Anticorrelation of Shubnikov–deHaas Amplitudes and Negative Magnetoresistance Magnitudes in Intercalated Graphite Fibers *+

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Introduction

Pitch based carbon fibers when annealed to high temperatures and then intercalated are of potential interest for electrical conductors[1]. They are graphitizable, low cost, and mass producible. The P100 Union Carbide fibers are one example. P100 fibers were annealed to greater than 3000°C and then intercalated with $CuCl_2$ and with bromine. The magnetoresistances in fields to 20 Tesla at various temperatures were measured in an attempt to characterize the electronic properties of these intercalated fibers. This paper reports on measurements of the simultaneously present Shubnikov-deHaas and negative magnetoresistance effects in intercalated fibers.

Samples and Experiments

The fibers designated P100-3 and P100-4 are production fibers which have been further annealed (by Dr. Leonard Singer, Union Carbide) to above 3000°C to promote the maximum graphitization. In both fiber types the basal planes are radially oriented[2]. In the P100-4 group virtually all cross sections are split: that is, they look like a pie with one piece missing. Samples were intercalated from vapor sources. The copper chloride intercalations were described earlier , and bromine intercalations were done by the conventional vapor transport technique.

All high field experiments were done at the FBNML at MIT in fields to 20T at 4K, 78K, and 300K. At 4K the Shubnikov-deHaas and negative magnetoresistance effects were maximum, and it is these effects which are the main subject of this paper.

Results and Discussion

A typical example of resistance vs magnetic field is shown in Figure 1. Notice the simultaneous presence of the Shubnikov-deHaas (SdH) and the negative magnetoresistance (MR) effects. In the negative MR effect the resistance first decreases with increasing field, and then increases. Beginning at about 10 Tesla one observes the onset of

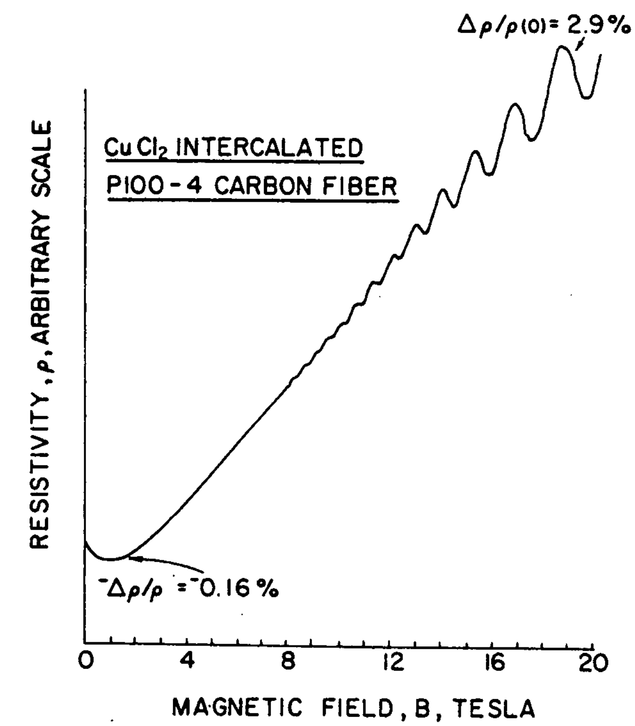

Figure 1. Typical example of resistance versus magnetic field.

resistance oscillations, and these grow in amplitude with increasing field. The negative component is generally less than 0.5 percent and the oscillatory component is as large as 4 percent of the background. Numerous traces were taken with fibers nominally of the same source (e.g. P100-4) and same intercalant. The interesting feature is a wide variation in magnitudes of the two effects. Figure 2 shows that the SdH amplitude and the magnitude of the negative MR anticorrelate. That is, when the SdH oscillation amplitude is large the magnitude of the negative MR is small.

The SdH effect can arise when intercalated crystallites have c axes within ±30 degrees of the applied field direction. The negative MR can result from two possible causes: 1) Small regions of un-intercalated turbostratic graphite (Bright and

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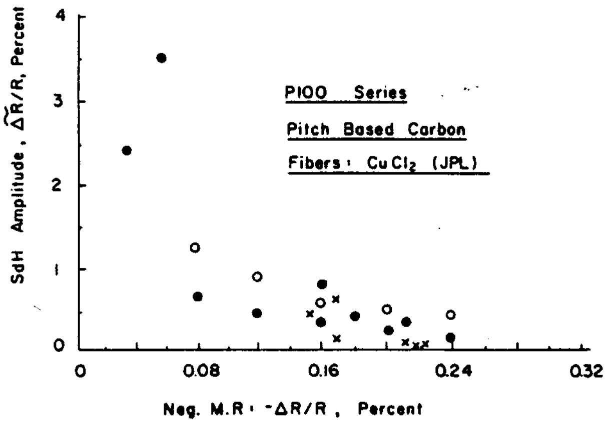

Figure 2. SdH amplitude relation to negative MR.

Singer[3]), or 2) Scattering from spin centers[4]. Pitch based fibers are known to have regions of differing microstructure, including small graphite (crystalline), turbostratic, and amorphous ("crumpled sheets") parts[5]. We can explain the anticorrelations observed in Figure 2 if the SdH oscillations come from the intercalated regions: The SdH frequences are of GIC not of graphite. If the total volume of intercalated graphitic regions is large then the volume remaining for either spin scattering or turbostratic regions will be smaller. This simple argument explains the anticorrelation.

References

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