higher frequency necessitates a higher temperature in order to keep the number of transitions per period constant. In other words, increasing frequency reduces the number of transitions per period at a constant "external" temperature and simulates a lower "effective" temperature.

In order to explain qualitatively brightness increases with frequency that are either faster or slower than linear as mentioned above, we consider a plot of electroluminescent brightness (B) as a function of the external temperature (T) at two different frequencies ($f_1<f_2$) and for a constant voltage applied to the phosphor (see Fig. 1). At the temperature T_1 we observe a certain brightness B_{11} with the frequency f_1. As we increase the frequency to f_2, the brightness is increased to B_{12}. One part of this change is due to a lifting of the brightness curve as a whole as the frequency is increased (dotted line); this will be called "action I." Because of "action I" only we would expect a brightness B_{12}', and a linear behavior. The other part of the change in brightness is the shift of the brightness curve along the T axis; this will be called "action II." Its effect is strongly dependent on the temperature of observation, and causes a decrease of brightness in the particular case considered, so that an increase of brightness with frequency slower than linear can be expected. This, however, may be hardly perceptible if the differential quotient dB/dT is very small and nearly constant around T_1. Now we consider a highly quenchable phosphor or an ordinary phosphor at a high temperature exhibiting a very low electroluminescence brightness B_{21} at low frequencies and at a temperature of observation T_2. The brightness increase $B_{22}-B_{21}$ which results upon increasing the frequency to f_2 is again composed of "action I" plus "action II." Here "action II" has an increasing effect ($B_{22}-B_{22}'>0$), whereas in the above case "action II" showed the opposite effect ($B_{12}-B_{12}'<0$). Thus brightness plots showing increases with frequency faster than linear can be easily obtained.

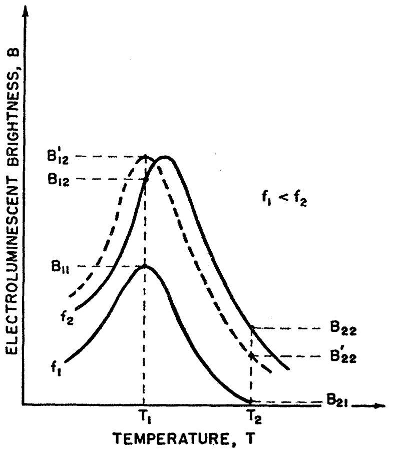

FIG. 1. Schematic representation of dependence of electroluminescent brightness on temperature at two different frequencies.

It therefore becomes obvious that it is misleading to discuss the dependence of electroluminescence brightness on frequency from experimental results unless the temperature-frequency relationship is taken into account.

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Use of Infrared Absorption to Determine Carrier Distribution in Germanium and Surface Recombination Velocity

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Absorption of infrared radiation by germanium can be increased by injecting additional carriers[1] and it has been observed in the present experiments that it can be decreased by extracting[2] carriers. Of particular interest is the utilization of this phenomenon to measure carrier distribution and especially transverse carrier distribution which affords a direct approach to the evaluation of the surface recombination velocity, s.

Using the theory of the motion of carriers injected into a germanium bar and subject to drift, diffusion, and recombination[3]; assuming that the measurements are made at a distance from the plane of injection great enough so that the higher order terms of the above theory may be neglected; and assuming that the change in the absorption coefficient is proportional to the number of excess carriers in the path of the

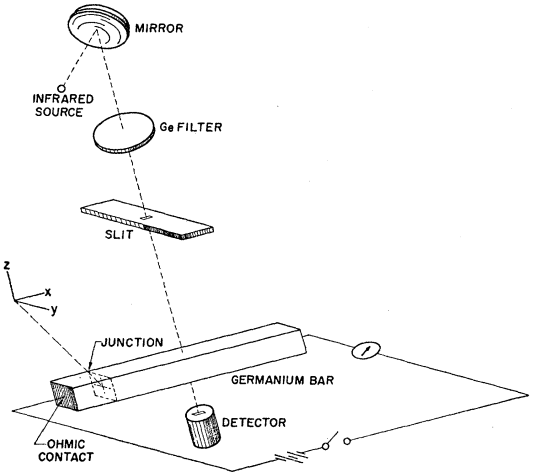

FIG. 1. Experimental arrangement for measuring carrier distribution using the absorption of infrared radiation.

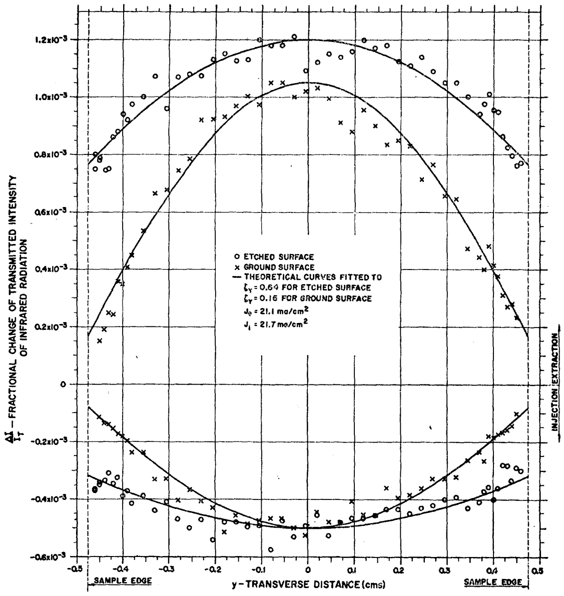

FIG. 2. The fractional change of transmitted infrared radiation caused by injection and extraction *vs* transverse distance for ground and etched surfaces. J_i and J_e are current densities for injection and extraction, respectively.

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.

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New Semiconducting Compounds

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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