RADIO PHYSICS

I. PHYSICAL ELECTRONICS

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RESEARCH OBJECTIVES

1. Theory of Energy Conversion Electronics

The effectiveness of energy conversion by means of thermionic emission from an emitter depends upon the existence of a suitable difference in work-function between the emitter and the collector. Many aspects of the physics of electronics are involved in this application and need to be examined in considerable detail, with theory compared with experiment. Thermionic converters are, at present, very difficult to make. The application of thermionic-emission theory, gas-discharge theory, and space-charge theory all contribute to a better understanding of the phenomena found in practical converters. It is, therefore, one of our objectives to organize these various branches of physics and relate them to experimental work that is generally carried on in laboratories.

2. Work-Function Determination by the Electron Energy Distribution Method

The maintenance of the collector work-function at a low and controllable value is of prime importance in the design and operation of an efficient thermionic converter. It is not enough to say that the collector work-function should be the absolute minimum attainable because, for particular surface conditions, this minimum might occur only at a relatively high temperature that, in turn, would indicate an excessive thermionic emission from the collector. It is important, therefore, to devise a scheme for determining the collector work-function for selected surfaces, especially single-crystal surfaces, in the presence of cesium.

The experimental method that is being used here involves the production of electron emission from a ribbon filament source. Parallel to this source there will be three conducting surfaces with a single small circular opening in each one, so lined up that electrons collimated by means of a magnetic field will be able to pass through all three of these apertures. This collimated beam of electrons will then impinge on the collector, which is similar in construction to the emitter. The part of the surface that receives the beam will be a single crystal with a selected crystallographic orientation. In order to determine the work-function of the collector by this means, it is necessary to study the current-voltage characteristic in the retarding range to determine the characteristic temperature that describes the electron-energy distribution. This temperature must be the same as that of the emitter for the experiment to be correctly interpreted. If this test proves satisfactory, the work-function of the collector can be determined directly from the knowledge of the current density and the applied voltage. In order to make this study in the temperature range for which an appreciable electron emission from the collector can take place, the center diaphragm of the three can be modulated by the application of a square-wave, cutoff potential, and a sharply tuned amplifier can detect the modulated current in the presence of a considerable background of direct current.

3. Adsorption Properties of Single Crystals of Tungsten before and after Carburization

Experiments with clean tungsten crystals show that different crystallographic orientations adsorb cesium with specific characteristics. Generally speaking, the (110) direction and the (112) direction hold cesium best. This is indicated by the fact that at a given cesium pressure these originally high work-function surfaces become the lowest of all. Experience in the field of thermionic emission from thoriated tungsten has led to the commercialized technique of carburizing the surface layer. After carburization, this layer holds thorium better than it did before. The purpose of this experiment is to find out whether or not surface treatment of tungsten can create a situation in which cesium will hold on to give a suitably low work-function at a very high temperature and

not also require an excessive arrival rate of cesium.

Selected tungsten wire can be polished and processed in such a manner as to make long single crystals grow in the wire. These single crystals exhibit all of the available crystal directions that combine as (11x), with x taking on values from zero to infinity. The electron emission is seen on a concentric fluorescent screen. After the crystal is grown and its orientation determined, it can be carburized. Cesium is then admitted and the emission pattern reinvestigated to see to what extent the carburization has influenced the adsorption properties of the single crystal.

4. Cesium Ionization on a Thoriated Filament

Surface ionization of cesium depends on the effective work-function of the surface and its temperature. The total number of ions produced depends also on the arrival rate of cesium. Under most conditions, the work-function itself depends on the cesium arrival rate and temperature and, therefore, it is very difficult to evaluate the influence of the work-function itself. A thoriated tungsten filament can be controlled to have an effective work-function between ~ 3 electron volts and ~ 4.5 electron volts. After having brought about the activation, its temperature can be raised sufficiently high so that practically no cesium atoms stick to the surface if the cesium pressure is not too high, and also no additional thorium activation takes place. It is the purpose of this experiment to try to evaluate qualitatively at least, and quantitatively if possible, the direct influence of the surface work-function on the cesium ion production rate.

5. McLeod Gauge Evaluation

Vacuum technology depends on there being some good standard of pressure measurement as a means of calibration for measuring devices that depend on other phenomena and, in particular, depend on the ionization that takes place in an ion gauge. There has been reason to believe that the McLeod gauge, which depends on the application of Boyle's law, does not always yield results as unambiguous as desired. An experiment is under way to test two McLeod gauges, one against the other, when both are constructed as nearly alike as possible. This comparison will be made with a static system, in contrast to a later comparison that will be made with gas flowing through apertures. The scheme involves the control of gas flow from a high-pressure region to a medium-pressure region and, finally, to a very low-pressure region. One McLeod gauge can be calibrated against another in terms of the areas of the apertures that connect these regions. It is the objective of this research to try to evaluate the influence of capillarity and other disturbances that may make the McLeod gauge inaccurate in unexpected ways.

