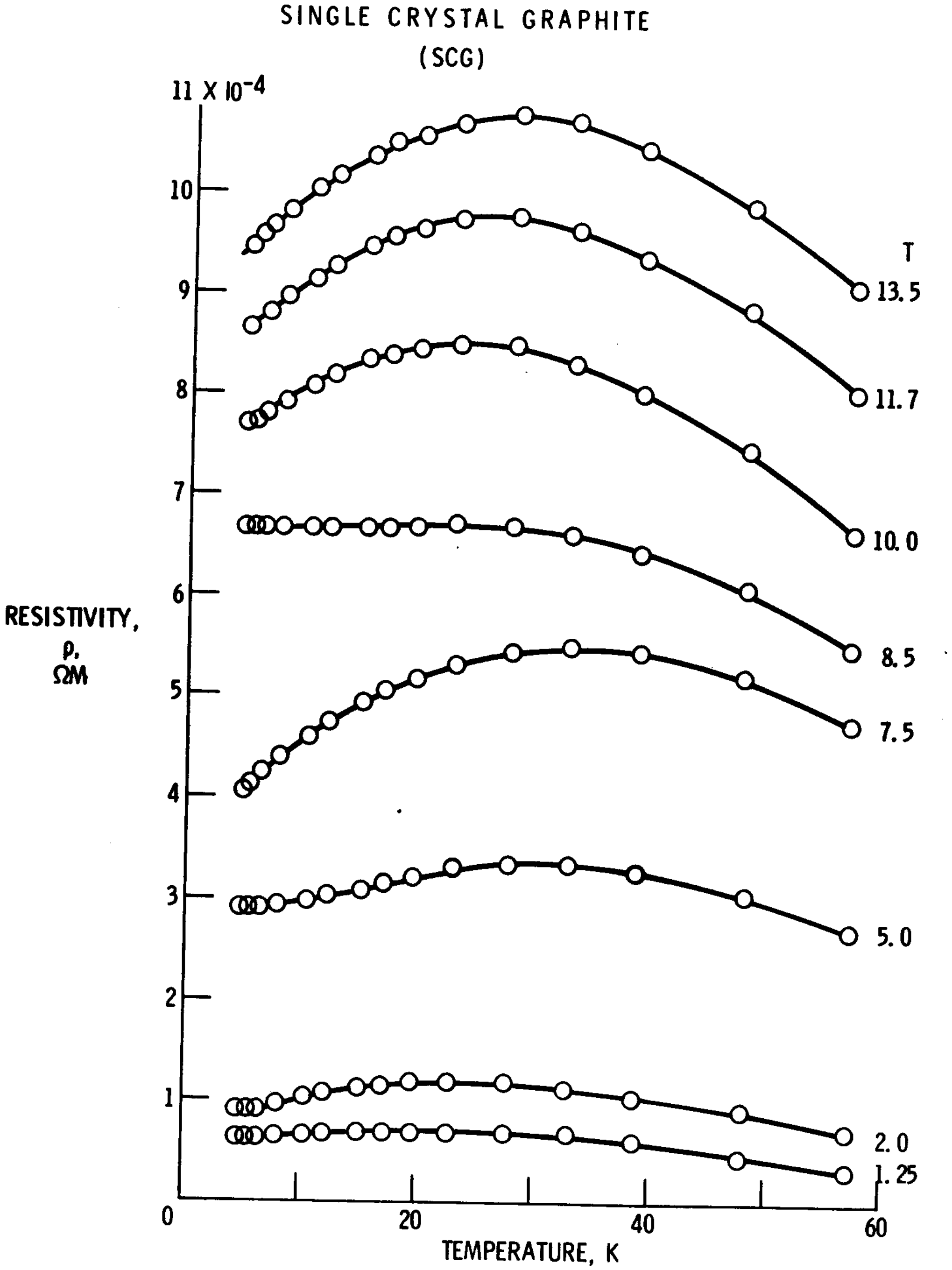

FIGURE I Electrical Resistivity vs. Temperature for a purified natural single crystal in a series of magnetic fields (in units of Tesla)