I. PHYSICAL ELECTRONICS

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A. ELECTRON EMISSION PROBLEMS

1. A Redetermination of the Crystallographic Variation of Electron Field Emission from Tungsten

Preliminary measurements have been made of the variation of field emission current density from the various crystallographic surfaces of a tungsten single crystal as a function of crystal temperature in the range 300-1300°K. The measurements were made by photometering the light from a field emission projection tube of the Mueller type. The voltage applied to the tube was held constant during the measurements in order to maintain constant electric field at the crystal surface.

All of the surfaces measured show an increase of emission with temperature, but the rates of increase vary widely with crystallographic direction. For example, the emission from the 111 and 112 surfaces increases approximately 70 percent in the range 300-1000°K, while the 310 emission increases only 15 percent. Also, all the curves of emission vs temperature have a discontinuous break in slope at approximately 800°K, the emission increasing more rapidly above that temperature. Since my temperature scale is not yet accurately established, it is probable that these discontinuities coincide with the discontinuity in slope noted at approximately 850°K in Goucher's (1) measurements of the tensile strength and the thermal expansion of single tungsten crystals. The reason for these discontinuities is still a complete mystery.

The measurements were limited to below 1300°K, since above that temperature the mobility of tungsten on tungsten was sufficiently high that the shape of the field emitting point changed significantly during the one-minute measuring period. At temperatures below 1300°K the light from any crystallographic direction and the total field emission current would return to their original room-temperature values when the point heating was removed, thus showing that the point shape was unchanged. A constant point shape is necessary to maintain constant electric field, without which the measurements are difficult to interpret.

The Fowler-Nordheim theory of field emission will be used to interpret the measurements. After correction for the thermal expansion of the tungsten crystal (which slightly lowers the electric field) and for the intrinsic temperature variation of field emission, it is expected that such measurements will yield the temperature variation of the work-functions of the various crystal surfaces of tungsten.

J. M. Houston

References

1. S. S. Goucher, Phil. Mag. 48, 229 (1924).

2. Growth of Single Crystals of Tantalum

An attempt is being made to grow single crystals of tantalum. In the past, several workers in this group employed single crystals of tungsten in studies of the forces acting on electrons that cross the metal-vacuum boundary in thermionic and field emission. It is felt that a contribution could be made to this field if single crystals of tantalum were available.

Heating and cold-work have been tried on various convenient sizes of tantalum 1-3 mils thick. Heating was done by direct current, 60-cycle alternating current, and rf induction. In the last case no crystals of a size even approaching usefulness were obtained; those obtained by alternating current and direct current were appreciably larger. Small cold stretch has been recommended for enhanced growth (1). While the largest crystals have been obtained with approximately 3 percent elongation, they are still only about 100 mils in diameter. In nearly every case where crystals of this size were obtained they occurred in the sharp temperature gradient at the ends, where the tantalum ribbon is supported by electrodes. This observation led to using mercury as one electrode and slowly lowering the mercury level in order to move the sharp temperature gradient along the ribbon. The setup for this has been completed but only one run has been made.

W. J. Lange

References

1. B. A. Mrowca, J. Appl. Phys. 14, 684 (1943).

3. Energy Dependence of Electron-Produced Poisoning of Oxide Cathodes

In the Quarterly Progress Report of April 15, 1954, a tube was described that was designed to study the poisoning of oxide cathodes by anode decomposition products resulting from electron bombardment and to study the analogous reduction of emission from a pure tungsten filament. This tube has been constructed and some of the proposed tests have been made.

The measurements to be made on the tube may be divided into two groups: those to be made on the test filament and those to be made on the oxide cathode. The first group is now almost complete. This work has included the layout of circuits for both of these cases.

Thus far, results have been obtained for test filament measurements alone. These include studies of electron emission from the poisoned test filament as a function of the electrons bombarding the anode. These emission tests were made with the test filament at two different temperatures, 1600°K and 1750°K, and the test filament-to-anode

potential at 5 volts, which was below the critical voltage for poisoning. During the bombarding period the test filament was kept at the same temperature as for the emission tests; the total number of electrons at each bombarding potential was kept constant by maintaining the product of the time and the bombarding filament-to-anode current constant for each potential.

