III. SOLID STATE PHYSICS

Prof. W. P. Allis
Prof. S. C. Brown
Prof. G. G. Harvey
Prof. L. Tisza
J. M. Goldey
R. Gollub
E. M. Gyorgy
T. D. Schultz

A. SOFT X-RAY VACUUM SPECTROGRAPH

We have completed the study of the 3P emission curve of manganese. The curves have sharp emission edges and clearly show the $P_{3/2,\ 1/2}$ separation. The results have in some ways been disappointing. The intensity is low, and it was not possible to obtain curves that were reproducible with the accuracy obtained for the copper, nickel, and chromium emission curves. We are now undertaking the study of iron. The use of alumina crucibles will allow us to evaporate the sample more rapidly than was previously possible.

An experiment is under way to determine quantitatively the rate at which exposure to air reduces the yield of a beryllium-copper electron multiplier of the Allen type.

G. G. Harvey, R. Gollub, E. M. Gyorgy

B. MICROWAVE PROPERTIES OF GERMANIUM

Using the resonant cavity technique, we have completed the experimental measurement of the dielectric coefficient of germanium in the 10-cm region. Conduction electrons in an alternating field give a contribution to the dielectric coefficient. It is necessary to subtract this contribution from experimentally determined values if one is to obtain the inherent dielectric coefficient of the lattice. If a complex expression is used for the conductivity of a medium in Maxwell's equations, it follows directly that the dielectric coefficient is given by

$$\frac{\epsilon_r}{\epsilon_o} = \frac{\epsilon}{\epsilon_o} + \frac{\sigma_j}{\omega\epsilon_o} \tag{1}$$

where ϵ is the lattice contribution to ϵ_r. σ_j is a negative quantity as is shown below; hence, the conduction electrons reduce the dielectric coefficient of the medium.

The expression for the complex conductivity may be obtained from transport theory. Margenau (Phys. Rev. 69, 508, 1946) has obtained this for an ionized gas in an alternating field. We have carried through the analysis for the semiconductor problem and have obtained the same result, assuming that the energy surfaces are spherical and the electron gas is nondegenerate. The expression for conductivity is

$$\sigma = \sigma_r + j\sigma_j = \frac{4\pi}{3}\frac{e^2}{m}\int \frac{\partial F_o/\partial v}{\nu_c + j\omega} v^3\, dv \tag{2}$$

where F_o is the electron energy distribution function, ν_c is the collision frequency v/ℓ,

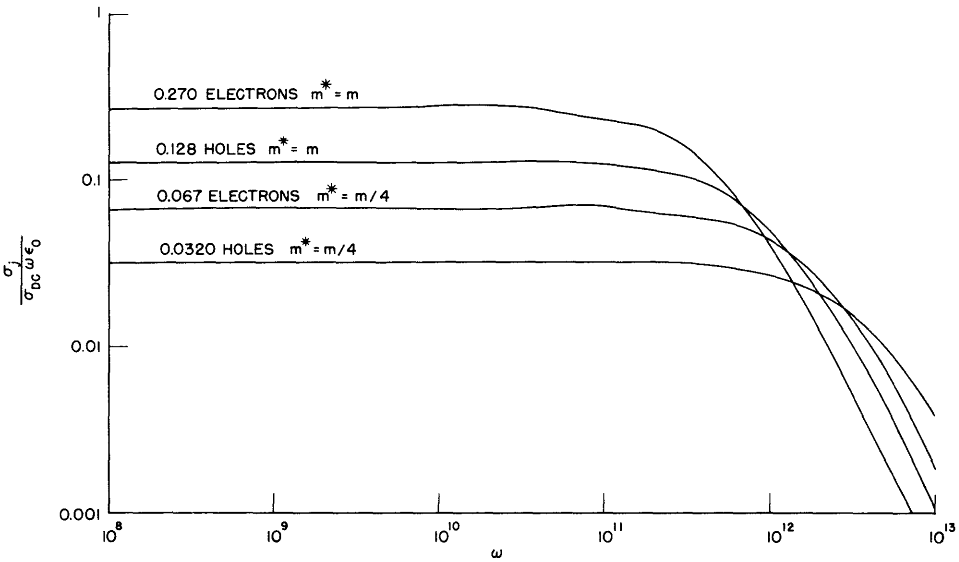

Fig. III-1

$\sigma_j/\sigma_{dc}\omega\epsilon_o$ as a function of frequency for electrons and holes in germanium for two values of the effective mass.

and ω is the (angular) applied frequency. The integration for constant mean-free path has been obtained by Margenau for the case of F_o Maxwellian. The relative magnitude of σ_r and σ_j is dependent upon the mass of the carriers involved, since the collision frequency depends on this quantity.

In Fig. III-1, we show the quantity $\sigma_j/\sigma_{dc}\omega\epsilon_o$ as a function of ω. We have made the calculation for both holes and electrons for two values of the effective mass. The mobilities were taken as μ_p = 1700 volt-sec/cm^2 and μ_n = 3600 volt-sec/cm^2. The effective mass m* was taken as m and as m/4, where m is the free electron mass. Once the dc conductivity and the carrier type are specified, the term $\sigma_j/\omega\epsilon_o$ may be obtained from these curves if the proper value of the effective mass is used.

It was mentioned above that the experimental work has been completed. Seventy-odd measurements were made on samples of both p and n types. The resistivities varied from intrinsic to 7.0 ohm-cm. Sample diameters ranged from 0.020 inch to 0.035 inch corresponding to a variation in the ratio of cavity diameter to sample diameter of 150 to 85. The large number of measurements permitted a statistical analysis of the data to be made. The correction for the conduction electron, discussed above, was applied, and a least-square analysis was made. The results are shown for the two cases of m* = m and m* = m/4

	m	m/4
ϵ/ϵ_o	18.9 ± 1.2	17.8 ± 0.6

It is to be noted that the value obtained here is not in good agreement with values in the neighborhood of 16 obtained in the infrared and at higher microwave frequencies.

The results of the conductivity measurements are in general agreement with dc values. This is expected at this frequency.

J. M. Goldey