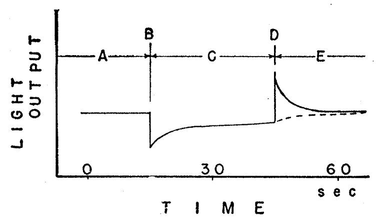

FIG. 1. Light output of ZnS:Cu phosphor *versus* time, schematic. *B*—field on; *D*—field off. Solid curve—10 000 cps; dashed curve—60 cps.

put from a near ultraviolet excited ZnS:Cu phosphor. This report gives the qualitative features of some of our observations.

A film of the powdered phosphor was obtained by immersing the phosphor in a parlodium-amylacetate solution and then pouring the mixture on a conducting glass plate. The phosphor film thickness was about 0.2 mm. After the film had dried, the outer uneven edges were cut away. An electrode of copper or some other metal was evaporated on the exposed surface of the phosphor film. We used potential differences from 0 to 400 volts with frequencies ranging from 0 to 10 000 cps. The output of a near ultraviolet source of constant energy excited the phosphor continuously. A photomultiplier responded to the light output from the phosphor with a filter arrangement designed to eliminate any ultraviolet which might be reflected by the phosphor-glass surface. The output from the photomultiplier was fed to an amplifier and then to the vertical plates of a cathode-ray oscilloscope.

If a potential difference of 400 volts and a frequency of 10 000 cps is applied across the phosphor film, a trace of the signal on the oscilloscope is obtained which is illustrated in Fig. 1. Regions *A* and *E* represent the light output before the field has been applied and after the field has been removed, respectively. *B* designates the time when the field is applied; *D* the time at which it is removed. *C* is the region during which the field is applied. The trace given in Fig. 1 is similar to those reported by Destriau with the exception of the momentary illumination at point *D*. The magnitude of this sudden light excess is a function of the field strength and of the frequency. At low frequencies, of the order of 60 cps and with the same high field strength, the momentary illumination at *D* disappears and the trace assumes the shape of the dashed curve. In Destriau's papers, however, this shape of the curve is reported for a fast decaying phosphor only; on the other hand, his slow decaying phosphors do show momentary illumination for 50 cps, the only frequency for which Destriau gives results.

Our preliminary investigation reveals that for decreasing field strength the magnitude of the overshoot at *D* decreases almost linearly. The rise at *D* is remarkedly steeper than the fall at *B*, with the decay beyond *D* being apparently of the power law type. The rise in region *C* is more complex. The extinguishing effect at *B* increases with frequency and field strength.

Application of a dc field yields only a momentary illumination of very short duration (about 10^{-4} sec), with another momentary illumination of reduced amplitude being obtained when the dc field is removed.

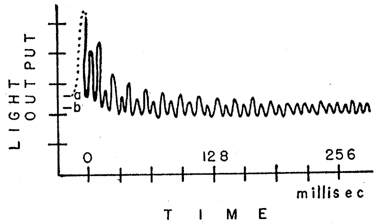

FIG. 2. "Blow-up" of region *B* of Fig. 1. *a* = light output before the field is applied; *b* = lowest average light output with field on; dotted curve = conjectured rise of output.

Point *B* is of further interest. If a fast sweep rate on the oscilloscope was used, we obtained a signal trace for *B* like that reproduced in Fig. 2 for a 60-cps field. Here we see another momentary illumination preceding the extinguishing effect. The light output fluctuates with twice the frequency of the electric field. These ripples alternate in intensity, probably because of the influence of the polarity of the electrodes. The general character of the trace was the same for all frequencies, but the amplitude of the ripples decreased with increasing frequency. The momentary illumination occurred always within 3–5 periods of the ac field.

Work is now in progress to obtain more quantitative information concerning the dependence of the effects on frequency, field strength, wave shape of the applied field, and on the nature of the phosphor. The time variation of light output in the regions *B*, *C*, and *E* will be investigated for possible correlations with the natural growth and decay processes of the phosphor.

[1] G. Destriau, Phil. Mag. **38**, 880 (1947); G. Destriau and J. Mattler, J. phys. et radium **9**, 258 (1948).

Anisotropic Susceptibility of Polycrystalline Graphite*

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ALTHOUGH the spur invariance of the susceptibility tensor has been frequently used in the study of single crystals, it is apparently not generally realized that a similar property holds for anisotropic polycrystalline materials of arbitrary preferred orientation. That polycrystals possess this property is almost self-evident from the single crystal invariance, but the experimental conditions under which the elements of the spur may be determined for a polycrystal can be seen most easily by analysis.

