

### III. SOLID STATE PHYSICS

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#### A. ELECTRICAL BREAKDOWN IN GERMANIUM

Measurements of breakdown in germanium at  $T = 4.2^\circ\text{K}$  were made on three groups of germanium single crystals: n-type, p-type, and compensated n-type. The compensated samples contained both n- and p-type impurities with the n-type impurity predominating.

An expression was derived for the electron density in the conduction band for the general case of a compensated sample at a low temperature. Volume recombination is the dominant loss mechanism.

$$n_- = \frac{(N_D - N_A) \bar{v}_i - N_A \bar{\alpha}}{(\bar{v}_i + \bar{\alpha})}$$

$n_-$  is 0 if  $(N_D - N_A) \bar{v}_i - N_A \bar{\alpha}$  is less than 0;  $N_D$  is the concentration of donor atoms,  $N_A$  is the concentration of acceptor atoms,  $\bar{v}_i$  is the average ionization rate of electrons per neutral atom, and  $\bar{\alpha}$  is the average recombination rate of electrons per ionized atom.

If there are no acceptor atoms present, the equation reduces to

$$n_- = N_D \frac{\bar{v}_i}{\bar{v}_i + \bar{\alpha}}$$

If only a small percentage of the donor atoms are ionized, then

$$n_- = N_D \frac{\bar{v}_i}{\bar{\alpha}}$$

It has been found experimentally that

$$\frac{\bar{v}_i}{\bar{\alpha}} = A e^{K(El/V_i)}$$

where  $V_i$  is the ionization potential,  $E$  is the electric field,  $l$  is the mean free path, and  $K$  is a constant whose value is approximately 1000.

The form of the equation for the compensated sample was found to fit reasonably well with measurements on different crystals grown from the same melt. The value for  $N_D - N_A$  was determined from the conductivity at room temperature, and it was assumed that the percentage change in  $N_D - N_A$  was much larger than the percentage change in  $N_A$  alone, or  $N_D$  alone for the different crystals.

To investigate the effect of recoil losses resulting from impurity scattering,

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measurements will be made on two different crystals of n-type germanium, one crystal having a phosphorus impurity; the other, a bismuth impurity. Phosphorus and bismuth are used because they have appreciably different atomic masses.

For samples with a high concentration of impurities, the observations in the "pre-breakdown" range were accompanied by a large amount of noise when viewed on the spectrum analyzer. A discontinuous change in the conductivity was observed for some of the high-loss samples.

An experimental investigation of the range of validity of the perturbation theory for a high-loss sample in a microwave cavity will be made.

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