existence of such a gradient of defects near the surface is indicated by the recent observations of the effect of irradiation on the solubility rate of Fe_2O_3 in hydrochloric acid.[2]

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Radiative Transitions in Semiconductors

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Radiation produced by carrier injection has been observed from GaSb, GaAs, InP, and the Ge-Si alloys at room temperature and 77°K. The spectral distributions of the radiation are maximum at energies close to the best estimates of the band gaps of these materials; consequently, the evidence is that the radiation is due to the direct recombination of electron-hole pairs. Direct electron-hole recombination radiation from a semiconductor has been previously observed from Ge and Si by Haynes and Briggs[1] and from SiC by Lehovec *et al.*[2]

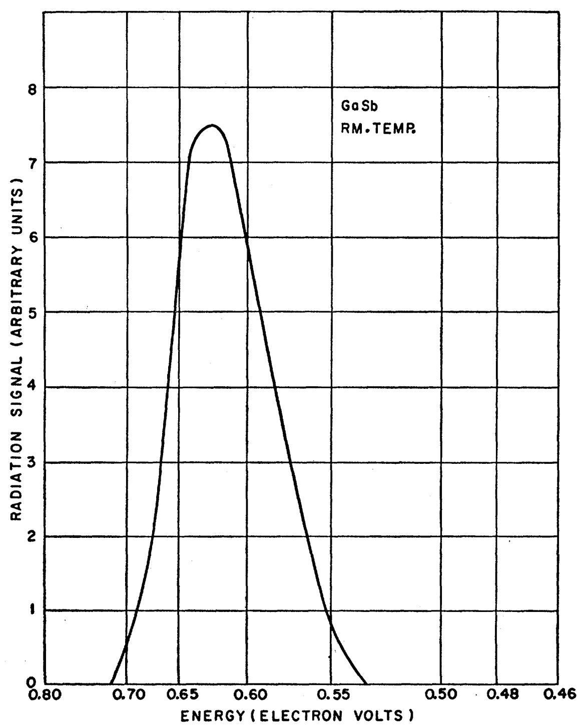

Fig. 1. Spectral distribution of recombination radiation from GaSb at room temperature.

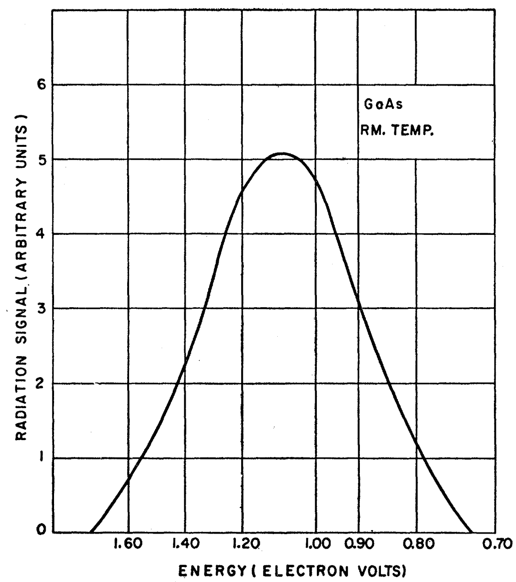

Fig. 2. Spectral distribution of recombination radiation from GaAs at room temperature.

The radiation was obtained by injecting minority carriers into 0.02 in. thick samples of material by means of point contacts or by broad area injecting contacts of silver paint applied to the surface of an appropriately etched semiconductor. The samples were soldered to kovar rings and mounted on temperature-controlled copper blocks. The diodes were pulsed by a 50% on-off square wave generator operating at 100 cps; currents up to 1 amp/cm^2 were passed in the forward direction. Radiation was detected by a dry-ice cooled PbS cell. The spectral distribution of the radiation from GaSb and GaAs was obtained by using a Perkin-Elmer monochromator with a fused quartz prism.

Figure 1 shows the spectral distribution of the radiation from GaSb at room temperature. The peak of the emission line occurs at 0.625 ev. This is to be compared with the value of 0.67 ev for the band gap of GaSb obtained by Blunt *et al.*[3] from absorption measurements. The present sample was n-type having a free carrier density of $\sim 10^{17}/cm^3$.

