LOW TEMPERATURE MAGNETIC AND THERMAL PROPERTIES OF AN AMORPHOUS CARBON

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Introduction

The physical properties of a series of anthracen chars heattreated at temperatures (HTT) lower than 1500°C have been extensively studied and reported in other publications{1} {2} {3}. A non-metal transition was evidenced and interpreted by the existence of density fluctuations {3}

We shall report further measurements of the magnetization between 0.1 and 2K, the magnetocaloric effect and the specific heat under 2K of the sample heattreated at 700°C which lays on the non-metallic side of the pseudo transition.

Magnetization measurements

The magnetization M of the sample was measured over the temperature range 0.1-4.2K under various magnetic fields H increasing from 0.8 to 70 kOe. We have reported in the insert of figure 1 the reverse low field susceptibility versus temperature : there is evidence of a CURIE-WEISS law :

$$\chi_p = \frac{C}{T-\Theta}$$

with $\Theta = 0.8$ and $C = 38\ 10^{-6}$ uem cgs g^{-1} K.

Defining the reduced variable x as :

$$x = \frac{\mu H}{k(T-\Theta)}$$

where μ is the BOHR magneton and k the BOLTZMAN constant, we have reported the experimental values of M versus x for the low and high values of x on figure 1 and figure 2 respectively. Figure 1 shows the expected linear x dependence of M.

We have drawn on figure 2 the line calculated with the LANGEVIN relation of the magnetization of N dipoles of spin 1/2

$$M = N\mu \text{ th } x \qquad [1]$$

Magnetocaloric effect

A (small) magnetic field change ΔH acting on a perfect paramagnetic material at temperature T under adiabatic conditions results in a temperature change ΔT such as :

$$\Delta T = -\frac{T}{C_{p,H}} \left(\frac{\partial M}{\partial T}\right)_{P,H} \Delta H$$

where $\left(\frac{\Delta M}{\Delta T}\right)_H$ is the derivative of the magnetization of the sample at constant pressure and field by respect to temperature, and $C_{p,H}$ the specific heat at constant pressure and field. $C_{p,H}$ being known {1} for the three magnetic field strenghts 20,30 and 40 kOe, we have determined $\left(\frac{\partial M}{\partial T}\right)_{P,H}$ for the same values of H.

We have reported on figure 3 the values of :

$$\left(\frac{\partial M}{\partial x}\right)_{P,H} = -\frac{\mu H}{kx^2} \left(\frac{\partial M}{\partial T}\right)_{P,H} \quad \text{versus } x$$

From relation [1] we can deduce :

$$\left(\frac{\partial M}{\partial x}\right) = N\mu \left(\frac{2}{e^{x} + e^{-x}}\right)^2 \qquad [2]$$

which gives the theoretical curve drawn on figure 3.

Specific heat under 2K

The specific heat results between 0.15 and 2K are given in log-log coordinates on figure 4. The previous results {1} above 1.5K are recalled. The present measurements agree with a temperature dependence of the form :

$$C_p \sim T^n$$

with $n \sim 0.6$ significantly less than 1. Reporting the results in a C_p/T versus T^2 plot (insert of figure 4) the experimental values diverge as T decreases. Such a behaviour has been already reported in low HTT soft carbons {4} with a quite similar characteristic. But, there is no evidence of a true peak for sometimes reported on other amorphous carbons {5}.

Discussion

The first striking feature which emerges from these results is the magnetization and the magnetocaloric effect do not depend simply on the reduced variable x at very low temperature and strong fields. The other interesting fact is the non-linear temperature dependence of the very low temperature specific heat, which contradicts the linear dependence found at higher temperatures {1}. Such a non-integer exponent was already found in other disordered solids {6} but appears here as a puzzling result . It seems to us that at very low temperatures we have a magnetic interaction between localized centers with an energy spectrum due to a very short range order {3}. This char therefore behaves as a kind of spin glass. A definite model has to be proposed to explain this behaviour.

