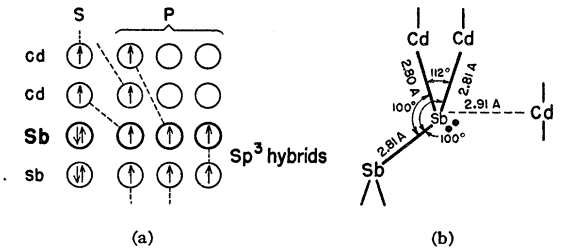

FIG. 1. (a) Schematic representation of valence electron orbitals of Cd and Sb atoms in CdSb. Arrows indicate occupation of orbitals by one or two electrons. Dotted lines indicate chemical bonds. As all orbitals are equivalent in the hybridized sp^3 bonds formed by Sb, there is no significance in the particular orbitals selected in indicating chemical bonds by the dotted lines. (b) Approximate bond angles and distances of the nearest neighbors of an Sb atom in CdSb.

by demonstrating the presence of the semiconducting bond. We give here only one example, that of the semiconductor CdSb which has not so far received a satisfactory explanation. Each Sb atom is surrounded approximately tetrahedrally by two Cd atoms and one Sb atom. The other pair of electrons on the Sb atom presumably takes the fourth tetrahedral position so that each Sb atom forms sp^3 bonds and has a filled subshell. Another Cd atom is also located in the vicinity of the Sb atom but at a greater distance than the two considered above and at widely varying bond angles to the other atoms about Sb. We do not, therefore, consider it as entering the bonding scheme, which is illustrated in Fig. 1. We see that the conditions for the semiconducting bond are then fulfilled as the Sb atom forms a filled subshell and the Cd atoms which have vacant metallic orbitals are not bonded together, while the Sb—Cd bonds run continuously throughout the lattice.

So far our discussion has shown that the semiconducting bond allows a distinction to be made between semiconductors on the one hand and metals on the other hand, while it also shows the relationship between ionic solids and semiconductors. It remains to add that the formation of a continuous network of bonds in semiconductors distinguishes them from the last of the main classes of solids, namely the molecular crystals. The necessity of such networks for the occurrence of electronic conduction in solids has been discussed by Krebs and Schottky.[1]

A more detailed account of the present work together with its application to the prediction of semiconductivity in solids will be published elsewhere in due course.

We are particularly indebted to Dr. J. S. Dugdale and to many others with whom we have discussed aspects of this work.

* National Research Laboratories Postdoctorate Fellow—now with Eidgenössische Technische Hochschule, Zurich, Switzerland.

[1] H. Krebs and W. Schottky, *Halbleiterprobleme. I* (Friedrich Vieweg und Sohn, Braunschweig, 1954).

[2] L. Pauling, Proc. Roy. Soc. (London) **A196**, 343 (1949).

[3] L. Pauling, *The Nature of the Chemical Bond* (Cornell University Press, Ithaca, 1939).

Recombination Radiation from InSb

T. S. MOSS AND T. H. HAWKINS

Royal Aircraft Establishment, South Farnborough, England

(Received December 27, 1955)

RADIATION from InSb produced by the recombination of optically produced excess carriers has been detected in the wavelength region near the absorption edge.

Thin specimens of pure InSb were prepared by grinding and etching small single-crystal samples obtained from a zone-melted ingot. Chopped radiation from a tungsten filament lamp was focused on the specimen by glass lenses which completely prevented all long-wavelength radiation from reaching the specimen. The emitted radiation was collected by an $f/0.8$ mirror and analyzed by a double monochromator.

In spite of a well-designed detector system using a high-sensitivity Hilger-Schwarz thermopile, low-noise 5-cps amplifier, and synchronous detection with effective band width $\sim\frac{1}{4}$ cps, signal/noise ratios were poor and consequently resolution was poor.

The curve of Fig. 1 was obtained for a specimen 12μ thick. The peak of the curves lies near the absorption edge for pure InSb, as expected. The absolute magnitude of the emission was obtained by calibrating the system by replacing the specimen by a known blackbody. The total rate of incidence of quanta on the specimen was found by measuring the total energy falling on the specimen, and by estimating the source temperature—which is not critical.

With allowance for surface reflection the total rate of absorption of incident quanta was 1.3×10^{17}/sec.

Assuming unity efficiency of production of hole electron pairs, and a fraction α of the total recombinations to be radiative, it is estimated from the theory for photocarrier distribution given by Moss[1] and from the theory of radiative recombination and absorption that $\sim\frac{1}{6}$ of the photons reach the back surface of the sample. Here there is a reflection loss of 33% and a loss of 170:1 resulting from the fact that only radiation falling within a semiangle of $\pm8°$ reaches the collecting mirror. Hence

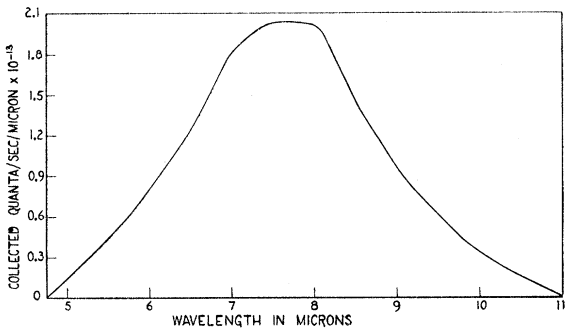

FIG. 1. Spectral distribution of recombination radiation from InSb.

the total expected radiation is $\sim 10^{14}\alpha$/quanta sec. Integration of Fig. 1 shows the measured radiation to be 6×10^{13} quanta/sec.

