I. PHYSICAL ELECTRONICS

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A. ELECTRON EMISSION AND CESIUM PLASMA

1. THERMIONIC ENERGY CONVERTERS

In the theoretical investigation of the general theory of the plasma diode, one of the developments was the formulation of new equations for the pressure-temperature relation of cesium. The formula that seems to be a good representation of available data is

$$p = 2.45 \times 10^8 \, T^{-1/2} \, e^{-8910/T} \text{ mm} \tag{1}$$

Although the analysis is not complete, the meager experimental data available on ionization and recombination lead to the conclusions that apply in a plasma sufficiently far away from boundaries so that the only ion loss mechanism is electron-ion recombination Here the losses are equated to the ionization of the neutrals by the higher-energy electrons. If the electron temperature can be characterized as one in excess of 4600°K, the fraction of all of the cesium atoms that will be ionized is in excess of 90 per cent. If the electron temperature is less than 3000°K, the fractional ionization is probably less than 20 per cent. These calculations demonstrate the importance of having additional experimental data on the electron energy distribution found in plasma diodes.

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2. THERMIONIC WORK-FUNCTION OF ZIRCONIUM CARBIDE

Because of the interest in zirconium carbide as an emitter surface in plasma thermo electric transducers, an attempt to make accurate determinations of its work-function is planned.

The method of measuring the work-function is similar to the ideal retarding potential experiment devised by Shelton (1), in which a magnetically collimated electron beam is used. The design for the tube is in a preliminary state; we are awaiting the arrival of a suitably large crystal face that will allow single-crystal measurements.

With the cooperation of Professor John Wulff of the Department of Metallurgy, M.I.T., single crystals of zirconium have been grown and carburized on the surface. It is not yet known whether or not the zirconium carbide on the surface is a single crystal.

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References

1. H. Shelton, Thermionic emission from a planar tantalum crystal, Phys. Rev. 107, 1553 (1957); Technical Report 327, Research Laboratory of Electronics, M.I.T., March 21, 1957.

B. PHYSICAL ELECTRONICS IN THE SOLID STATE

1. CHARACTERISTICS OF SEMICONDUCTOR JUNCTIONS

Since the last report measurements of the complete voltage-current characteristics of two silicon diodes have been made. The measurements, which were carried out at temperatures from 20°C to 140°C at 20° intervals, include the voltage-current relation for voltages of less than 10^{-3} volt in the forward and reverse directions to 10^{-2} ampere in the forward direction, and to breakdown in the reverse direction. Because of the instabilities in the reverse direction, the current for each voltage was followed on a recorder in order to obtain the limiting value. This limit was approached from the directions of increasing and decreasing voltage. In this manner, the final current for any voltage can be bracketed in a time range of from 5 to 30 minutes, which depends on the temperature of the diode. Since each run involved reading approximately 50 points, the runs tended to take up many hours, and complete characteristics were obtained on only two junctions. In addition to these measurements, the lifetime as a function of the temperature was obtained by using the method of Lederhandler and Giacoletto (1); the voltage-capacitance characteristics were obtained as a function of the temperature, and the initial currents at reverse voltages from 10^{-1} to 10 were obtained for several temperatures. Also, measurements were made of the forward voltage-impedance characteristics at 100 kc and at 1 kc, at one temperature only. Another measurement was made, on one junction only, of the conductance and capacitance at zero voltage as a function of frequency.

This large volume of data is not yet completely analyzed, but some general observations and tentative conclusions can be made. Judging by the temperature dependence of various parts of the characteristic, we believe that the entire characteristic, except possibly at high forward currents, results from the same mechanism; and judging by the forward voltage-impedance measurements, we believe that the mechanism is associated with the surface of the junction.

Time variations of the reverse currents and capacitances are consistent in some ways with the formation of a surface channel (2), but certain features of the time-dependent changes of one of the junctions are difficult to reconcile with the channel model. This junction tends to show a reverse current that decreases in time for a range of smaller reverse voltages. This behavior indicates that the channel model does not give a complete picture.

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References

1. S. R. Lederhandler and L. J. Giacoletto, Proc. IRE 43, 477 (1955).

2. W. L. Brown, Phys. Rev. 91, 518 (1953); A. L. McWhorter and R. H. Kingston, Proc. IRE 42, 1376 (1954).

2. TEMPERATURE DEPENDENCE OF ESAKI TUNNELING

An investigation of the variation of tunnel current with temperature in Esaki diodes has been undertaken. The objective of this work is to determine the proportion of current carried by the direct tunneling process and that carried by the indirect, or phonon-assisted, process. Measurements were made on germanium diodes at 77°K, 195°K, and 300°K. This work is being extended to cover the range of temperature from 4.2°K to 300°K, with germanium, silicon, and gallium arsenide diodes used.

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