I. PHYSICAL ELECTRONICS

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A. PHYSICAL ELECTRONICS IN THE SOLID STATE

1. CHARACTERISTICS OF SEMICONDUCTOR JUNCTIONS

Considerable experimental data have been accumulated on four different diodes of a series of ten kindly supplied by Dr. R. M. Ryder of Bell Telephone Laboratories, Murray Hill, New Jersey. The series consists of two each of five different types with breakdown voltages ranging from 6.2 volts to 150 volts – values that correspond to impurity gradients ranging from 10^{23} cm^{-4} to 10^{19} cm^{-4}. Figure I-1 is a semilogarithmic plot of the forward characteristic at several temperatures of a 1N672 diode

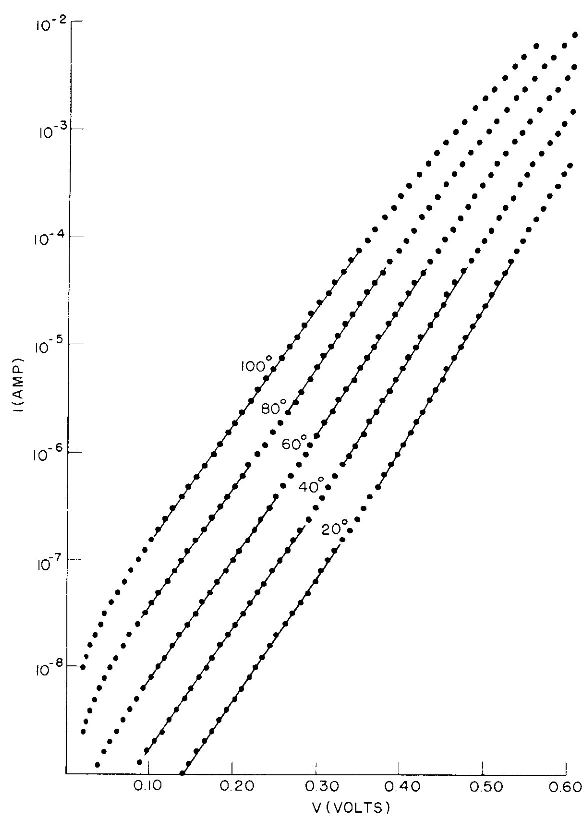

Fig. I-1. Forward characteristic of junction 1N672-2.

having a 152-volt breakdown. The dots on this plot are the actual experimental points, and the lines are a good fit to the linear portions of the curves.

At the lower temperatures we see three distinct regions: At the lowest currents we find an exponential dependence of current on voltage; in the range of intermediate currents the dependence is again exponential, but with a distinctly different slope on a semilogarithmic plot; and at the highest currents we find that, empirically, $I \propto V^m$, where, for this junction, m (an empirical constant) is in the range from 10 to 20 (the values depend on the temperature). In the range of medium currents the current is well represented by $I \propto \exp(qV/nkT)$, where the empirical constant n is somewhere between 1 and 2. For this junction, n appears to be approximately 1.26 and is essentially independent of temperature below 80°C. For the range of smaller currents a good empirical relation is $I \propto \exp(BV)$, where, again, B is independent of temperature below 80°C and is approximately 26 volt^{-1} for this junction. Thus it appears that the mechanism that determines the voltage dependence of the current within this range of currents is independent of temperature.

It has been postulated by Sah, Noyce, and Shockley (1) that the current in the lower exponential range is due to barrier recombination, and that the current in the upper exponential range is diffusion current which eventually becomes dominant because of its voltage dependence. Further analysis of the present data is necessary to assign possible mechanisms to the different regions.

