

I. PHYSICAL ELECTRONICS

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A. ELECTRON-EMISSION PROBLEMS

1. Thermionic Work Function and Conductivity of Oxide-Coated Cathodes

The investigation of the thermionic emission and conductivity of an oxide-coated cathode is being continued in order to determine the true values of the energy levels in (Ba, Sr)O. With the cathode activated on the vacuum system it yielded a thermionic work function of 1.38 eV and a conductivity activation energy of 1.31 eV. Another attempt was made to increase the activation of the cathode. When this was completed, the tube was removed from the vacuum system. With the Bayard-Alpert ion gauge running, the straight-line portion of a Richardson plot resulted in $\phi = 0.98$ eV.

In the low-temperature region of Richardson plots taken at this state of activation, the observed electron emission decreased with time. Contamination of some sort was suspected. To measure the contamination involved, observations were made of the

decrease in emission of one of the ion gauge filaments run at 1660°K as a function of the time after flashing the filament to 2200°K. Contamination was evident even though the pressure remained constant at 1.5×10^{-8} from day to day. The getter was flashed at this time with the ion gauge inoperative. One-half hour after turning on the ion gauge the rate of contamination had decreased. Furthermore, after 15 hours of gauge operation, there was a very marked decrease in the contamination rate. The conclusion is that both an operating ion gauge and a flashed getter were needed to clean up the contaminating gases. A probable explanation of this cleanup action is that the gauge breaks up molecules or ionizes molecules and atoms which then react readily with the getter.

An experiment was done with the ion gauge which showed that positive ions were flashed off a hot tungsten filament which

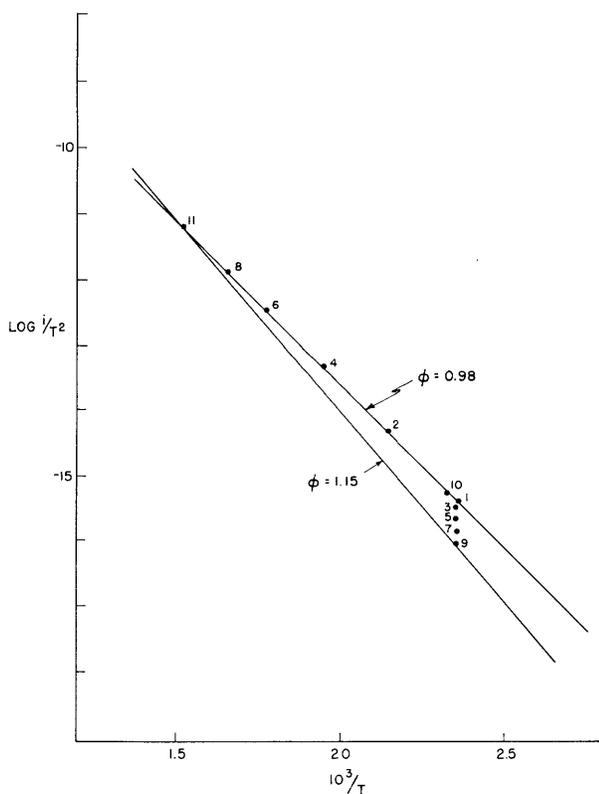


Fig. I-1 Richardson plot.

(I. PHYSICAL ELECTRONICS)

had been resting at room temperature for 13 days. The positive ion current in this case was at least 1.5×10^{-7} amp. This is interesting because only a few atoms and molecules have ionization potentials close to the work function of tungsten. This result has been found and is recorded in the work on ionization gauges elsewhere in this report.

After the getter was flashed, research on Richardson plots in the temperature range from 700°K to 295°K revealed several interesting results. The low-temperature deviation observed before the getter flash was no longer present. Temperature cycling and jumping from low to high to low temperatures as shown in Fig. I-1 was carried out in order to show that straight lines can be obtained and yet be unreliable. Whether or not the ion gauge was operating made a definite difference. This indicated that the emission from the oxide depended both on the particular gases present in the tube and whether or not the gases were ionized or disassociated at pressures of 10^{-9} to 10^{-7} mm Hg.