Figures 2 and 3 show the lines observed from GaAs at room temperature and 77°K, respectively. The peak of the radiation occurs at 1.10 ev at room temperature and at 1.19 ev at 77°K. If we assume a linear variation of the line position with temperature, the line position is given by $1.22-4\times10^{-4}T$ electron volt. If we attribute the radiation to the recombination of injected holes and electrons with the emission of a photon and the simultaneous absorption or the emission of a phonon, the line positions are at variance with the value of 1.35 ev

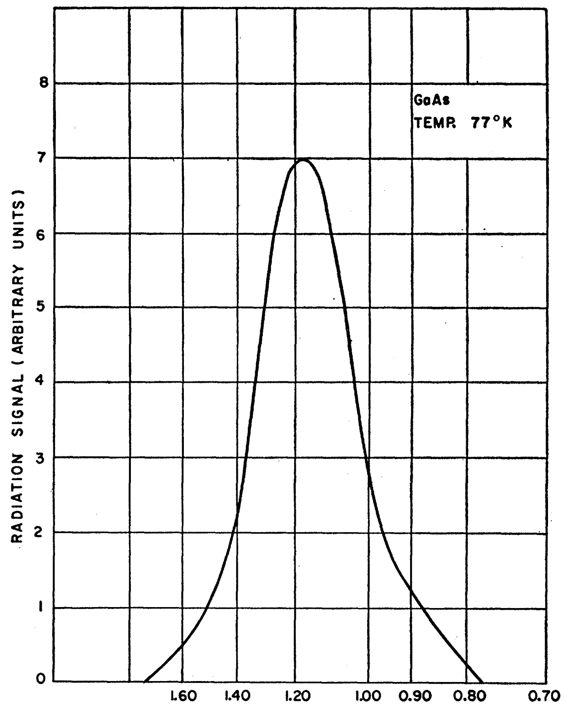

FIG. 3. Spectral distribution of recombination radiation from GaAs at 77°K. This line is to be compared with the line in Fig. 2 taken at room temperature. As the temperature is lowered, the peak intensity of the line increases, the width at half-maximum decreases, and the line shifts to higher energies.

for the room temperature band gap of GaAs as reported by Welker.[4] The absorption or the emission of a phonon can shift a line by only a few hundredths of an electron volt. Self-absorption of the radiation in the sample is also not sufficient to account for the apparent discrepancy. The sample of GaAs was n-type and had a free carrier density of $\sim 10^{17}/\text{cm}^3$.

The emission lines of InP and the Ge-Si alloys were not obtained. However, by appropriate filters, the radiation peaks were shown to occur at energies close to the band gaps of these materials.

The intensity of the radiation in all cases was observed to be a linear function of the injection current for the range of forward currents used (up to 1 amp/cm^2). The radiative recombination of electron-hole pairs is a bimolecular process and thus should be proportional to the product of the electron-hole concentrations. However, for the forward currents used, the majority carrier densities remained essentially constant and consequently to a first approximation the radiation will appear to very linearly with the minority carrier densities. In all cases, the integrated intensity of the radiation increased as the temperature of the sample was lowered.

Further results on radiative transitions in semiconductors will be presented at a later date.

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Infrared Absorption in Indium Antimonide*

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THE optical transmission of indium antimonide has been measured from 5 to 150 microns and at different temperatures. A residual ray monochromator was used for wavelengths beyond 35 microns. A number of lattice absorption bands were observed which indicate that there is some ionic binding in the crystal.

Figure 1 shows the transmission curves for a single crystal specimen with an acceptor concentration, N_A, of 10^{15} cm^{-3}. At 297°K, there are two absorption bands at 28.2 and 30 microns. With decreasing temperature these bands shift slightly to shorter wavelength. Measurements on samples of different impurity concentrations varying between 10^{15} to 10^{17} cm^{-3} show that the magnitudes of these bands are independent of carrier or impurity concentrations, indicating that these bands are inherent to the lattice.

Figure 2 shows the reflectivity curves at long wavelength for two temperatures. There is a strong band near 52 microns at both temperatures. While in the 78°K curve the reflectivity drops to 35% at longer wavelengths, the 297°K curve shows another rise of the reflectivity beyond 100 microns. These results show that

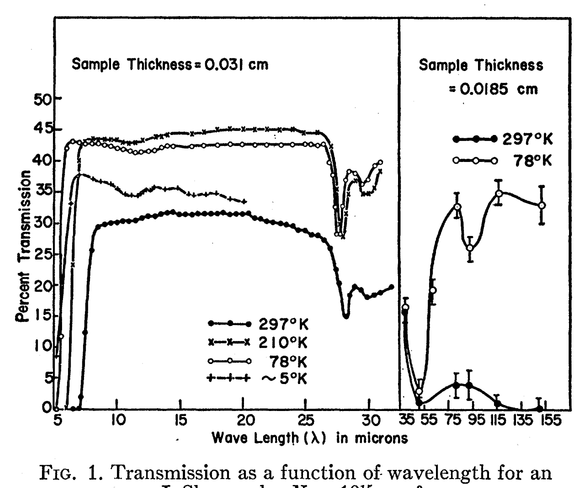

FIG. 1. Transmission as a function of wavelength for an InSb sample; $N_A = 10^{15}$ cm^{-3}.