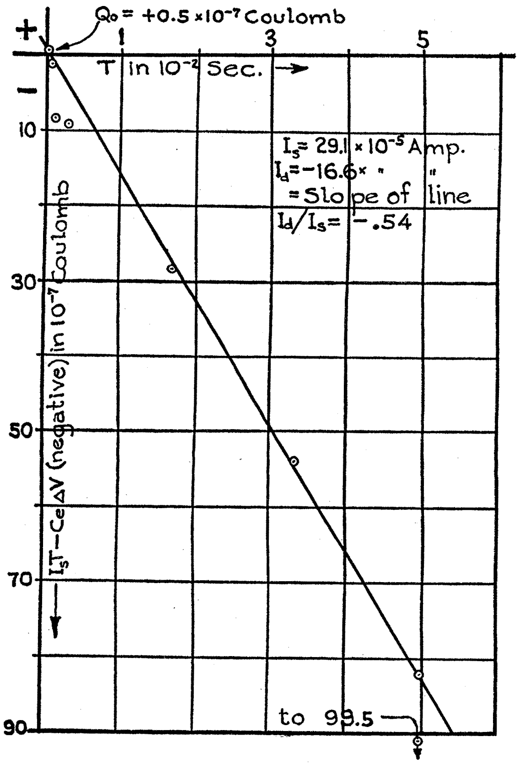

FIG. 3. $(I_sT - C_e\Delta V)$ *vs* T. Pressure = 0.16 mm Hg; D = 275 mm; gas H_2; electrodes: Cu disks 20.1 cm in diameter.

relative to the supply current and aids in the recharging of the condensers.

For still lower pressures, I_d was many times $-I_s$. A large number of experiments were made at various pressures, and the ratios I_d/I_s were plotted against log$P$. Figure 4 shows the results. Thus, at higher pressures I_d/I_s approaches unity. At lower pressures I_d/I_s may be -5, -20, or even more negative.

From the fact that the dark current is reversed at low pressures and the further fact that just before a flash the potential difference must be in the normal direction, it is believed that the dark current at low pressure undergoes one back and forth relaxation oscillation each period. On that assumption the intermittent glow discharge at low pressures may be interpreted as consisting of a series of current pulses of rapidly oscillating electrons separated by intervals during which the current through the gas probably oscillates once.

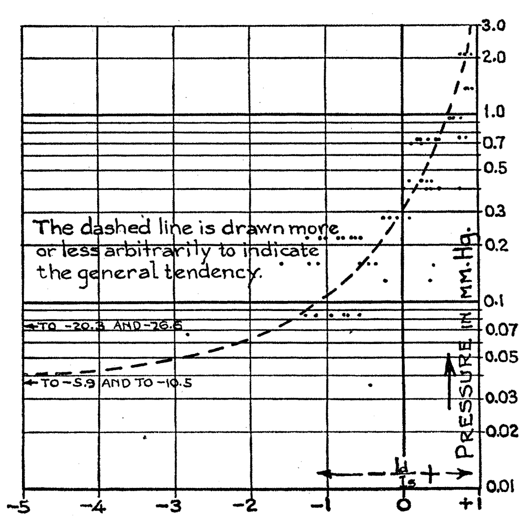

FIG. 4. Dark to charging current ratio *vs* gas pressure. Gas H_2; D = 275 mm; electrodes: Cu disks 20.1 cm in diameter.

So far as the writer knows, there is no mention in the literature of the relatively high magnitude of the dark current nor of its reversal of direction.

The writer wishes to acknowledge his indebtedness to the Department of Physics, Northwestern University, for making available to him the experimental facilities used for these measurements.

[1] E. W. B. Gill, Phil. Mag. 8, 955 (1929).
[2] S. K. Mitra, Phil. Mag. 14, 616 (1932).
[3] D. E. Clark, unpublished studies at Northwestern University (1935).

The Dispersion of Permittivity and Conductivity of Semiconductors

R. E. BURGESS
Radio Research Station, Slough, Bucks, England
(Received February 7, 1952)

IN the recent paper by the late C. G. Koops[1] on the dispersion of permittivity and resistivity of nickel-zinc ferrites, use is made of the two-layer model of the dielectric medium in which one layer represents the grains of the ferrite, and the other the insulating intergranular material which may owe its low conductivity to a physical barrier layer or to chemical differences from the grain material.

