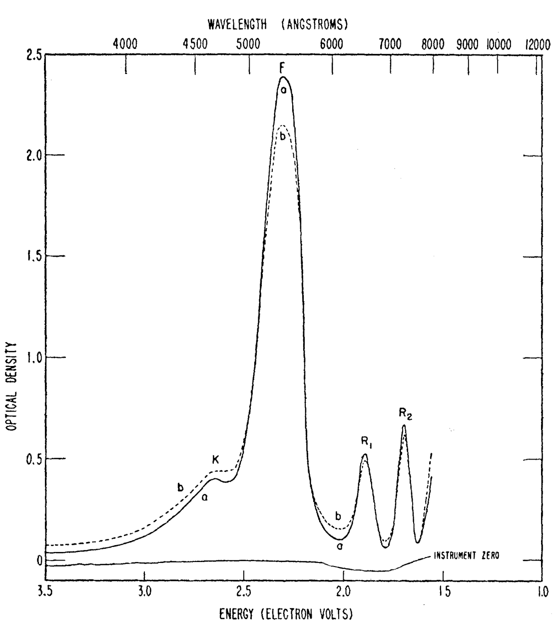

FIG. 2. Absorption measurements on additively colored KCl at −160°C. Curve (*a*), no optical bleach; Curve (*b*), after 2½-hour bleach with *F* light (5600 A) at +50°C.

the *K* band observed here could be the *V*-type center as suggested by Duerig[6] since the crystals were colored additively and should contain no holes. The *K* band appears then to be some combination of an electron and negative ion vacancy in such a way as not to form a normal *F* center. Further work is planned to determine the nature of the center.

The additive coloration, by R. J. Ginther, of the crystals used in the room temperature measurements is deeply appreciated.

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Injection Breakdown in Iron-Doped Germanium Diodes

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IRON dissolved in germanium introduces two deep energy levels in the forbidden band. It is possible to produce both *n*- and *p*-type samples of Fe-doped Ge which exhibit high resistivity when cooled to liquid nitrogen temperature. Thermal ionization energies characteristic of *n* and *p* samples are ~0.27 ev and ~0.34 ev, respectively. Studies of the recovery of photoconductivity after exposure to light indicate that *n*-type samples are much more photosensitive and slower in recovery than are *p*-type samples, suggesting that states introduced by Fe act as hole traps in *n*-type crystals.[1] The purpose of this letter is to describe briefly an experiment with diodes which tends to confirm the presence of hole traps in high-resistivity *n*-type Fe-doped Ge.

Diodes were formed by fusing an indium contact on one face of an ~1/8-in. cube of germanium. The "ohmic" base contact on the opposite face was of fused tin. Sixty-cycle ac voltage was applied to the diodes and current-voltage characteristics were observed on a calibrated oscilloscope. At 300°K the diodes show normal behavior with high reverse saturation currents due to the low carrier lifetime (~5 μsec) in the Fe-doped crystals. When cooled to liquid nitrogen temperature (77°K), in the dark, a typical diode behaves like a high resistance for small voltages of either polarity. (The equilibrium value of resistivity for the Fe-doped Ge at this temperature is ~10^{12} ohm-cm.) On increasing the applied ac voltage (to ~15 volts peak) injection currents of several microamperes are seen on the forward cycle. At sufficiently high voltage (~50 volts peak) a breakdown process takes place after which the effective resistivity of the Ge drops to about 100 ohm-cm. This breakdown condition is maintained until the applied voltage is reduced to less than several volts. Light ($h\nu > 0.7$ ev) falling on the diode greatly reduces the voltage necessary to initiate the breakdown condition.

Figure 1 shows the current voltage characteristic of a typical diode before breakdown. The diode is immersed in liquid nitrogen. Pre-breakdown injection current of about 1 microampere is noticeable on the forward cycle. Breakdown is initiated by a short light pulse from a neon lamp. Figures 2 and 3 show current-

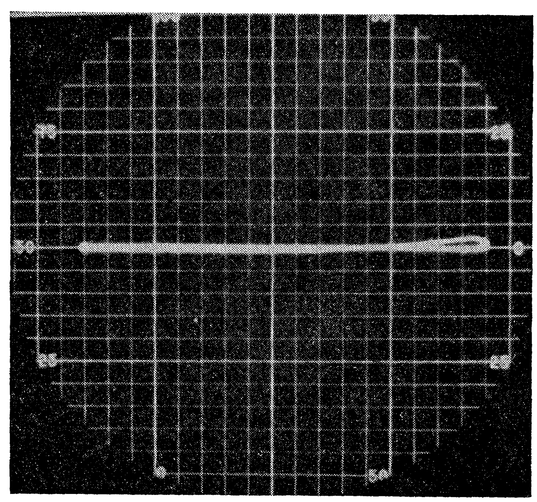

FIG. 1. Current-voltage characteristic before breakdown. Horizontal scale calibration is 2 volts per small division. Vertical scale calibration is 2 microamperes per small division.