1-G. BLONDET-GONTE, P. DELHAES and M. DAUREL, Sol. St Comm. 10, 819 (1972)

2-F. CARMONA, P. DELHAES, G. KERYER and J.P. MANCEAU, Sol. St Comm. 14, 1183 (1974)

3-F. CARMONA and P. DELHAES to be published

4-K. KAMIYA, S. MROZOWSKI and A.S. VAGH, Carbon 10, 267 (1972)

5-S. MROZOWSKI and A.S. VAGH, Carbon 14, 211 (1976)

6-J.C. LASJAUNIAS, P. MAYNARD and D. THOULOUZE, Sol St Comm 10, 215 (1972)

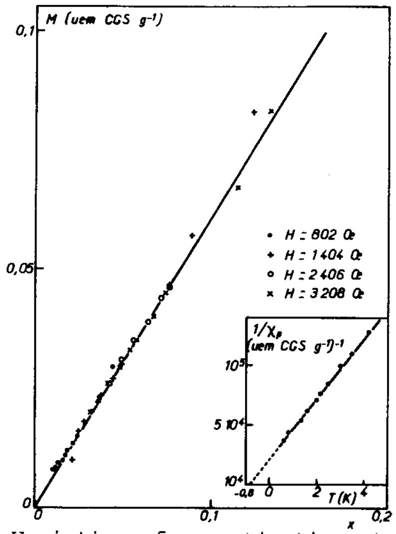

Figure 1 : Variation of magnetization at low fields and Curie-Weiss law (see insert)

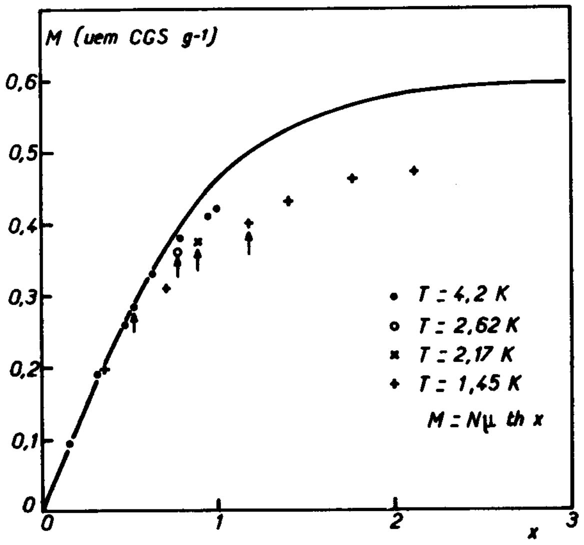

Figure 2 : Variation of magnetization at high fields

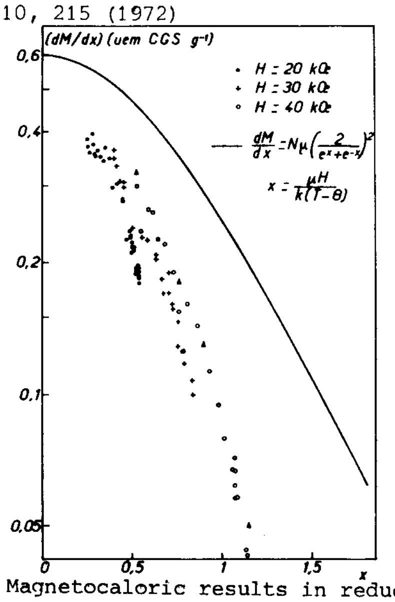

Figure 3 : Magnetocaloric results in reduced coordinates.

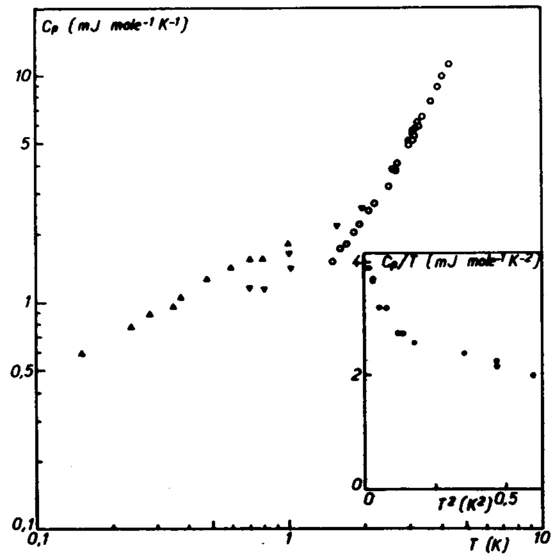

Figure 4 : Thermal variation of the specific heat Cp in logarithmic coordinates and C_p/T versus T^2 (see insert)