

IV. SOLID STATE PHYSICS

Prof. W. P. Allis
Prof. S. C. Brown
Prof. C. W. Garland
Prof. G. G. Harvey

Dr. E. R. Pike
G. Ascarelli
T. Higier

L. L. Isaacs
R. G. Newburgh
J. Silverman
R. Weber

A. RECOMBINATION OF ELECTRONS AND DONORS IN GERMANIUM

During the last quarter we have carried out measurements of the recombination cross section of electrons with arsenic donors in germanium with the same technique used for antimony (1). Again, we studied the temperature dependence of the recombination time τ , and the cross section σ ; the results are in good agreement with those measured for antimony (Fig. IV-1). The compensation was determined from the intercept of the exponential decay of the density with the time axis, as in the previous case, and the mobility was again assumed as 10^5 cm²/volt-sec (Fig. IV-2). The value of the cross sections at 4.2° K are 9.6 times smaller than those for antimony, and therefore there is a dependence of the recombination cross section on the binding energy similar to that predicted theoretically (Fig. IV-3).

Furthermore, it was noticed, both in the antimony sample and in the arsenic sample, that the intercept of the exponential with the time axis is nearly independent of temperature. This could be explained either by the action of neutral impurities on the mobility

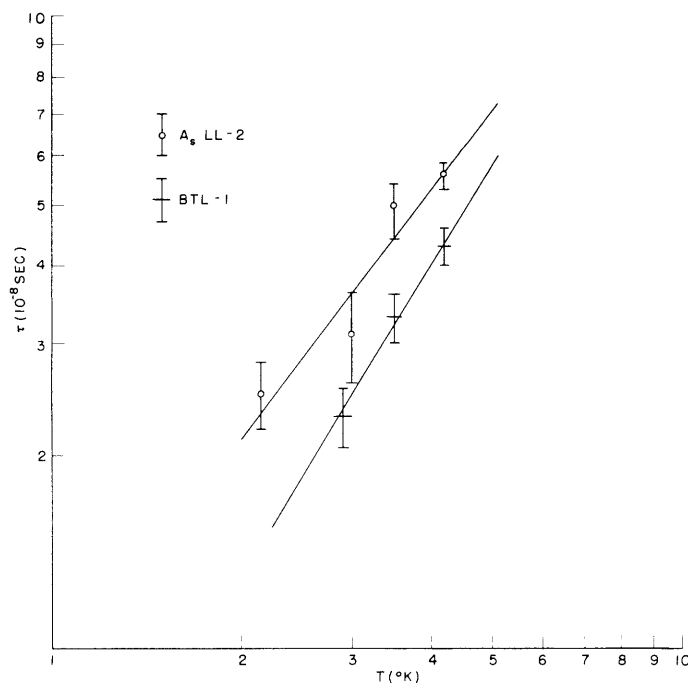


Fig. IV-1. Measured time constants for the recombination of electrons with arsenic and antimony as a function of temperature.

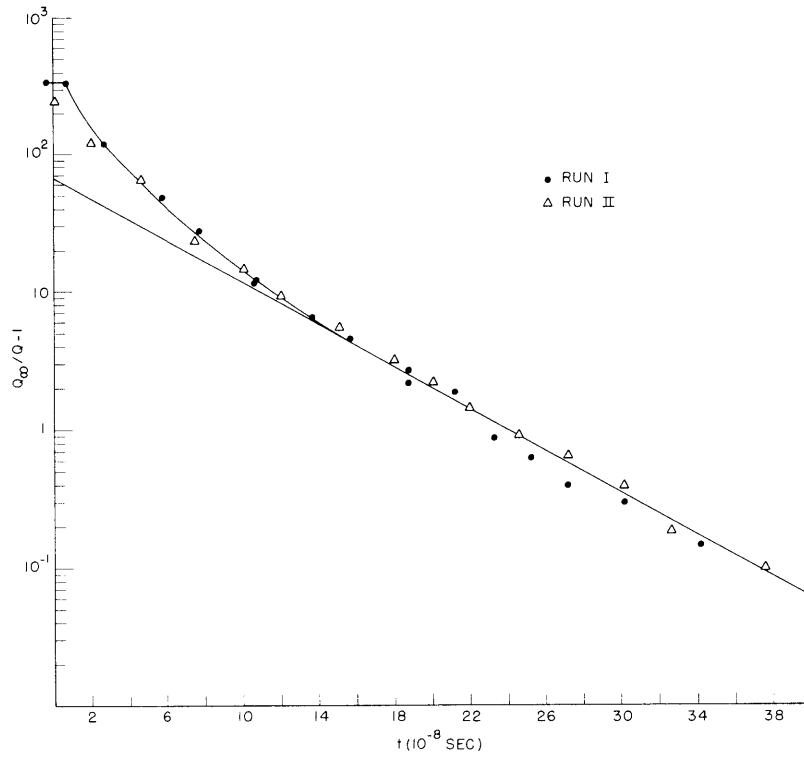


Fig. IV-2. Cross section for recombination of electrons with arsenic donors. ($N_A = 3.54 \times 10^{12}$ cc).