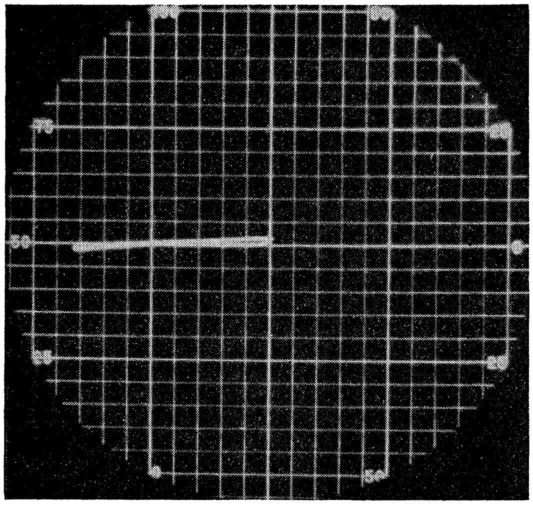

FIG. 2. Current-voltage characteristic after breakdown. Scale calibration is the same as in Fig. 1.

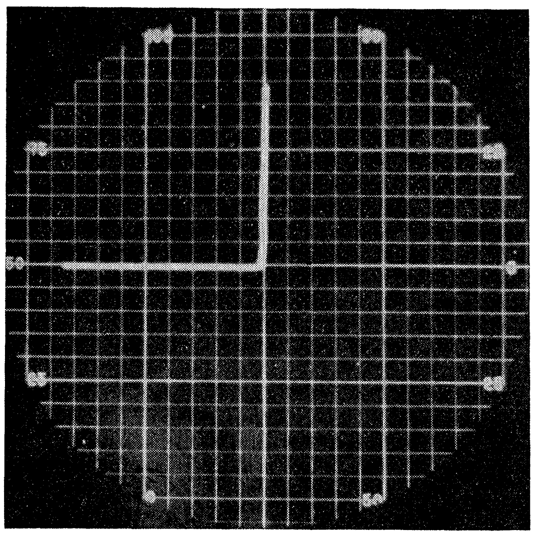

FIG. 3. The same characteristic shown in Fig. 2 except that the vertical scale calibration has been changed to 2 milliamperes per small division.

voltage characteristics after breakdown. In Fig. 3 current sensitivity has been decreased by a factor of 10^3. The peak forward current of 15 milliamperes is limited by external resistance. A thermocouple fused to the diode indicates no detectable (<0.05°K) increase in temperature after many minutes of operation under these conditions. The breakdown may be extinguished by decreasing the series resistance, permitting sufficiently high forward currents to heat the Ge to $\sim$100°K.

The process described has been termed injection breakdown. Although the kinetics of the voltage-induced breakdown are not quantitatively understood, the steady-state breakdown condition may be explained by assuming high, nonequilibrium conduction in the Ge due to mobile electrons which neutralize trapped holes, with injected holes continuously being retrapped, replacing evaporation or recombination losses. On sixty-cycle operation, a sufficient number of nonequilibrium carriers remain after the reverse cycle so that applied forward voltage again localizes at the junction and injection saturates the traps during the first part of the forward cycle (assuming sufficient current density). Because of this reloading process, a small discontinuity is always observed in the current voltage characteristic during the first part of the forward cycle. This is barely discernible in Fig. 3 as a change in slope near the origin. Heating the Ge to $\sim$100°K increases the rate of hole evaporation sufficiently that it is difficult to maintain the breakdown condition.