W. B. Nottingham

A. TEMPERATURE DEPENDENCE OF ELECTRICAL LEAKAGE CAUSED BY CESIUM ON GLASS

Experiments concerned with the measurement of small currents (electron emission, ion emission, and so forth) in the presence of cesium vapor are often harassed by electrical leakage caused by cesium atoms which adsorb on the glass walls and presses of the tube. The adverse effects of this leakage are commonly reduced by raising the glass temperature and by the use of "guard rings." The experiments reported here relate specifically to the quantitative investigation of the effect of glass wall temperature and cesium bath temperature on the leakage resistance.

1. Experimental Arrangement

The experimental tube is sketched in Fig. I-1. Potentials of 0-45 volts are applied across the two electrodes and the corresponding currents measured with a sensitive dc electrometer. The entire tube is contained in a shielded temperature-regulated oven.
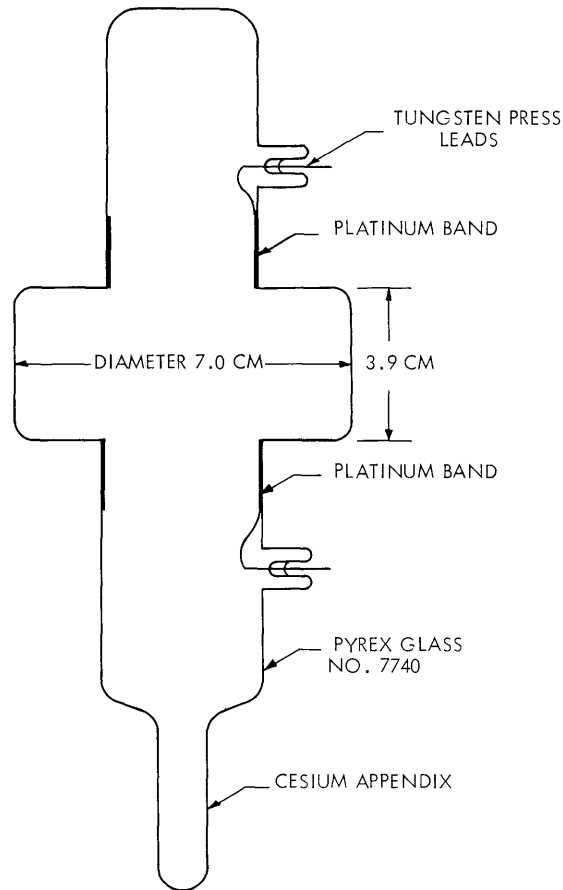

Fig. I-1. Experimental tube.

The cesium appendix is immersed in a water bath whose temperature is regulated independently of the oven. The enlarged section of the tube is equipped with a heating tape powered by direct current to avoid pickup in the electrometer circuitry.

The oven temperature is always maintained higher than that of the cesium bath so that the pressure in the tube is controlled by the bath temperature.

2. Experimental Results

The leakage values are characterized by a quantity ρ_s which denotes the resistance of a square of the cesium covered glass surface. The resistance R of a rectangular

shaped surface is given by

$$R = \frac{\rho_s \ell}{d},$$ (1)

where ℓ is the length parallel to the current, and d the length in the perpendicular direction.

Figure I-2 shows ρ_s as a function of the glass temperature T_G at two different values of cesium bath temperature T_{Cs}. It is seen that ρ_s has an exponential dependence on $1/T_G$ for T_G less than 100°C, and that the constant in the exponential is nearly independent of T_{Cs} in the measured temperature range. The decrease of ρ_s at the higher
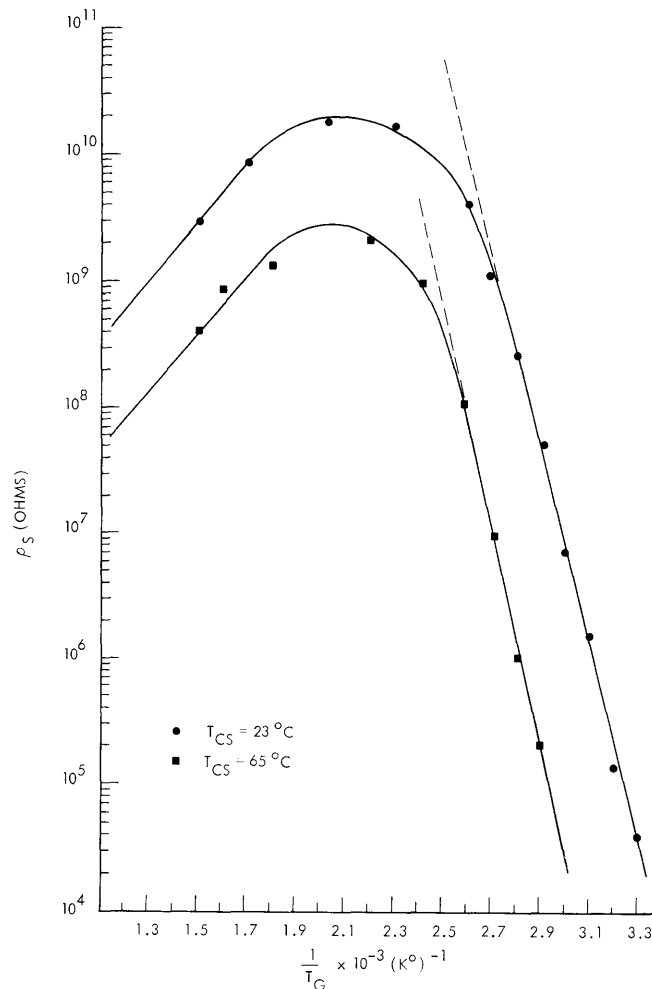