The proof is quite simple: Let k_{ij} be the susceptibility tensor of a single crystal referred to its principal axes, and hence it is diagonal. A crystallite with orientation θ, ϕ, ψ will possess the susceptibility tensor $k_{ij}'=R_{im}^{-1}k_{mn}R_{nj}$, where $R(\theta, \phi, \psi)$ is the three-dimensional rotational operator. Let $w(\theta, \phi, \psi)$ be the normalized density function of crystallites with given orientation in the range $d\tau$. The potential energy is then

$$U=\tfrac{1}{2}\int_V\int_\tau H_ik_{ij}'H_jwd\tau dV,$$

where the integrations are over the space of θ, ϕ, ψ and over the volume V of the sample. The force exerted by the sample in the direction x_l is

$$F_l=-\frac{\partial U}{\partial x_l}=-\int_V\int_\tau H_ik_{ij}'\frac{\partial H_j}{\partial x_l}wd\tau dV,$$

since k_{ij}' is symmetric. If grad$|H|^2$ is sensibly constant over the volume V, and H also unidirectional over the volume, then we may without loss of generality take H to be in the direction x_1 and obtain

$$F_l=-\int_V H_1\frac{\partial H_1}{\partial x_l}\int_\tau k_{11}'wd\tau dV.$$

Since this depends only on k_{11}', it serves to determine one element of the spur. If we make three determinations of F_l in three independent orthogonal directions by rotating the sample in the field, then their sum is

$$\sum_{m=1}^{3}(F_l)_m=-\int_V H\frac{\partial H}{\partial x_l}\text{ Spur }k'wd\tau dV=H(\partial H/\partial x_l)_{\text{Av}}V\text{ Spur }k.$$

Defining the apparent susceptibility k_m as $(F_l)_m/(VH\partial H/\partial x_l)$, we obtain $\Sigma k_m=\text{Spur }k$, providing the sample is perfectly compact. This last restriction may be removed by using the specific susceptibility χ, for which

$$\Sigma\chi_m=\text{Spur }\chi.$$

The left side refers to the three orthogonal susceptibilities of the solid polycrystalline sample, the right to the single crystal susceptibility.

An apparatus of the Faraday type which satisfies the condition of uniformity for H and grad$|H|$ over a suitable volume has been designed[1] and applied to the measurement of polycrystalline graphite. A Honda-Owen correction has been employed to determine the effect of ferromagnetic impurities, using field strengths from 8000 to 16 000 oersteds. The total susceptibility $\Sigma\chi_m$ has been measured for various grades running from various petroleum base Atcheson graphites to natural and lampblack graphites. Although the accuracy of the measurements is of the order of 1 percent, the precision and relative values are correct to better than 0.5 percent. Small cubical samples $\frac{5}{8}$ inch on edge were employed. For a given type of graphite the invariance of the total susceptibility was verified to 0.5 percent, and all the Atcheson graphites examined fell in the range -20.5×10^{-6} to -21.2×10^{-6} cgs. For comparison, Guha and Roy[2] find for the spur of a single crystal the value -23.5×10^{-6} cgs. The "anisotropy ratio" for the manufactured graphites ranged from 1:1 to 9:1, whereas that reported for the single crystal was of the order of 60/1. One may interpret these results as suggesting that not more than 10 percent of the material in the artificial graphites is of a nongraphitic nature.

One should expect a single determination of the susceptibility of a powdered, and presumably randomly oriented, artificial graphite to be one-third of -21×10^{-6}, or about -7×10^{-6}. Values reported in the literature range from -3×10^{-6} to -5×10^{-6}. These low values are probably due to orientation of the powder either in packing or in the magnetic field, or possibly to a ferromagnetic impurity. The present results demonstrate that manufactured graphite yields the same susceptibility as natural graphite, up to a minor correction for intercrystallite carbon, or crystallites too minute to develop a crystalline field.

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* This report is based on studies conducted for the U. S. Atomic Energy Commission.

[1] J. J. Donoghue (to be published).

[2] B. C. Guha and B. P. Roy, Indian J. Phys. **17**, 348 (1934).

The Statistics of a Two-Dimensional, Hexagonal Net

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In a recent paper,[1] Gurney discusses the specific heat of graphite and shows that for low temperatures, the specific heat goes as T^2 and is consistent with the model he proposes to describe the distribution of normal modes. In this model, the only contributing modes at these low temperatures are those that propagated in the plane of the hexagonal network of the carbon atoms and whose displacements are perpendicular to these planes. It is the two-dimensional nature of the problem that leads to the T^2 law, and the analysis of the problem is completed using a Debye frequency distribution and a Debye temperature.

However, for this problem, a closed analytic expression can be found for the frequency distribution by methods previously described[2] for the case of nearest neighbor interactions. The coupling constant between nearest neighbors can be evaluated from the comparison of the value of the distribution function at zero frequency and the low temperature behavior of the specific heat.