Two observations of Newman support the model proposed for the steady-state operation of the breakdown diode. The infrared absorption of injected carriers in the breakdown diode does not show the structure characteristic of hole absorption which is found in most normal diodes.[2] With the applied voltage just greater than the minimum sustaining voltage, it is possible to extinguish the breakdown by irradiation of the diode with monochromatic light in the wavelength interval ($\sim$0.35 to 0.7 ev) which had previously been found effective in quenching intrinsic photoconductivity in n-type Fe-doped crystals.[3]

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Effect of Dislocations on the Optical Absorption Edge in Nonmetals*†

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THE absorption spectra of many nonmetals exhibit a long-wavelength tail which has been attributed to lattice disorder.[1] Seitz[2] discussed the absorption spectra of the silver halides in the near ultraviolet and concluded on the basis of the magnitude of the radiation matrix element for a crystal containing edge type dislocations, that this type of lattice disorder can account for the long-wavelength tail observed.[3] This letter summarizes the results of calculations on the order of magnitude of the absorption coefficient to be expected in a crystal containing edge-type dislocations.

There are three ways in which dislocations can modify the fundamental absorption edge: (1) Optical (i.e., momentum) selection rules are relaxed by the deviation from periodicity. (2) Local density variations in the neighborhood of the dislocations change the local width of the forbidden gap, permitting lower-energy allowed

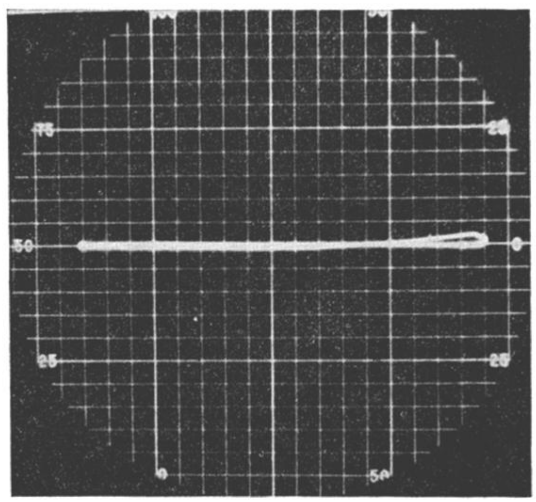

FIG. 1. Current-voltage characteristic before breakdown. Horizontal scale calibration is 2 volts per small division. Vertical scale calibration is 2 microamperes per small division.

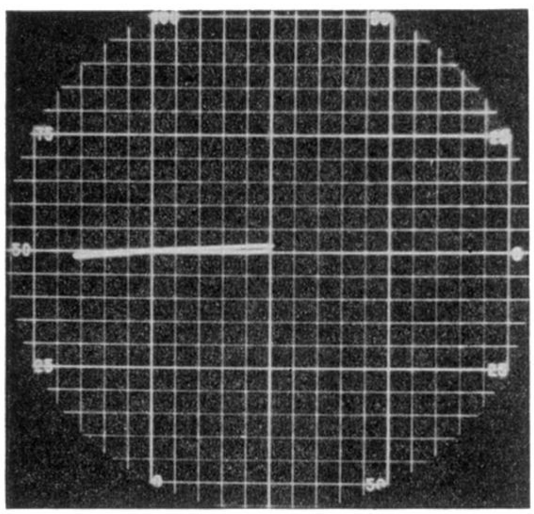

Fig. 2. Current-voltage characteristic after breakdown. Scale calibration is the same as in Fig. 1.

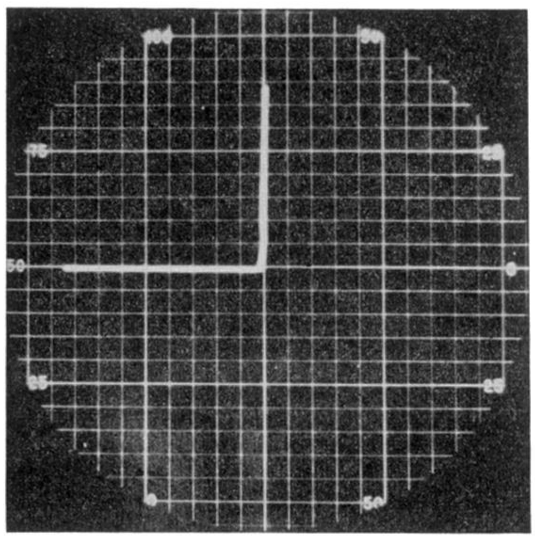

FIG. 3. The same characteristic shown in Fig. 2 except that the vertical scale calibration has been changed to 2 milliamperes per small division.