Research is being done on the photoelectric effect caused by the ion gauge filament. The results of this work are not yet conclusive. R. T. Watson

2. Magnetic Velocity Analyzer Investigation of Thermionic Emission from Tungsten

The contemplated measurements of the thermionic work function and its temperature derivative are to be made on a recrystallized tungsten filament. It is required that the filament have a single crystal occupying the entire cross section of the wire and extending at least 2 cm in length. One such filament has been obtained, and the techniques have been mastered thoroughly enough so that these filaments may be prepared as needed.

The schedule of preparation for such a filament is as follows:

1. A length of 0.003-inch diameter G. E. No. 218 "Non-sag" is ground and polished until it appears as a smooth cylinder microscopically. The final diameter is 0.002 inch.
2. The wire is then spring-mounted between press leads at the ends of a cylindrical glass envelope. The envelope is coated inside with a ZnS phosphor, and is provided with a cylindrically symmetrical wire structure which serves to collect the secondary electrons from the phosphor in step No. 4.
3. The wire is then heated by conduction. Starting at 1700°K its temperature is raised 100° at one-hour intervals until it has reached 2500°K where it is given one-half hour.
4. A potential of 5000 volts is then applied to the collector, and with a filament temperature of about 2300°K, the thermionic emission pattern characteristic of the single crystals that have grown in the filament is observed. This pattern may be photographed with good contrast by using a Wratten C-4 deep blue filter.

A. R. Hutson

3. Photoelectric Emission

Some preliminary retarding potential and spectral energy distribution data have been obtained on the molybdenum surfaces to be used as the substratum for the deposition of germanium films in the experimental tube described previously. In order to obtain these data, ultraviolet spectral lines from cadmium, mercury, and tellurium discharge tubes described in the last report were used. The ultraviolet lines generated are as follows: 2001A, 2064A, 2142A, 2208A, 2259A, 2288A, 2385A, 2378A, 2399A, 2482A, 2537A, 2345A, 2654A, 2698A, 2760A, 2804A and 2893A. These lines are sufficiently close together to permit a thorough investigation of a wide spectral range. All but the 2001A and 2064A lines were used in the data.

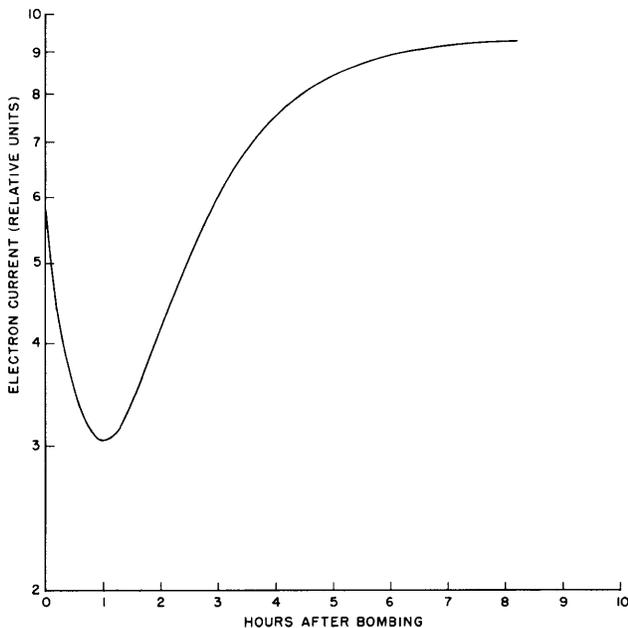


Fig. I-2 Rate of surface contamination.

The molybdenum surfaces were heated by electron bombardment to 2000°K prior to the time the data were taken. If the emission from a given spectral line is tabulated as a function of time after heating, a curve similar to that shown in Fig. I-2 for the mercury 2537A line is obtained. Apparently the decreasing part of the curve is the cooling curve for the molybdenum cathode, while the increasing portion is a gas contamination curve. The surface seems to saturate after eight hours, and the work function remains constant for a period of days. The pressure in the tube as read by a Bayard gauge is 6×10^{-9} mm Hg.

