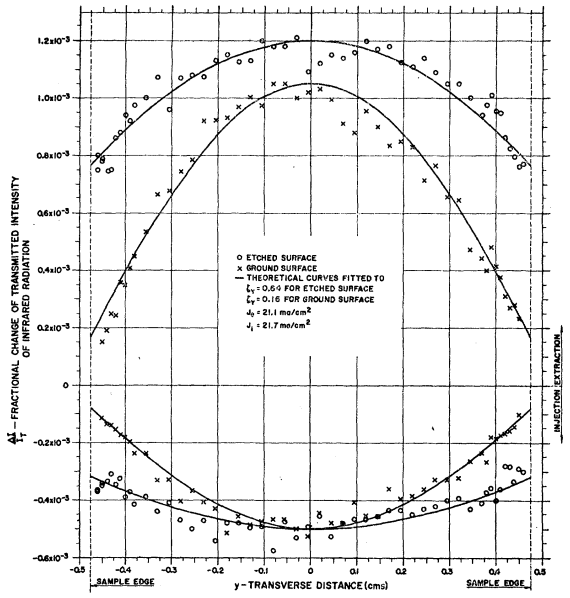

FIG. 2. The fractional change of transmitted infrared radiation caused by injection and extraction *vs* transverse distance for ground and etched surfaces. J_i and J_e are current densities for injection and extraction, respectively.

infrared radiation, one can show that

$$s=\frac{D}{Y}\left(\frac{(1-\zeta_Y^2)^{\frac{1}{2}}}{\zeta_Y}\right)\cos^{-1}\zeta_Y.$$

Here D is the diffusion constant, Y is the half-width of the sample, and $\zeta_Y=(\Delta I)_{y=Y}/(\Delta I)_{y=0}$, where the ΔI's are the changes in the transmitted infrared intensity. The ΔI's have been normalized with respect to the total transmitted intensity prior to injection or extraction, I_T. This is necessitated by the nonhomogeneity of the transmission of the sample. It can be shown that the above formula is valid for the case of extraction as well as injection.

Figure 1 is schematic of the setup which has been used in the present experiments to measure infrared absorption. A globar is used as the source of infrared radiation. A thin piece of germanium, for filtering out radiation of wavelength less than 1.8 microns, and a 0.5×3.5 mm slit are interposed between the infrared source and germanium sample. A thermopile serves to detect the radiation which is transmitted by the germanium bar. The data consist of the measurement of I_T and the changes in the transmitted infrared radiation due to injection or extraction, which are just the negative of the changes in absorbed radiation. The present measurements were made on a 45 ohm cm, p-type, high bulk lifetime, 9.5×9.5×70 mm germanium bar. One end was highly doped p-type and served to inject or extract holes.

Figure 2 shows some measurements of $\Delta I/I_T$ as a function of transverse distance, y. The experimental points indicating a decrease in transmitted intensity are due to injection, while those indicating an increase are due to extraction. The solid lines are theoretical curves which have been fitted to the experimental measurements at two points. These curves, but inverted, correspond to the actual carrier distributions due to injection or extraction and are similar to those shown by Shockley.[3] The good agreement between experiment and theory justifies the assumptions made and indicates that infrared absorption measurements can be used to determine carrier distributions. In the plot the circles correspond to the case where all surfaces were originally etched with CP-4 but exposed to room atmosphere for many days. Measurements recorded with ×'s were taken after two opposing longitudinal surfaces, parallel to the direction of the radiation, were ground with American Optical Company centriforce abrasive No. 305. It may be noted that for the same current, the signal due to extraction is much larger than that due to injection for the near intrinsic sample used. The measurements were made about 12 mm from the junction.

By using the data from Fig. 2 and the above formula, s is found to be 250 cm/sec for the surfaces which had originally been etched and 1900 cm/sec for the ground surfaces. The error in these values is believed to be less than 25%.

Work is being continued to study the effects of other surface treatments, and to investigate longitudinal distributions of injected or extracted carriers from which bulk lifetime may be evaluated.

Acknowledgements.—Dr. W. L. Brown of Bell Telephone Laboratories has kindly furnished the germanium ingot for the sample used in the present experiment. The author is indebted to Dr. F. K. du Pré for helpful theoretical hints and to Dr. P. H. Dowling and Dr. N. C. Jamison for assistance and discussions.

[1] A. F. Gibson, Proc. Phys. Soc. (London) **B66**, 588 (1953); H. B. Briggs and R. C. Fletcher, Phys. Rev. **91**, 1342 (1953).

[2] The phenomena of extraction has been previously observed by other means. See J. B. Arthur *et al.*; Proc. Phys. Soc. (London) **B68**, 121 (1955).

[3] W. Shockley, *Electrons and Holes in Semiconductors* (D. Van Nostrand Company, Inc., New York, 1950), p. 319.

