STUDY OF THE ELASTIC CONSTANT C_{44} OF PYROLYTIC GRAPHITE AFTER LOW TEMPERATURE IRRADIATION (4 K)

J.B. AYASSE and E. BONJOUR

Centre d'Etudes Nucléaires de Grenoble
Service des Basses Températures

Introduction :

The Granato-Lücke Theory [1] about the pinning of dislocations by the defects was successfully applied to metals [2]. With this theory, we tried to analyse experiments [3] of electron irradiation on pyrolytic graphite at liquid helium temperature. We have performed new experiments to study the irradiation effects on the shear modulus of the perfect lattice C_{44L}. We have irradiated under the same conditions that previously a pyrocarbon sample (H.T.T. $\sim$ 2400°C) where the effects of dislocations are supposed to be zero.
We also measured the specific heat of a pyrolytic graphite (U.C. grade ZYH) between 1.2 K and 5 K, after neutron irradiation at liquid nitrogen temperature and subsequent annealing at room temperature.

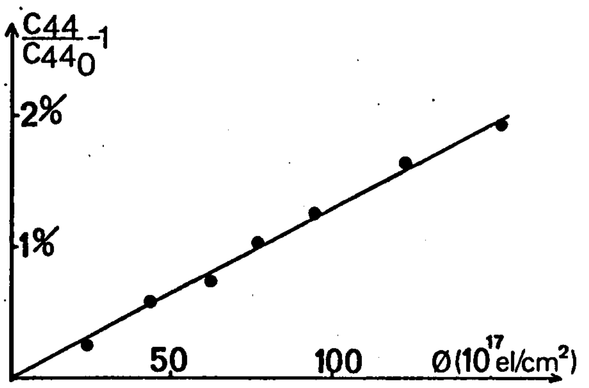

FIG.1 - C_{44L} change for the pyrocarbon sample at 4 K. C_{44o} = 1.18 10^{10}dynes/cm^2

Experimental results :

The figure 1 presents the shear modulus change of a pyrocarbon sample which shows a linear dependance upon the dose.

The figure 2 shows the specific heat of pyrolytic graphite before and after irradiation for 2 doses (10^{17}-10^{18} neutrons/cm^2). The experimental data may be fitted on a linear law versus T^2, $C/T = \gamma + \beta T^2$ where the slope $\beta=(1/\Theta_D)^3$ and $\Theta_D^3 \alpha C_{44L} (C_{33})^{1/2}$ (Θ_D Debye temperature).

The relative changes $\Delta C_{44L}/C_{44oL}=-\Delta\beta/\beta_o$ are about + 6 % and + 26 % for 10^{17} and 10^{18} n/cm^2 respectively with $\beta_o \sim$ 30 µJ/M/K^4 [4]. These values are certainly overestimated because of the existence of a peak on the specific heat

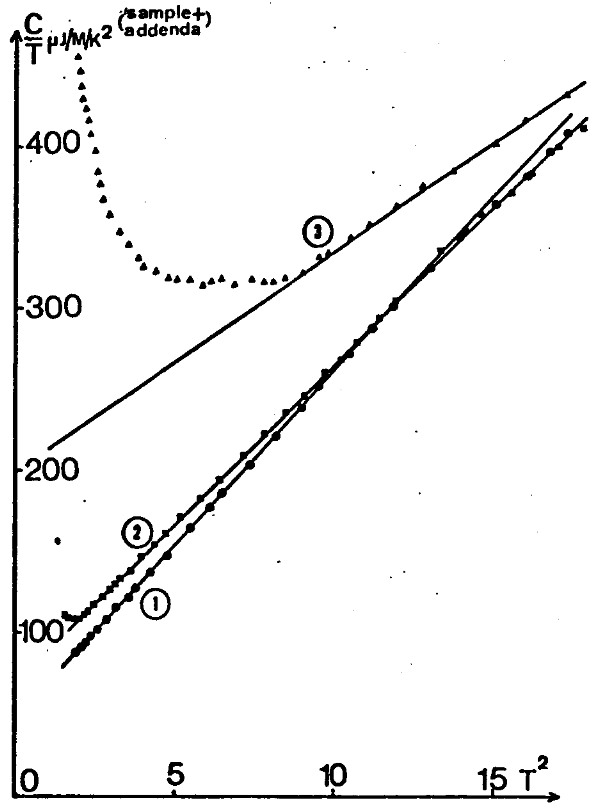

FIG. 2 - Specific heat data obtained in the range 1.2 - 4 K for the pyrolytic graphite : ① before irradiation
② 10^{17} n/cm^2
③ 10^{18} n/cm^2

curves at low temperature already seen by other authors [5]. Nevertheless this 2 results show a large increase of the shear modulus C_{44L} with damage.