Figure I-3 shows the retarding potential curves obtained for the wavelength 2385A for a contaminated molybdenum surface after it has reached the saturation value described above. The dashed curve represents the duBridge (1) theory. Although not plotted, the theory of Mitchell (2), which takes into account the transition probability of the electron, will lie between the experimental and the duBridge curve.

To obtain a spectral energy distribution curve, or Fowler plot, the relative intensity of the spectral lines must be known. These intensities were obtained from a radiation thermocouple and a ZnSiO_4 phosphor painted on a 929 phototube. For the brighter lines the thermocouple was used; for the dim lines the phosphor was used in conjunction with the excitation spectrum found by Kröger (3). Figure I-4 shows the Fowler plot for the molybdenum with saturated contamination. The ordinate is in relative units proportional

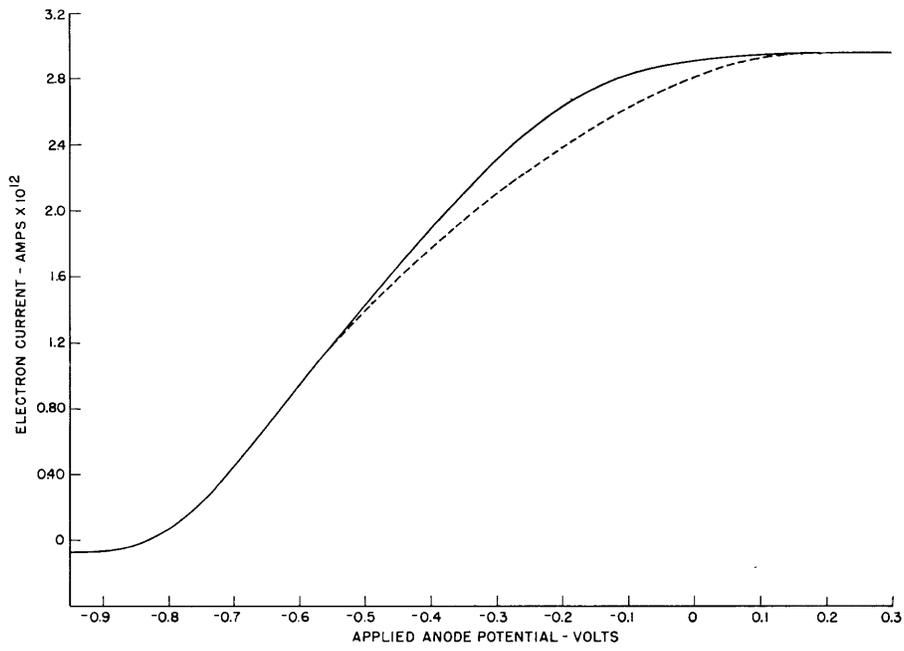


Fig. I-3 Retarding potential plot $\lambda = 2385 \text{ \AA}$.

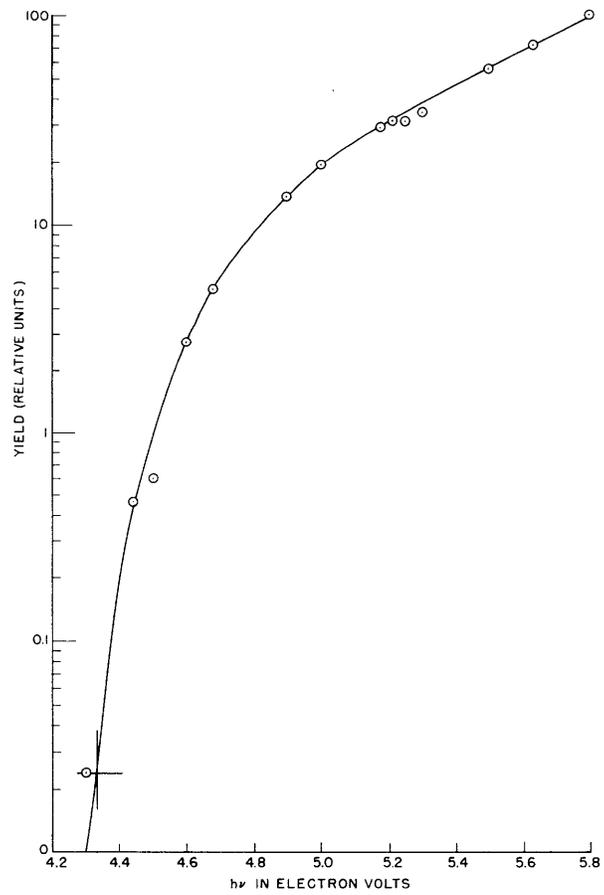


Fig. I-4 Fowler plot for molybdenum work function 4.33 eV.