New Semiconducting Compounds

E. MOOSER* AND W. B. PEARSON
Division of Pure Physics, National Research Council, Ottawa, Canada

(Received November 7, 1955)

DURING the course of an investigation of the fundamental factors which are responsible for intrinsic semiconductivity,[1] it became of interest to examine certain intermetallic compounds and compounds formed by the metalloids Se and Te for experimental evidence of semiconductivity. We have accordingly measured the temperature dependence of resistivity

and Hall constant of a series of substances, the following of which were found to exhibit typical semiconductor properties: Ag_2Se, Li_3Bi, TlSe, "Tl_2Se_3," SnSe, $SnSe_2$, In_2Tl_3, $InTe_3$, and $AgInTe_2$. Metallic behavior was found in Tl_2Se, BiSe, Bi_2Se_3, In_2Te, InTe, and TlTe. Since this work was carried out, Appel and Lantz[2] reported conductivity measurements on In_2Te_3 and Goodman and Douglas[3] suggested that chalcopyrites such as $AgInTe_2$ were semiconductors. Earlier Davidenko[4] mentioned the semiconducting properties of SnSe and Bi_2Se_3, without however giving any detailed measurements. While the semiconducting character of SnSe is confirmed by our measurements, we found a positive temperature coefficient of the resistivity in all samples of Bi_2Se_3 investigated.

The sample of composition Tl_2Se_3 showed semiconducting properties. However our microscopic examination confirms observations of Ketelaar *et al.*[5] that a phase of this composition, reported in earlier literature, does not exist; we believe that the behavior of this sample is due to the presence of TlSe.

All of the measurements were carried out in the apparatus described elsewhere by Dauphinee and Mooser[6] and in a temperature region extending in most cases from ~80°K up to the melting point of the sample under investigation. The homogeneity of the annealed specimens was checked by microscopic examination and, where necessary, composition was checked by chemical analysis. Full details of this work will be published elsewhere.

* National Research Laboratories Postdoctorate Fellow—now with Eidgenossische Technische Hochschule, Zürich, Switzerland.

[1] E. Mooser and W. B. Pearson (to be published).

[2] J. Appel and G. Lantz, Physica **20**, 1110 (1954).

[3] C. H. L. Goodman and R. W. Douglas, Physica **20**, 1107 (1954).

[4] V. A. Davidenko, J. Phys. (U.S.S.R.) **4**, 170 (1941).

[5] Ketelaar, t'Hart, Moerel, and Polder, Z. Krist. **A101**, 396 (1939).

[6] T. M. Dauphinee and E. Mooser, Rev. Sci. Instr. **26**, 660 (1955).

$K^+ - \tau^+$ Mass Difference*

S. Fung, A. Pevsner, and D. Ritson, *Laboratory for Nuclear Science and Physics Department, Massachusetts Institute of Technology, Cambridge, Massachusetts*

and

N. Mohler, *Physics Department, Smith College, Northampton, Massachusetts*

(Received October 21, 1955)

THEORETICAL evidence indicates the existence of a heavy meson in addition to the τ meson. The availability of analyzed K-meson beams at the Berkeley Bevatron[1] allows a comparison of τ and K-meson masses with much greater statistical accuracy than was hitherto possible. This letter reports on the result of such a comparison between 743 K-particles and 65 τ mesons.

A stack of 100 emulsions,[2] 10 in.×16 in.×400μ, was exposed to the focused and magnetically analyzed K-meson beam at Berkeley. The stack was so oriented that only particles of a constant momentum, and hence for a given mass of constant range, stopped in each pellicle. However, the momentum slowly varied across the stack from 316 to 340 Mev/c. The momentum variation was determined by measuring in each pellicle the range of the protons present in the momentum channel. A straight line was then fitted to the measured proton ranges by the method of least squares.

The region in which particles of about 900 to 1000 times the mass of the electron would stop was area-scanned for particles that stopped and decayed. The distance at which these particles stopped from the edge of the pellicles was then measured and normalized to give a range corresponding to that in a pellicle in which protons had a 1.0-cm range. Figure 1 shows these distances plotted for 743 K^+-mesons and 65 τ^+ mesons. In a separate experiment[2] the composition of this

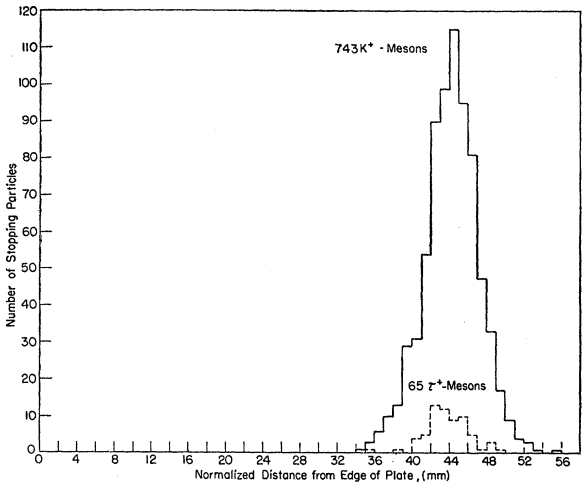

FIG. 1. Ranges of K^+- and τ^+ mesons of the same momentum in emulsion.

mixture of K^+-mesons was determined to be 63% $K_{\mu 2}$-mesons and 34% $K_{\pi 2}$ mesons.

The ratio of the mean range of the K^+-mesons to that of the τ^+ mesons can be used to determine their relative masses. The result of this determination is

$$m_{\tau^+} - m_{K^+} = (4 \pm 4) m_e. \quad (1)$$

It is of interest to note that this result is very insensitive to variations in the range-energy relation as the relative masses are determined from the ratio of two ranges. The result is also less sensitive to systematic errors than other methods of mass determination, as most systematic corrections apply equally to both. Hence, unless the energy loss mechanism for the two groups differs in such a manner as to precisely compensate for an otherwise expected range difference, we conclude that there is little, if any, mass difference between the K^+ and τ^+ meson. The statistical error quoted is the standard deviation and was calculated