EXTENDED ABSTRACTS

GRAPHITE INTERCALATION COMPOUNDS

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CRITICAL EXPONENT γ OF THE MAGNETIC ANOMALY OF STAGE-6 $FeCl_3$ INTERCALATED GRAPHITE*

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We have discovered a susceptibility maximum in all stages of $FeCl_3$ intercalated graphite which occurs at about 1.7K.[1,2] The size of the maximum varies by a factor of 30, being smallest in stage 1 and greatest in stage 6. This phenomenon appears to be two dimensional in origin. The temperature of the maximum does not vary from stage to stage. In stage 2, we have correlated the size of the maximum with the number of iron vacancies[3]. The measurements shown here are for stage-6 $FeCl_3$ intercalated graphite where the maximum is most pronounced.

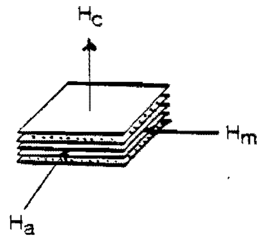

Figure 1

Intercalated Graphite
H_m is the measuring field
H_a and H_c are externally applied fields

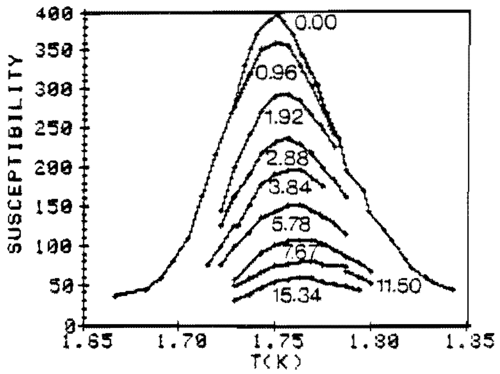

Figure 2

Susceptibility as a function of temperature in an applied magnetic field (numbers denote field in Gauss)

Fig. 1 shows the geometry of our arrangement. The susceptibility was measured by a standard A.C.[4] technique at 40Hz with the measuring field H_m parallel to the graphite planes. The measuring field was always smaller than 0.1 G.

Fig. 2 shows the magnetic susceptibility as a function of temperature. The highest peak is zero magnetic field, while the consecutively lower peaks are in fields of 0.96, 1.92, 2.88, 3.84, 5.75, 7.67, 11.50 and 15.34 G respectively along the a-direction (Fig. 1). One observes that in addition to attenuating the maximum, an applied field shifts the temperature of the maximum to a higher temperature.

Because of the high susceptibility at the maximum the external measuring field which each individual magnetic spin sees is shielded by the neighboring spins and that shielding depends on the shape of the sample. We measure χ_{ext} and would like to measure χ_{int}, where χ denotes the magnetic susceptibility. χ_{int} is the response of the magnetic spin to the field it experiences while χ_{ext} is the response to an external field. The relation between χ_{int} and χ_{ext} is[5]

$$\chi_{int} = \chi_{ext}/(1-\varepsilon\chi_{ext})$$

If one assumes that at the maximum χ_{int} is infinite, then

$$\varepsilon = 1/\chi_{ext}$$

When this correction is applied to the susceptibility at zero applied magnetic field one obtains the points in Fig. 3.

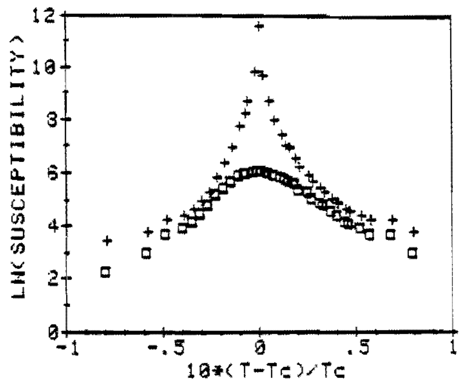

Figure 3

Natural logarithm of the susceptibility at 0 field as a function of the reduced temperature