(I. PHYSICAL ELECTRONICS)

to the number of electrons emitted per incident quantum. The cross represents the work function of the molybdenum as 4.33 ev, which is in close agreement with results found by other experimenters (4).

References

1. L. A. duBridge: Phys. Rev. 43, 727 (1933).
2. K. Mitchell: Proc. Camb. Phil. Soc. 31, 46 (1935).
3. F. A. Kröger: Physica 6, 764 (1939).
4. L. A. duBridge, W. W. Roehr: Phys. Rev. 42, 52 (1932).

H. S. Jarrett

4. Photoelectric Emission from Quartz

Since the last report the experimental tube for measuring the photoelectric properties of surface electrons in quartz has been completed. From the data taken several conclusions can be drawn.

In the first place, the emission does occur and it can be measured by an apparatus of this sort. As might be expected from the transparency of quartz in this region, the photoelectric yield of the emission process is low. The currents induced in the electrometer circuit through the coupling capacitor were of the order 10^{-13} to 10^{-14} amp.

The threshold was not determined with the originally hoped-for precision, but apparently lies in the region 280 to 300 m μ . The corresponding work function is 4.33 to 4.13 ev.

In addition to the above photoelectric properties, some information was obtained relating to the first cross-over potential of crystalline quartz. It was found that primary electrons arriving with an energy of approximately 33 ev produced secondary electrons in a ratio greater than unity. There was evidence that the actual cross-over potential was not much less than this figure, though a limitation of this sort of experiment is that, at best, it can only set an upper limit.

D. Jeffries

B. STUDIES WITH GASEOUS DISCHARGE

1. Investigation of Low-Pressure Mercury Arcs

A program has been prepared for a continuation of the study of low-pressure mercury arcs. The work has not been undertaken.

J. M. Bailey

C. EXPERIMENTAL TECHNIQUES

1. Spectral Emissivity of Tungsten

The latest tube constructed for this investigation has been completed except for its evacuation. Although the evacuation has been started, it has been held up pending the development of better vacuum gauges and other vacuum studies.

(I. PHYSICAL ELECTRONICS)

2. Ionization Gauge Studies

The vacuum gauge most commonly used for high vacuum measurement is the ionization gauge constructed with a hairpin filament along the axis of the tube and generally used as the source of electrons. Surrounding this filament and wound in the form of an open helix is a second filament which serves as the electron collector. The ion collector is generally an open-ended cylinder more or less coaxial with the other two elements and operated at a potential negative with respect to the electron-emission filament. Although some photoelectric emission occurs at this ion collector as the result of the light emitted from the hot filament this background current is small and easy to correct. The "reverse photoelectric effect" or the X-ray effect sets a definite limit to the minimum gas pressure that can be measured for this gauge design. This reverse photoeffect was described in some detail in the Final Report, June 30, 1946, page 16. The phenomenon involves the emission of a photon from the electron collector when it receives an electron from the filament. This photon in turn may be absorbed by the ion collector and cause it to emit an electron which finally goes to the electron collector and gives the same indication as the arrival of a positive ion at the ion collector. This effect is hard to distinguish from the arrival of positive ions although by making a detailed