The figure 3 shows C_{44} changes versus dose Φ for a pyrolytic graphite sample (U.C. grade ZYA) irradiated at 4.2 K. The large C_{44} increase forbids certain approximations of the Granato-Lücke Theory ordinarily used for the metals which have variations of about a few per cent.

The final relation is :

$$\frac{(C_{44L}/C_{44}-1)\ \text{irrad.}}{(C_{44oL}/C_{44o}-1)\text{unirrad.}} = \frac{(C_{44L}/C_{44oL})^{1/2}}{(1+nr/n_o)^2}$$

where n_r/n_o is the ratio between the pinning points n_r created by irradiation and those n_o existing before ; let $n_r/n_o = p\,\Phi$ be linear with the dose Φ (p parameter). Two stages are required for the fit on

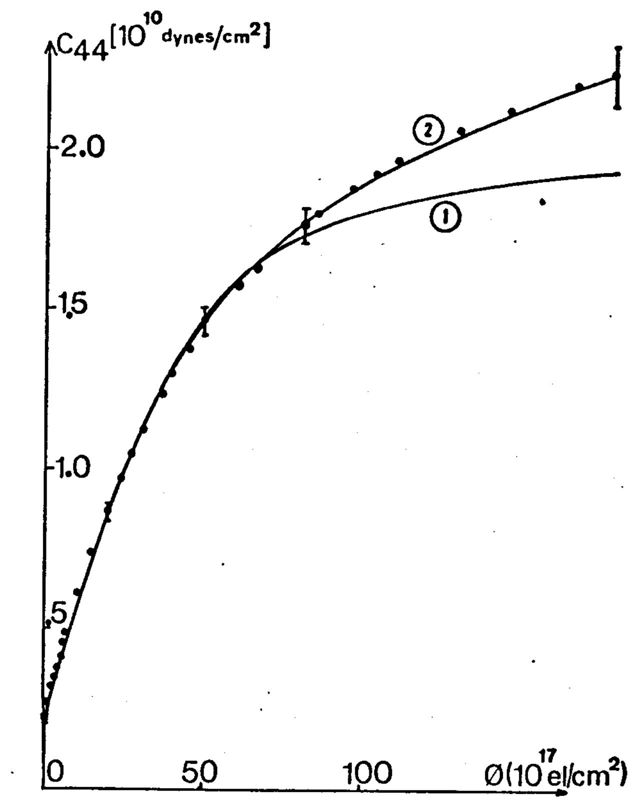

FIG.3 - C_{44} change for the pyrolytic graphite C_{44_O} =(.22 ±.02) 10^{10} dynes/cm^2

the experimental curve.

1) Assuming that the effect of the defects remains negligible on C_{44_L} : $C_{44_L} = C_{44_{OL}}$, we can fit the experimental points up to $\Phi \sim \Phi max/3$ only. For higher doses the theoretical curve (1) is below the experimental curve. In this case the parameter values are :
C_{44_L} = 2 10^{10} dynes/cm^2, p = 7.5 10^{-19}cm^2/el

2) Taking into account a linear increase of C_{44_L} with the dose :
$C_{44_L} = C_{44_{OL}} (1 + b\Phi)$ we can fit, at about 5 %, the whole experimental curve 2.
The new parameters are :
$C_{44_{OL}}$ = 1.8 10^{10} dynes/cm^2
p = 7.5 10^{-19} cm^2/el, b = .16 10^{-19} cm^2/el

Discussion :

These results show the existence of both processes :

Pinning of dislocations by the defects and linear increase with the dose of the shear modulus of the lattice C_{44L}. The concentration of defects is about 10^{-3} for 10^{18} n/cm^2 [6]. The specific heat results $\Delta C_{44_L}/C_{44_{OL}} \sim + 6$ % for 10^{-4} and + 26 % for 10^{-3} are the same order of magnitude than those for electron irradiation : $\Delta C_{44_L}/C_{44_{OL}} = b\ \Phi max \sim 28$ % for a concentration of defects about 4 10^{-4} [7].

On the other hand, the changes are smaller for the pyrocarbon, probably because of larger space between the planes. The lattice shear modulus deduced : $C_{44_{OL}} \sim 1.8$ 10^{10} dynes/cm^2 is smaller than the usually adopted value (4 10^{10} dynes/cm^2).

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