+ is shape-corrected susceptibility

□ is uncorrected susceptibility

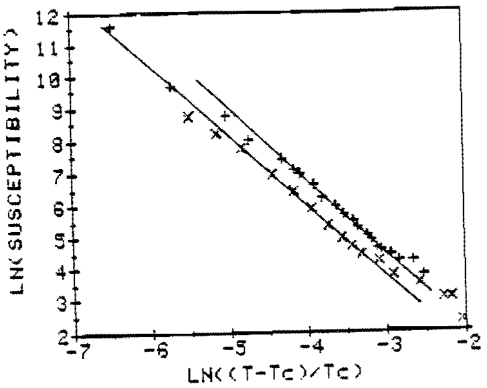

Figure 4

Logarithm of the susceptibility at 0 field as a function of the reduced temperature showing the universal power law behavior

$+ = T > T_c$ $\times = T < T_c$

Fig. 3 shows the natural Logarithm of the susceptibility plotted against the reduced temperature (T - Tc)/Tc where Tc is the temperature of the maximum. The + are the corrected susceptibilities while the □ are the uncorrected values. The reduced temperature was expanded by a factor of 10.

Fig. 4 shows the natural logarithm of the susceptibility as a function of the reduced temperature. The + are for T > Tc while X denotes points for T < Tc. This plot suggests that the susceptibility χ goes as

$$\chi \propto |(T-Tc)/Tc|^{-\gamma}$$

with $\gamma = 1.97 \pm .1$ for T > Tc and $\gamma = 1.85 \pm .1$ for T < Tc. The slopes of the drawn lines denote the values of γ. Similar functional behavior of the susceptibility has been observed in many other systems and is a consequence of the universality of the characteristics of second order phase transitions, the value of γ is between 1 and 1.25 in three dimensional transitions, while it is predicted to be 1.75 for a two dimensional Ising model. Our values appear to be higher than that. We are thus dealing with a new phenomenon.

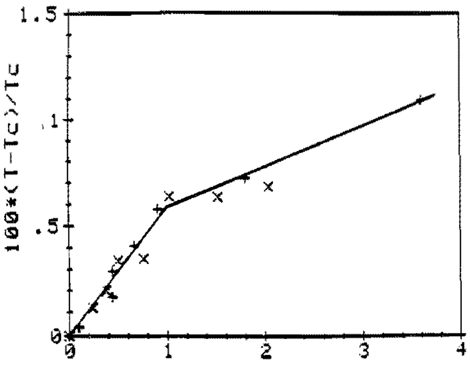

Figure 5

Temperature dependence of the maximum as a function of the applied magnetic field

+=H_c
x=H_a

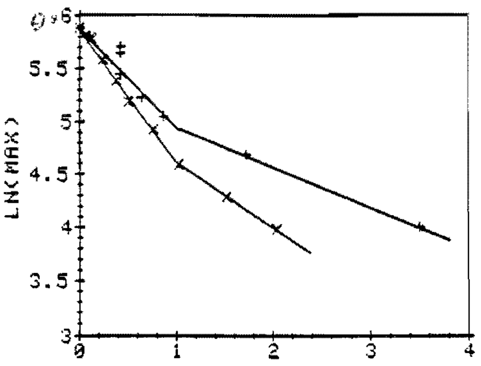

Figure 6

Logarithm of the maximum susceptibility as a function of the applied magnetic field

+=H_c
x=H_a

Fig. 5 shows the magnetic field dependence of the temperature at the susceptibility maximum. + denotes the points for the field applied along a direction normal to the planes while x denotes the field applied parallel to the planes. The temperature is the reduced temperature multiplied by 100 where Tc is the temperature of the maximum at zero field. The field is in units of Ho where Ho is 17 G for the Hc direction and 7.5 G for the Ha direction, and denotes the transition from low field to high field behavior. A field applied along Ha is more than a factor of 2 more effective than that applied along He. The slope of (T − Tc)/Tc at low field is a factor of 3 greater than that at high field.

Fig. 6 shows the size of maximum, plotted on a logarithms scale as a function of the scaled field H/Ho with + along Hc and x along Ha as shown in Fig. 1, with the same values of Ho as in Fig. 5 and observes a low and a high field behavior

$$\chi_{max}(H) = \chi_{max}(0)\exp(-\phi H/Ho)$$

with $\phi_{low} = 1.3$, $\phi_{high} = 0.6$ for Ha; and $\phi_{low} = 1$, $\phi_{high} = 0.4$ for Hc. Similar behavior was observed in other magnetic intercalation compounds.[2]

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