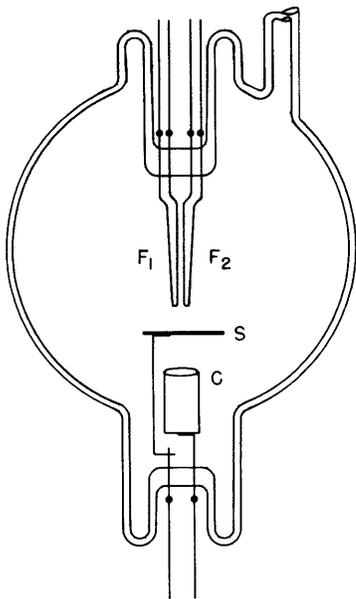


Fig. I-5

Ionization gauge. F_1 is electron emitter; F_2 is electron collector; S is shield (used as electron collector or at ion collector potential); C is ion collector.

study of the voltage-current characteristics of the gauge one can establish that the observed current in the limiting case is the result of reverse photoeffect only. The first major step in the elimination of this effect was made by Alpert and Bayard (see Rev. Sci. Instr. 21, 571, 1950). Their method of reducing the reverse photoeffect is to build a gauge with an ion collector of very much smaller cross section by placing it inside of the electron collector. The source of the electrons is the filament outside the cylindrical electron collector. The Bayard method of solving the problem is definitely limited to an improvement of the order of one hundred fold in the limiting range. Since the ordinary gauge is of very little use for a vacuum better than 2×10^{-8} mm Hg, the Bayard gauge is limited to 10^{-10} mm and higher pressures.

An entirely new gauge design has been developed in connection with these studies

(I. PHYSICAL ELECTRONICS)

and is illustrated in Fig. 1-5. Two filaments F_1 and F_2 are shown mounted on a four-lead press. One of these filaments serves as the electron emitter while the other one is the electron receiver. These filaments are located at the center of a spherical bulb. The ion collector is a small cylinder C and the disk S serves as a shield so that the light from filament F_1 cannot reach the collector C and the photons produced by electron absorption at F_2 cannot go directly to the ion collector. The purpose of the spherical bulb is to reflect all of this light back to the filament region. It should be noted that this gauge is of an extremely simplified design and therefore much easier to build than either the commonly used gauge or the Bayard gauge. Two models of this gauge have been produced and others are well underway. When properly designed and operated this gauge has no obvious limitation as regards the minimum pressure at which it can be used. The indications are that if the surface reflections from the glass wall are reduced sufficiently Experiments reported in the October Quarterly Progress Report by Dr. M. K. Wilkenson indicate that 10^{-12} mm can be obtained in suitably processed sealed-off tubes. The experiments carried on so far with the new gauge shortly after it was sealed-off of the vacuum system indicate a pressure of 10^{-10} mm. the vacuum system indicate a pressure of 10^{-10} mm.

The first gauge made according to this new design and operated as described above showed a sensitivity equal to that of a good Bayard gauge. Two others were much lower in sensitivity except when operated with the shield S functioning as an electron collector as well as a shield. Progress to date indicates that this alternate method of operation is free of reverse photoeffect.

It has been well established for the past two or three years that, unless very perfect vacuum conditions are obtained, gas atoms will adsorb on a clean tungsten filament until a considerable fraction of a monolayer is produced there. By suddenly increasing the temperature of this filament after specific time periods of cold standby, one observes a "burst" of ion current which is a measure of the rate of adsorption of atoms on a clean surface. A new phenomenon of this type has been observed recently and may be of some interest. The experimental arrangement in this case involves the presence of a cold filament which just before flashing can be made very positive with respect to the ion collector. No other voltages are needed in the tube. If the filament has been standing by in high vacuum for some days a very measurable positive ion current is observed as soon as the filament is flashed to a temperature to the order of 1000°K or higher. The introduction of a high pressure of mercury vapor does not enhance the effect and likewise the presence of nitrogen at pressure of the order of 10^{-6} mm seems to have no effect. After a few hours of baking at about 450°C this ion flash is extremely great and actually yields a much greater number of ions to the ion collector than is the case for the ordinary flash filament method of observing the presence of gas. We assume that one of the more likely atoms that might yield this effect could possibly be sodium. This

(I. PHYSICAL ELECTRONICS)

experimental result is described in detail so that other workers in the field prepared to identify the presence of ions by mass spectrographic methods might be interested in looking for a similar phenomenon and may be able to identify the mass associated with the substance.

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