The distribution function is written as $g(\bar{\omega}^2)d(\bar{\omega}^2)$, where $\bar{\omega}^2$ is the dimensionless frequency whose range is $0\leq\bar{\omega}^2\leq1$ and is related to the maximum frequency $\omega=\omega_{\max}\bar{\omega}$. In this expression $\omega_{\max}=(6\alpha)^{\frac{1}{2}}$, where α is the ratio of the force constant and the atomic mass and is described by writing the contribution to the acceleration of the nth atoms as $-\alpha(u_n-u_N)$, where u_n is the atomic coordinate and u_N is the coordinate of a nearest neighbor.

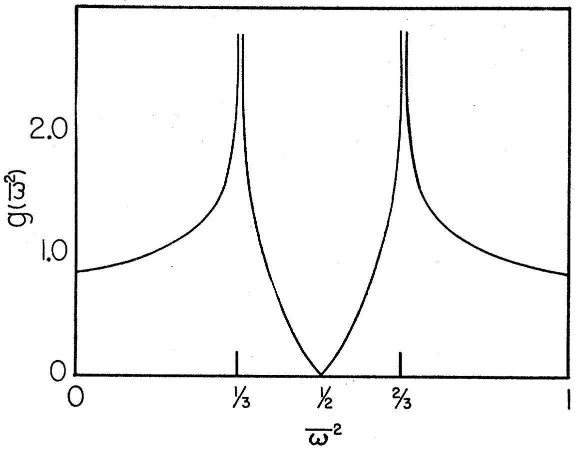

FIG. 1. The distribution function $g(\bar{\omega}^2)$ *vs* $\bar{\omega}^2$ for the two-dimensional hexagonal net in nearest neighbor interaction in normal vibration to the plane of the net.

With this notation, the expression for $g(\bar{\omega}^2)$ is

$$g(\bar{\omega}^2)=\frac{9}{\pi^2}\left[\frac{1-2\bar{\omega}^2}{3}\right]^{\frac{1}{2}}K\left[\frac{\bar{\omega}^2(2-3\bar{\omega}^2)^3}{(1-2\bar{\omega}^2)}\right]^{\frac{1}{2}},\quad 0\leq\bar{\omega}^2\leq\tfrac{1}{3};$$

$$g(\bar{\omega}^2)=\frac{9}{\pi^2}\frac{1-2\bar{\omega}^2}{[3\bar{\omega}^2(2-3\bar{\omega}^2)^3]^{\frac{1}{2}}}K\left[\frac{1-2\bar{\omega}^2}{\bar{\omega}^2(2-3\bar{\omega}^2)^3}\right]^{\frac{1}{2}},\quad \tfrac{1}{3}\leq\bar{\omega}^2\leq\tfrac{1}{2};\qquad(1)$$

where

$$K(p)=\int_0^1\frac{dx}{[(1-x^2)(1-p^2x^2)]^{\frac{1}{2}}},$$

and the function is symmetric about $\bar{\omega}^2=\frac{1}{2}$.

Figure 1 is a plot of $g(\bar{\omega}^2)$. There are two symmetric infinite peaks whose asymptotic behavior is described by

$$g(\bar{\omega}^2)\cong\frac{9}{2\pi^2}\log\frac{2}{1-3\bar{\omega}^2},\qquad(2)$$

$$\bar{\omega}^2\rightarrow\tfrac{1}{3}.$$

The specific heat at low temperatures is determined by $g(0)$, whose value is

$$g(0)=9/2\pi\sqrt{3}.\qquad(3)$$

The specific heat per mole at low temperatures can be found from the following expression for a two-dimensional lattice:

$$C_V=3.606Nkg(0)T^2/\theta^2,\qquad(4)$$

where $g(0)\neq0$ and is finite and $\theta=\hbar\omega_{\max}/2k$. Using the data[3] from reference 1, we find $\alpha=13.34\times10^{26}$ sec^{-2}, and $\omega_{\max}=8.95\times10^{13}$ sec^{-1}.

The details of the calculation will be published elsewhere.

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[1] Ronald W. Gurney, Phys. Rev. **88**, 465 (1952).

[2] W. A. Nierenberg, J. Chem. Phys. **19**, 659 (1951).

[3] It can be remarked that the first entry in reference 1, Table I, for θ^2 should be 373 000, improving the T^2 fit and changing the mean θ^2 to 375 200.

Normal Fluid Concentration in Liquid Helium II below 1°K*

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MEASUREMENTS of second sound velocity u_2 recently obtained by the authors[1] permit one to calculate the normal fluid concentration ρ_n/ρ at temperatures below 1°K. This has been done, employing the well-known relationship

$$\rho_n/\rho_s=\frac{S^2T}{C}\frac{1}{u_2^2},\qquad(1)$$