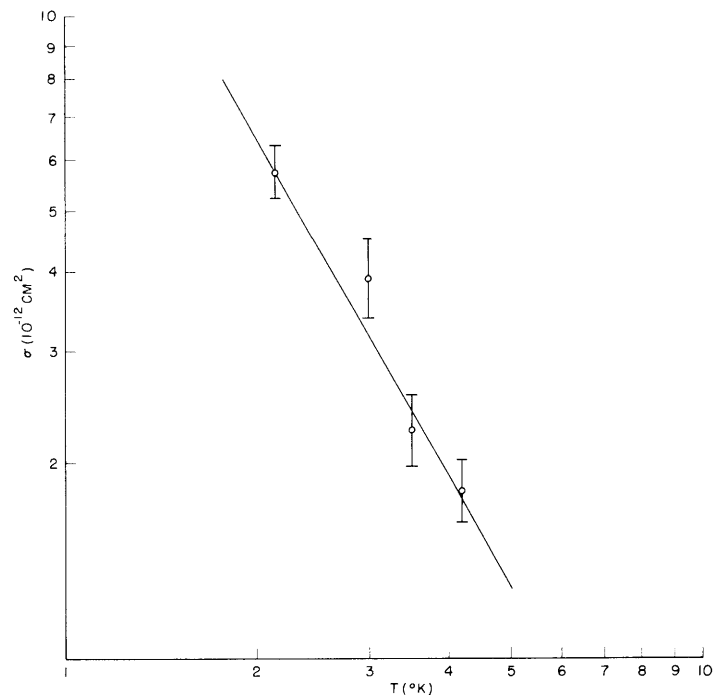


Fig. IV-3. Recombination of electrons with arsenic donors at 4.2° K.

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(N₂, H₂, O₂) that would produce a temperature-independent mobility, or by the fact that ionized impurity scattering is beginning to be important but still of the same order of magnitude as lattice scattering, the combination of which produces a region where the mobility is nearly independent of temperature.

We exchanged samples with Dr. S. H. Koenig, of IBM Corporation, who has made measurements similar to ours. His measurement of the decay time constant of sample BTL-1 yielded $\tau = 5 \times 10^{-8}$ sec, as compared with ours, $\tau = 4.3 \times 10^{-8}$ sec. The difference is outside experimental error. From his sample, n WLB 28-6, our result is $\tau = 3.3 \times 10^{-8}$ sec, as compared with 9×10^{-8} sec measured at Watson Laboratories. (Koenig's results were reported in Quarterly Progress Report No. 53, pp. 29-30.) The differences might be attributed to heating, and work is continuing in an attempt to account for the discrepancies.

G. Ascarelli

References

1. G. Ascarelli, Recombination of electrons with donors in germanium, Quarterly Progress Report No. 53, Research Laboratory of Electronics, M.I.T., April 15, 1959, p. 27.

B. M-EMISSION BANDS OF COPPER AND NICKEL IN THE SOLID STATE

The vacuum spectrograph built by Piore, Harvey, and Kingston, and used by Gyorgy (1) to study the transition elements, has been used to re-examine copper and nickel. The spectrograph consists of a grating set for grazing incidence with a Rowland mounting. The detector is a movable beryllium-copper photomultiplier. Radiation can be measured in the range 50-800 Å. By several minor modifications, primarily an improved trapping system for the diffusion pump attached to the X-ray chamber, the