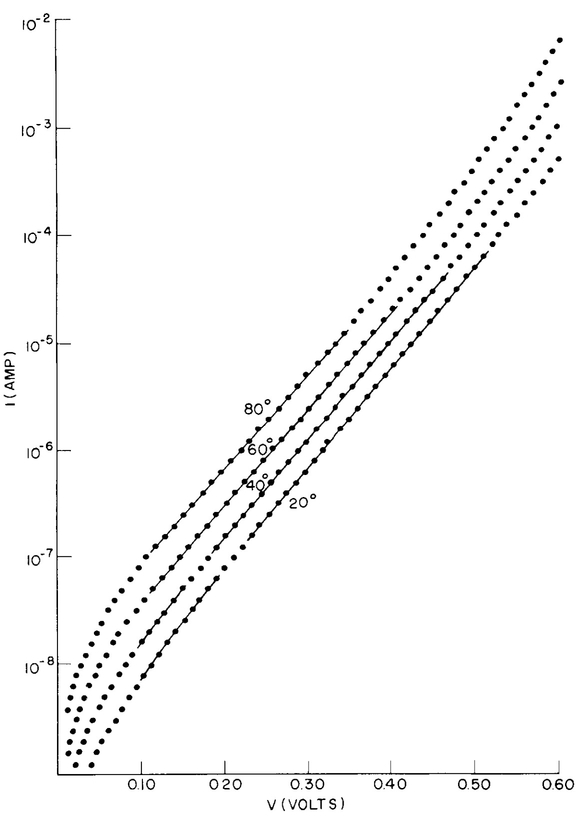

Fig. I-2. Forward characteristic of junction 1N675-2.

Junctions having somewhat larger impurity gradients than that of Fig. I-1 appear to show much the same behavior, although the lower exponential range is missing at the temperatures measured thus far. This is what would be expected if this portion of the characteristic were due to barrier recombination, since the larger impurity gradient would produce a smaller transition region.

For very large impurity gradients the junction characteristics change somewhat. Figure I-2 shows the forward characteristic of a 1N675 diode having a 6.22-volt breakdown. For the lower temperatures there are two exponential regions, but the lower region now bends in the opposite direction. Instead of giving the impression that we are dealing with two parallel current sources, as in the junction of Fig. I-1, it appears that this junction has two series voltage drops, both varying logarithmically with the junction current. In addition, the top region of current now curves up rather than down and appears to follow a power law only roughly.

The computer program reported on last time has not yet been completed, but should be shortly. Measurements of the diode characteristics are being continued.

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References

1. C. T. Sah, R. N. Noyce, and W. Shockley, Proc. IRE 45, 1228 (1957).

2. OHMIC CONTACTS ON GERMANIUM

The objective of this project is the comparison of ohmic contacts made on germanium by various soldering and bonding processes. This work was originally undertaken by A. K. Hampikian (1).

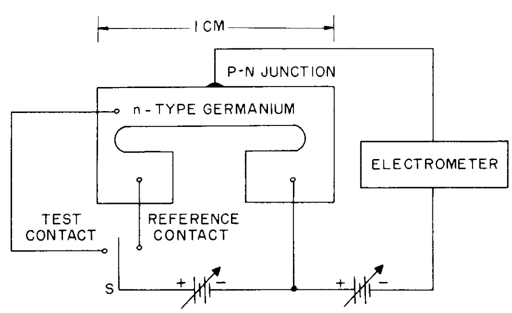

Fig. I-3. Simplified diagram of measurement circuit.

Figure I-3 is a simplified diagram of the circuit for use with n-type germanium. Samples are cut from germanium slices that are 0.5 mm thick. A p-n junction is created in the middle of the bar by alloying a small dot. The reference contacts at either end are also made by the alloying process. Test contacts are made at either end of the bar on each side. Samples were supplied by R. H. Rediker, of Lincoln Laboratory, M.I.T.

The method of measurement is as follows. A current is passed through the sample by using the reference contacts. The reverse saturation current of the p-n junction is measured. Switch S is then moved to the test contact. Any injection of minority carriers by the test contact will cause a change in the reverse saturation current of the junction if the field along the sample is large enough to sweep the carriers past the junction before recombination.

The current through the sample must be pulsed to avoid heating effects. A rectangular wave generator has been constructed for this purpose, and various other modifications to the equipment used by Hampikian are being made.

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References

1. A. K. Hampikian, Investigation of ohmic contacts on germanium monocrystals, S.M. Thesis, Department of Electrical Engineering, M.I.T., May 1959.