A study of the emission of the poisoned test filament as a function of the temperature of the test filament during the bombarding process has also been made. In this case the test emissions were always drawn at the same test filament temperature (1600°K). This temperature was different for each bombarding process, the entire run varying in temperature between 1600°K and 2400°K. The bombarding filament-to-anode potential was maintained constant.

The first-mentioned test filament investigation is the more important to this study. The plot of $\log_e$ of test filament emission vs electron energy appears to be a straight line from 40-200 volts, a curved line from the poisoning onset potential to 40 volts. This plot is a representation of the work-function change as a function of the adsorption of anode decomposition products on the filament. If it is valid to assume that each molecule that is adsorbed on the filament has the same effect on the work-function; that is, when the total number of molecules adsorbed on the filament is small, the described plot also represents an amount proportional to the decomposition of the anode impurities as a function of the bombing voltage.

No concrete data have been obtained on the electron energy dependence of poisoning for the oxide cathode itself. There have been many problems connected with the activation of the cathode. The problem of getting the cathode back to the same state of activation before each poisoning test is not yet solved. When these problems are resolved, tests similar to those made on the tungsten test filament will be made on the oxide cathode.

<div align="right">J. D. Hobbs, L. W. Swenson</div>

B. EXPERIMENTAL STUDIES

1. Infrared Radiation Pyrometer

Several improvements on the device previously reported (1) have been made and more measurements to determine its characteristics have been taken.

An additional pentode stage has been incorporated in the amplifier following the peaking triode stage, as shown in the block diagram of Fig. I-1. With this addition the total gain has been increased to about 10^5, enabling the detection of a change in the lead sulphide cell resistance of the order of 1 ohm. Measurements using a single-channel optical system (2) indicate that temperature comparisons can be made to within 1°C at cathode temperatures of 250°C or higher.
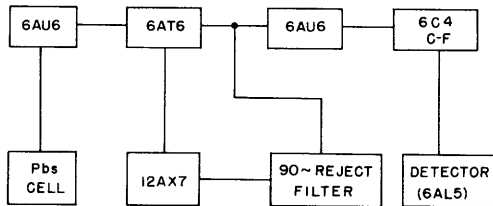
Fig. I-1

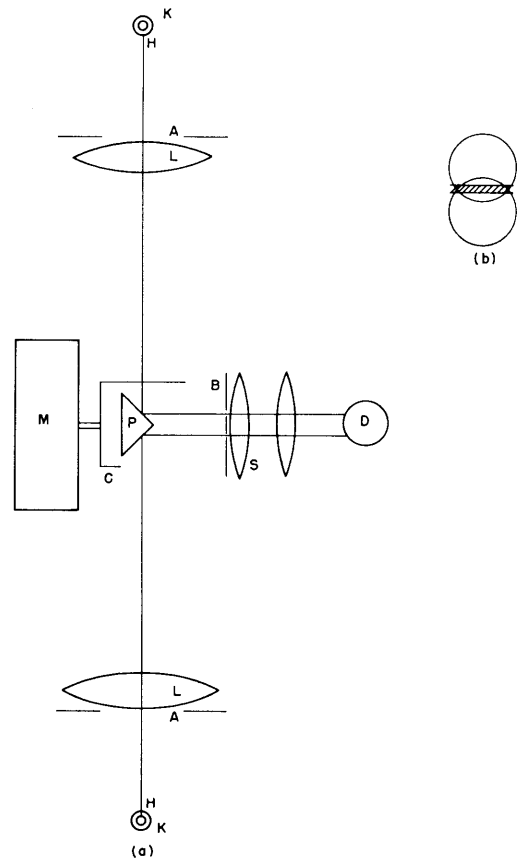Infrared pyrometer: Amplifier

Fig. I-2

Infrared pyrometer: (a) Optical system;
(b) Image on detector.

A detecting circuit, utilizing a diode rectifier and a diode limiter, has been added to the amplifier to facilitate null measurements. For aligning the instrument, when a maximum signal is desired, the limiter can be switched out.

An improved optical system, shown schematically in Fig. I-2(a), has been designed. In this system, light from each point on the cathode surface is spread out over the entire surface of the lead sulphide cell. Thus, any local inhomogeneity in the lead sulphide film will not affect the measurements.