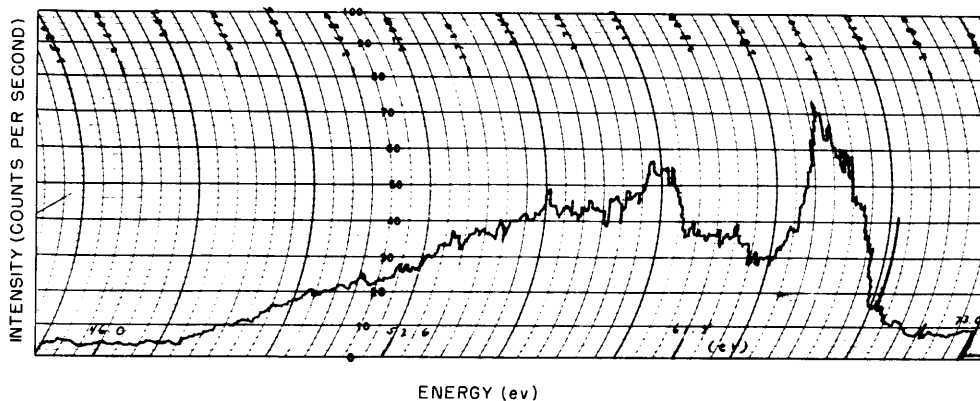


Fig. IV-4. Solid copper.

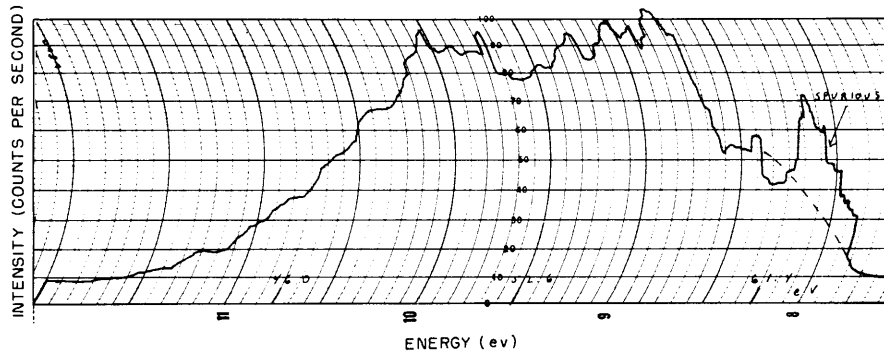


Fig. IV-5. Solid nickel.

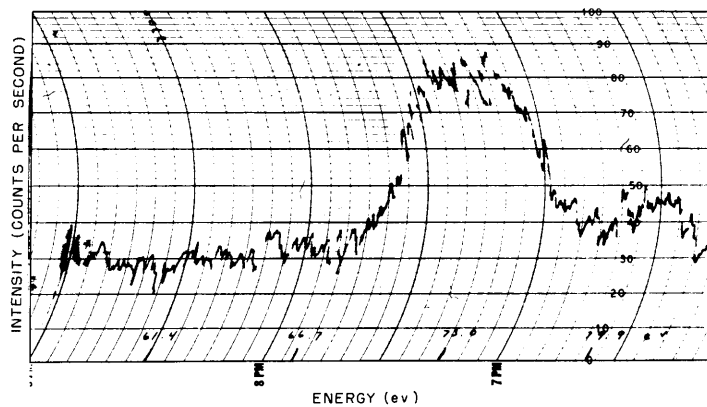


Fig. IV-6. Evaporated copper.

operating pressure was improved to 1×10^{-7} mm Hg. This improved pressure and the use of hydrogen firing as a cleaning technique permit the use of solid, as opposed to evaporated, targets.

The earlier work in this field was done with evaporated films, laid down at pressures between 10^{-5} and 10^{-6} mm Hg. At these pressures an appreciable amount of oil molecules strikes the target during evaporation. If a film is laid down at the rate of 1000 Å/min at 10^{-6} mm Hg, one oil molecule strikes the target for every eight metal atoms. In addition, the structure of thin evaporated films often differs very greatly from that of the pure bulk solid.

It was found that the results for solids (Figs. IV-4 and IV-5) differed markedly from those for evaporated films (Fig. IV-6). The spectra examined arise from transitions from the valence levels into the $^3p_{1/2}$, $^3p_{3/2}$ atomic levels. The bands from the solid targets did not agree with Gyorgy's results from evaporated films. Where he found single peaked bands, 7.1 eV and 5.3 eV wide, for copper and nickel, the solid targets had double peaked bands approximately 15 eV and 12 eV wide, respectively.

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The earlier results were confirmed by evaporating in poor vacuum onto contaminated surfaces. Because of this confirmation and the difficulty in preparing evaporated films with a well-ordered crystal lattice, the present results obtained with solid materials are presumably the more reliable of the two. The two peaks and the large width suggest that the 3d-band in copper and nickel is not so narrow as previously believed.

R. G. Newburgh

References

1. E. M. Gyorgy, M emission bands of the transition metals in the solid state, Technical Report 254, Research Laboratory of Electronics, M.I.T., May 25, 1953.