Fig. I-2. Resistance of a square as a function of glass temperature at two values of cesium bath temperature. T_G varies from 30°C to 400°C.

temperatures is caused by leakage through the glass itself rather than across the surface. This statement was verified by measurements made on the bare glass before cesium was admitted into the tube. At the lowest value of T_G and T_{Cs} a waiting period of several hours is required for the leakage current to increase to equilibrium when the glass is free of cesium initially. The fact that both curves do not approach the same value at high temperatures is assumed to be due to a permanent reaction that occurs between the glass and cesium during high-temperature operation. Evidence for this assumption is obtained from an earlier curve taken at T_{Cs} = 23°C. It had a maximum value of ρ_s approximately three times greater than the curve for T_{Cs} = 23°C in Fig. I-2. This earlier curve is not reported here because it represents nonequilibrium data at the low values of T_G. The data at T_{Cs} = 65°C were taken after those at T_{Cs} = 23°C.
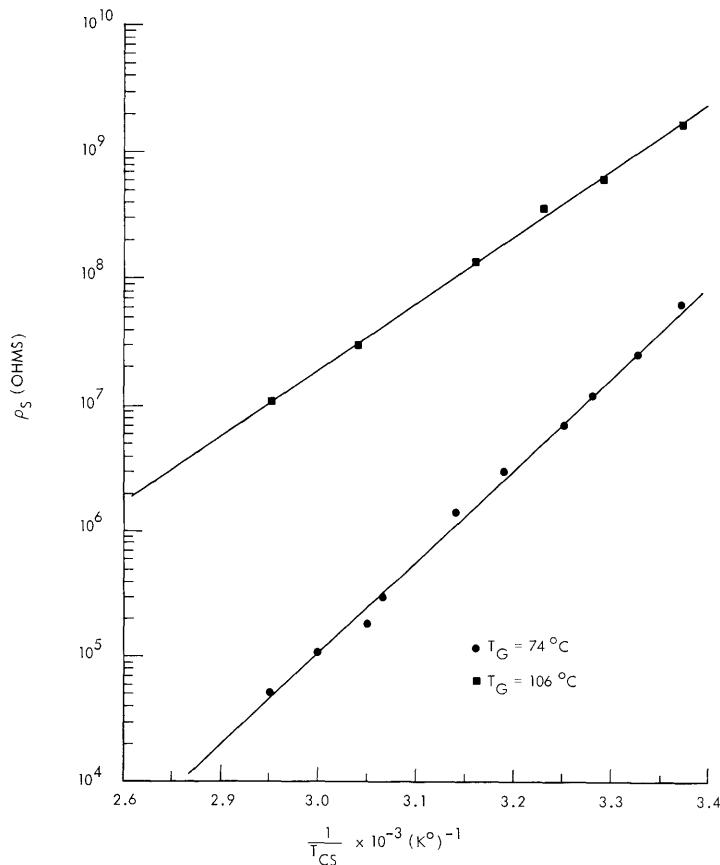

Fig. I-3.   Resistance of a square as a function of cesium bath temperature at two values of glass temperature. T_{Cs} varies from 20°C to 65°C.

Figure I-3 shows ρ_s as a function of T_{Cs} at two different values of T_G. Here again

ρ_s depends exponentially on $1/T_{Cs}$ but the slope has a noticeable dependence on T_G. At $T_G = 74\,°C$, ρ_s is approximately proportional to the square of the cesium vapor pressure; this indicates that ρ_s is strongly dependent on atom arrival rate.

Regarding the amount of cesium present on the glass surface at given values of T_G and T_{Cs}, a simple interpretation of the data gives evidence that the coverage is somewhat less than a monolayer in the temperature ranges of Fig. I-3.

Photocurrents were observed when the tube was subjected to external light. With ordinary room light they are of such magnitude as to mask the leakage current at $T_{Cs} = 23\,°C$ and T_G above $\sim 100\,°C$. This made it necessary to take the data with the tube shielded from all light. Several simple experiments gave evidence that these photocurrents are produced by photoemission of electrons from the cesium-covered glass, particularly in the regions near the electrodes.

3. Summary

The significant results of this report can be conveniently summarized as follows. (a) Useful data relating electrical leakage across cesium-covered glass surfaces to glass temperature and cesium-bath temperature have been obtained for a limited range of temperature. (b) Photocurrents capable of masking leakage currents over a large temperature range were observed.

Further work with ceramic surfaces used is planned. This will allow data to be obtained over a larger temperature range.

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