Thus $\alpha \sim 0.8$, i.e., the fraction of total recombinations which are radiative in this material approaches 100%.

As a result of the low signal levels and the difficulties of accurately calibrating the spectrometer system and the primary radiation, the above figure may be in error by as much as 2:1 either up or down. Nevertheless the experiment shows clearly that radiative recombination is the main recombination mechanism in this material.

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Ultrasonic Attenuation in Superconducting Indium*

R. W. Morse, P. Tamarkin, and H. Bohm

Physics Department, Brown University, Providence, Rhode Island

(Received January 4, 1956)

RECENT papers have reported an ultrasonic attenuation in metals at helium temperatures which is electronic in origin.[1–4] In superconducting tin and lead this attenuation has been found to diminish rapidly when the temperature is lowered below the transition temperature. The present paper reports the temperature dependence of this attenuation in superconducting, polycrystalline indium of two different purities. The measuring equipment is the same as that employed by Mackinnon[3]: a 10-Mc/sec longitudinal ultrasonic pulse is applied to one end of the sample by a quartz crystal, and is received by a similar crystal at the other end. After being amplified and rectified, the pulse is displayed on an oscilloscope screen, where

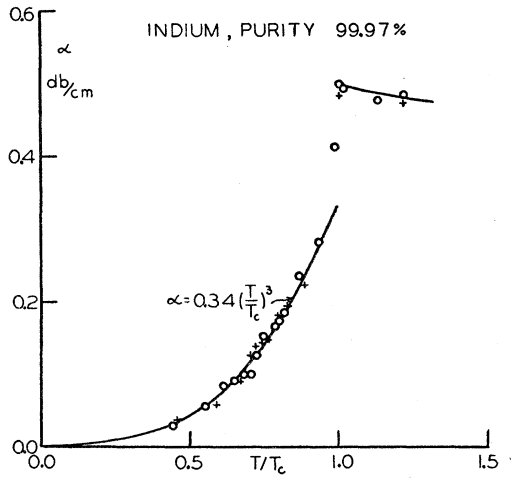

FIG. 1. Attenuation at 10 Mc/sec in polycrystalline indium of purity 99.97%. Different symbols for points denote different experimental runs.

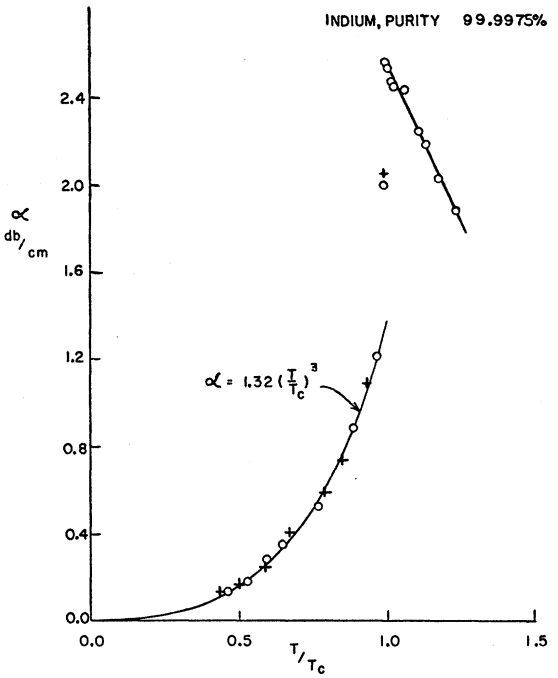

FIG. 2. Attenuation at 10 Mc/sec in polycrystalline indium of purity 99.9975%. Different symbols for points represent different experimental runs.

it is photographed. These recorded amplitudes are then measured as a function of temperature. It is not possible without further assumptions to determine the absolute attenuation by this means but relative values can be calculated on the assumption (reasonable at these temperatures) that the principal temperature-dependent factor affecting the pulse amplitude is the attenuation. We have proceeded as follows: the measured pulse amplitudes at temperatures between 4.2°K and 1.5°K were reduced to attenuation coefficients relative to the attenuation at the lowest temperature reached; the curve of relative attenuation *vs* temperature was then extrapolated to absolute zero and the intercept so obtained was chosen as a new zero reference level. Measurements of absolute attenuation in tin and lead indicate that the electronic contribution in the superconducting state goes to zero with the temperature.[1,4] If this is also true for indium, then a reduction in the manner outlined would yield absolute values of the electronic attenuation. The results are shown by the points in Figs. 1 and 2.

Several explanations of ultrasonic attenuation by conduction electrons in *normal* metals have been proposed.[5–8] For electron mean-free-paths smaller than the wavelength (this condition holds here), these explanations all indicate basically that a small lack of equilibrium between the electron distribution and the motion of the lattice leads to a thermal dissipation of energy. There is, however, no clear picture of what is happening in the superconducting state. It has been