In the paper the validity of this model was tested by attempting to find the best fit to the curves of resistivity, permittivity, and loss tangent (as functions of frequency) using the theoretical dependence of these quantities on frequency. The goodness of the fit so obtained is not very satisfactory, as may be seen from the tanδ curves in which the calculated values reach a maximum considerably higher than the experimental observations. It is, therefore, relevant to examine the applicability of the two-layer model to these observations, and to determine in some unequivocal manner the parameters defining the model which best fit the data.

A simple general method for such an analysis of dispersion in semiconductors is as follows: The permittivity ϵ and conductivity σ of a dielectric conforming to the two-layer model are given by equations of the Debye type:

$$\epsilon=\epsilon_\infty+\frac{\epsilon_0-\epsilon_\infty}{1+\omega^2\tau^2} \quad \text{and} \quad \sigma=\sigma_\infty-\frac{\sigma_\infty-\sigma_0}{1+\omega^2\tau^2}, \tag{1}$$

where $\omega=2\pi\times$frequency, τ = relaxation time, and the suffixes denote the values at zero and infinite frequency. Furthermore

$$\tau=\frac{1}{4\pi}\frac{\epsilon_0-\epsilon_\infty}{\sigma_\infty-\sigma_0}. \tag{2}$$

Thus, if ϵ is plotted against σ (with frequency as parameter) a straight line of slope $-(\epsilon_0-\epsilon_\infty)/(\sigma_\infty-\sigma_0)=-4\pi\tau$ should be obtained. Hence the degree of linearity of the ϵ, σ plot is a measure of the closeness with which the two-layer model in fact accounts for the observed data, and the best straight line which can be drawn through the experimental points enables the relaxation time τ to be determined directly.

This method is illustrated by Fig. 1, in which the data from Table I of Koops's paper have been replotted on an ϵ, σ basis. The plot is quite curved, thus showing that the simple model is not very closely obeyed, especially at the higher frequencies.

From Eq. (2) the value of τ fitting the over-all range of permittivity and conductivity values is 1.1×10^{-4} sec. However, for the lower frequencies a higher value is clearly appropriate in view of the slope of the ϵ, σ curve, while at the higher frequencies a lower value of τ is inferred.

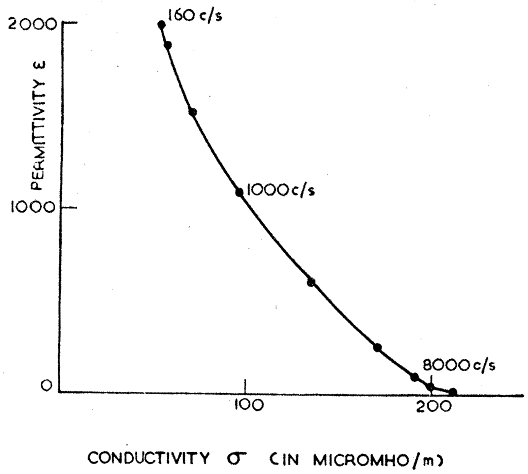

FIG. 1. Replot of Koops' data from Table I.

The loss tangent for the model is given by

$$\tan\delta \equiv \frac{4\pi\sigma}{\omega\epsilon} = \frac{4\pi}{\omega}\,\frac{\sigma_0+\omega^2\tau^2\sigma_\infty}{\epsilon_0+\omega^2\tau^2\epsilon_\infty}.$$

For the materials under discussion, $\epsilon_0/\epsilon_\infty \gg \sigma_0/\sigma_\infty$, and $\tan\delta$ then has minimum and maximum values of

$$\tan\delta_{\min} = 2(\sigma_0\sigma_\infty)^{\frac{1}{2}}/(\sigma_\infty-\sigma_0) \quad \text{at} \quad \omega\tau = (\sigma_0/\sigma_\infty)^{\frac{1}{2}},$$
$$\tan\delta_{\max} = (\epsilon_0-\epsilon_\infty)/[2(\epsilon_0\epsilon_\infty)^{\frac{1}{2}}] \quad \text{at} \quad \omega\tau = (\epsilon_0/\epsilon_\infty)^{\frac{1}{2}}.$$

From Koops' data $\sigma_\infty/\sigma_0 \approx 4$, whence $\tan\delta_{\min} = 1.3$ and $\epsilon_0/\epsilon_\infty \approx 130$ giving $\tan\delta_{\max} = 5.7$; these values lie close to the experimental ones of 1.4 and 6.7.

[1] C. G. Koops, Phys. Rev. 83, 121 (1951).

The Inelastic Scattering of Fast Neutrons from Iron*

P. H. STELSON AND W. M. PRESTON
Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts
(Received February 13, 1952)

WITH adequate resolution and at moderate energies, the energy distribution of inelastically scattered neutrons should exhibit a "line spectrum." The theory has been given by Feld and others.[1] Experimental difficulties, particularly the low efficiency of high-resolution fast-neutron spectrometers, have thus far prevented the direct detection of separated neutron groups.