Radiation from the cathode K passes through the anode hole H and is focused on the circular aperture B by means of the lens L and the aluminized prism P. This aperture defines the area of the cathode which the detector D sees. Another circular aperture A, placed before the lens L, limits the cone angle accepted from each point on the cathode. The sizes of the two apertures, A and B, define a minimum size for the anode hole. A three-section chopper and shutter C, driven by a synchronous motor M, exposes the cathodes to the detector alternately at 90 cps.

The lens system S forms an image of the two lenses (L) on the detector. These images overlap, as shown in Fig. I-2(b), each covering the sensitive area of the detector.

Since calculations show that the amount of radiation through the new system is of the same order of magnitude as the amount of radiation through the old system, it is expected that the early measurements will be approximately correct for the new system.

Some trouble has been encountered with spurious fluctuations when the amplifier is set to its highest gain. These difficulties do not arise within the amplifier itself and are thought either to be inherent in the lead sulphide cell or to be caused by vibrations or pickup in the present test setup.

Plans for a pilot model of the revised optical system are being drawn up. When this model is completed further tests will be made to determine the range and applicability of the instrument.

W. M. Bullis

References

1. Quarterly Progress Report, Research Laboratory of Electronics, M.I.T., July 15, 1952; July 15, 1953.

2. Quarterly Progress Report, Research Laboratory of Electronics, M.I.T., July 15, 1953; Jan. 15, 1954.

2. Cleanup and Diffusion of Helium in Ionization Gauges

Upon investigating the systematic variations of experiment with our theory of the cleanup of helium, a modification of the theory was found necessary. In order to describe accurately the experimental curves, the following may be assumed:

$$\frac{dN_s}{dt} = -(\alpha i) N_s + \beta N_\omega + P_{(T)} \tag{1}$$

where we state that the rate of change of the number in the ionizing space, dN_s/dt, depends on the rate of cleanup caused by ionization $(-\alpha i) N_s$, the rate at which helium atoms are evolved from an internal surface, (βN_ω), N_ω being the number of helium atoms on the surface, and the rate at which helium permeates through the pyrex walls $P_{(T)}$.

Setting up a similar equation for the surface in equilibrium with the ionizing region, the following is assumed:

$$\frac{dN_\omega}{dt} = - \beta N_\omega + \gamma i N_s \tag{2}$$

where it is recognized that only a portion of the total number cleaned up is collected at the readmitting surface.

Solution of these equations gives

$$(N_s - N_\infty) = C_1 \exp(+r_1 t) + C_2 \exp(+r_2 t)$$

$$r_1, r_2 = \left[-A \mp (A^2 - 4B)^{1/2}\right]/2$$

$$A = ai + \beta, \quad B = \beta(ai - \gamma i)$$

This predicted curve is in very good agreement with experiment.

Notice that

$$r_1 + r_2 = -A = -(ai + \beta)$$

$$(r_1 - r_2)^2 = A^2 - 4B$$

Thus if two cleanup curves are used for which the electron currents are different, but the electron collector voltage is the same, experimental values of a, β, and γ may be determined for a particular value of electron collector voltage.

Data are being taken to determine a, β, and γ for the range of voltages common for the operation of the Bayard-Alpert ionization gauge.

D. H. Dickey

3. Ionization-Gauge Control Circuit

A direct-reading control circuit has been developed for use with both the standard ionization gauge and the Bayard-Alpert type of ionization gauge (shielded and unshielded) for the measurement of very low pressures. Some of the features and advantages of the circuit are:

(a) Batteries are not needed. The circuit is completely operated from the power line.

(b) It is very stable with respect to internal drift.

(c) Calibration procedure for the circuit is extremely simple and there is little need for readjustment.

(d) The calibration voltage (accurate to approximately 1 percent) is internally supplied by a resistance network and a voltage regulator tube.

(e) The electron collector potential applied to the ion gauge is obtained from a voltage regulator tube instead of a resistance network and therefore remains constant as the electron current is changed.

(f) The time constant of the circuit has been reduced considerably by the use of negative feedback.

(g) Provision has been made for the easy connection of an external recorder or meter.

(h) The circuit will readily serve as a very convenient vacuum tube electrometer without any modifications.

A second model with certain proposed improvements over the experimental circuit is being constructed. After the circuit has been used a little more to locate and eliminate any possible defects, a more complete description will be given.

S. Aisenberg