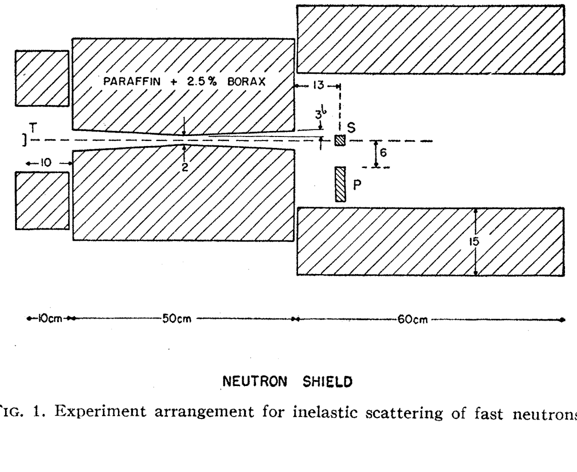

FIG. 1. Experiment arrangement for inelastic scattering of fast neutrons.

Their existence has been inferred by Feld[1] from the poor-geometry experiments of Barschall *et al.*,[2] in the case of 2–3 Mev neutrons scattered from iron, and for a number of elements by Grace *et al.*[3] by the detection of the γ-rays emitted from the low excited states in which the target nucleus is left, following inelastic scattering.

We have carried out a straightforward experiment as illustrated in Fig. 1. The neutron source, at T, was an evaporated layer of lithium having roughly 100-kev stopping power for protons at the bombarding energy of 3.61 Mev. The neutron energy distribution was, therefore, fairly uniform, from 1.82 to 1.92 Mev. The neutron beam passed through a tapered hole in the paraffin shield to the scatterer S, a cylinder of iron 2 cm in diameter and 2 cm long. Scattered neutrons were detected by the tracks of recoil protons in Eastman NTB emulsions of 200 micron thickness. The plates were placed at P, at right angles to the beam. The acceptance angle for tracks was ± 12 degrees. Exposures were for about 40 μa-hours, at an average proton current of 5 μa, but the actual monitoring was done with a BF_3 "long counter." Additional shields around the target and the plates served to reduce background from the walls of the room.

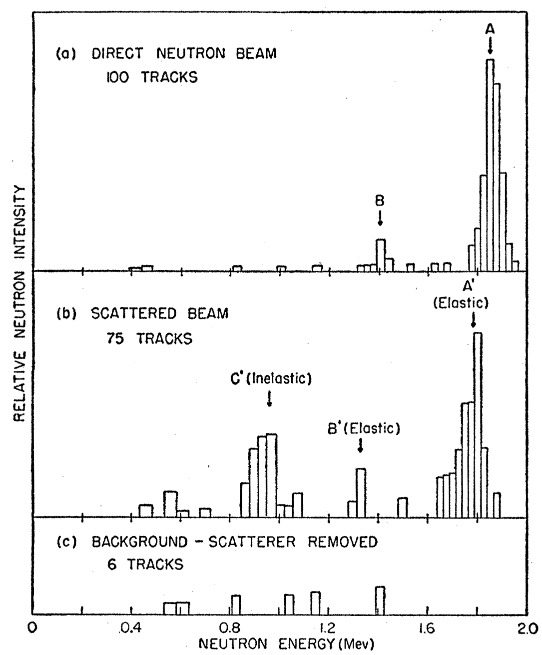

FIG. 2. Histograms of relative neutron intensity *vs* neutron energy derived from recoil proton track length distributions in nuclear track plates.

The results are shown in Fig. 2. Histogram (a) is the energy spectrum of the incident neutron beam determined by exposing plates at the position of the scatterer, S. Peaks A and B are the familiar primary and secondary neutron groups from the Li(p, n) reaction. The intensity of neutrons other than those in peaks A and B is low, showing that the arrangement produces a reasonably monoenergetic neutron beam at the position of the scatterer.

Histogram (b) is the neutron energy spectrum obtained by exposing plates at position P with the scatterer in place. Histogram (c) is the result of a similar exposure but with the scatterer removed to obtain a background measurement. The two histograms are normalized with respect to exposure time and area of emulsion measured. Corrections were applied to convert the track length distributions to relative neutron intensities.[4]

A new group of neutrons, C', is observed in the scattered neutrons shown in (b). Therefore, in addition to the elastic scattering shown by peaks A' and B', there is considerable inelastic scattering