I. PHYSICAL ELECTRONICS

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A. ELECTRON EMISSION PROBLEMS

1. Magnetic Velocity Analyzer Investigation of Thermionic Emission from Tungsten

The vacuum tube in which this experiment is to be carried out must be assembled very accurately, as alignment must be maintained between a rotatable filament and the entrance slit of a 180° magnetic velocity analyzer. Unfortunately, the existing spot-welding and assembly techniques proved inadequate. The need for the following improvements in technique became clear during the course of recent unsuccessful assembly attempts.

a. A method for "jigging" the main assembly rigidly in any position with respect to the large fixed jaws of the spot welder is necessary in order to make mechanically strong welds between the supporting members of the rotating filament structure without tearing them loose from the main structure. (These members are cantilevered from the main part of the structure so that insulating glass beads may be inserted without making it impossible to outgas the analyzer itself by induction heating during the final vacuum processing.) This jigging will now be accomplished by fastening the work to a lockable ball-and-socket joint mounted on an adjustable platform made from a "scissors" type of automobile jack.

b. Improved alignment jigs are necessary so that the axis of rotation of the filament will remain accurately parallel with the entrance slit of the analyzer chamber.

c. It became evident that a better design of the rotating filament yoke is necessary so that the delicate, crystallized filament can be accurately welded into place with a relatively small chance of breakage.

These improvements are now nearly complete.

A. R. Hutson

2. Photoelectric Study of Surface States on Insulators

A vibrating reed electrometer has been set up and preliminary tests show that the background current is less than 10^{-17} amp. A set of input shields has been constructed, so that the instrument is now ready for use.

After trying several designs for heaters and radiation shields, a suitable arrangement has been found whereby the crystal may be uniformly heated to well over 1000° K to clean the surface of the sample. The heater consists of a coil of 20-mil tungsten wound on a 1/8-inch mandrel, supported at the ends and in the middle. The entire radiation oven (except the surface to be studied) is surrounded by a double radiation shield. The crystal may be heated at any time during the operation of the tube.

The material being used in the experimental tube at the present is fused quartz. Since the study of this material will yield no information about crystalline insulators, it is planned to repeat the experiment on another substance. Some work has been done with mica; while it may be satisfactory, it decomposed at high temperatures. Consideration is being given to working with MgO and NaCl, both of which are available in single crystal form and have been studied for energy-band structure.

A vacuum thermopile has been set up for the absolute measurement of light intensities, and though it seems to be satisfactory for the intensities available in the visible spectrum, it lacks the necessary sensitivity for work in the ultraviolet.

R. N. Noyce

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

Study has continued on the problems arising when one measures electron field emission from a tungsten point. Several conclusions have been made from the literature of previous researches in this field. They are:

a. By means of field emission techniques, the absolute value of work-function for one crystallographic direction can only be determined within approximately 7 percent. This uncertainty is caused by the error present in measuring the radius of curvature of the tungsten point by means of an electron microscope shadowgraph. Since the work-function values for tungsten have been measured thermionically by Nichols (1) with an accuracy of considerably better than 7 percent, it seems, for this problem, that field emission measurements are not able to yield, by themselves, useful values of work-function.

b. However, field emission measurements can yield ratios of work-functions accurate to approximately 1 percent, for the various crystallographic directions present on a point. Wilkinson (2) measured these ratios, and his values are consistent with Nichols' values within 1 percent.

c. Considerable disagreement remains over the work-function of the 110 direction of tungsten. This crystallographic direction has the highest work-function of any of the directions yet measured. Thus, any spurious effects in an experimental measurement will affect most seriously the measurements made on the 110 crystal face. Published values of the work-function of the 110 direction range from 4.68 ev to 6.0 ev, although several authors have recently declared their values are in error due to spurious effects.

d. Therefore, the primary goal of this research will be to measure, by field emission techniques as free from spurious effects as possible, the ratios of field emission current density from various crystallographic faces of a tungsten crystal. From these ratios one can calculate the ratios of work-functions. One can then predict the work-function of the high work-function directions from the more accurately known values for the low work-function directions.

At present the following experimental program is visualized. A field emission projection tube will be constructed, consisting of a tungsten point at the center of a spherical envelope of conducting glass. On the inside of the glass envelope there will be a layer of phosphor held at a potential of several thousand volts positive with respect to the point. Field-emitted electrons will travel radially from the point to the phosphor and will be detected by photometering light from the phosphor. An additional electrode will be present in the tube which will cast an electron "shadow" on the phosphor. By photometering the light coming from the shadow region, one will be able to get an idea of the intensity of scattered light and soft X-rays.

If spurious effects in the phosphor tube are large enough to mask the field emission from the 110 direction, another type of tube will be constructed similar to tubes constructed by Müller (3). It will have a metal anode with a hole in it. Behind the hole will be an electron collector. The relative current densities of field-emitted electrons from various crystallographic directions can be measured by magnetically deflecting them into the anode hole.

A simple and exact method of determining work-functions from field emission measurements has been worked out. This involved numerically evaluating a function of the function v(y) found in the exponent of the Fowler-Nordheim equation for field emission. A letter incorporating these results has been prepared and submitted to The Physical Review.

J. M. Houston

References

1. M. H. Nichols: Phys. Rev. 57, 297, 1940
2. M. K. Wilkinson: Doctoral Thesis, Department of Physics, M.I.T. 1950
3. E. W. Müller: Z. Physik 102, 734, 1934

4. Conduction Mechanism in Oxide-Coated Cathodes

The development and construction of apparatus to be used in this investigation is virtually completed. It will be recalled that information regarding the "pore conduction" hypothesis is being sought by observing the possible effects of various pressures of helium gas on the conductivity of oxide-coated cathodes. The first phase of this problem is to determine the apparent mobility of slow electrons in helium over distances which are much too small for the steady state to have been reached. A double-cathode tube has been constructed in which one of the cathodes is movable, and the surface-to-surface distance can be taken to be a controllable parameter. The electron conduction across this gap is to be measured in high vacuum and also in the presence of purified helium gas at a wide range of pressure. The "helium super-leak" to be used to admit the helium to the system has undergone additional modifications and will soon be ready for use. The pressure is to be measured indirectly by the use of a differential-diaphragm type of manometer. This unit consists of a stainless steel diaphragm 3 inches in diameter and 0.004 inch thick stretched 0.030 inch above the bottom of a stainless steel cup. The chamber thus formed is connected by tubing to the double-cathode tube. The helium pressure is measured by adjusting the air pressure on the upper side of the diaphragm until it is in its unstrained position, as indicated by a capacitance probe. Very accurate measurements of the helium pressure are thus possible without danger of contamination. Some diffficulty was encountered in mounting the metal components of the system (two bakeable metal valves, the manometer, and a copper pinch-off tube) in relation to the glass components of the system, due to their difference in thermal expansion during bakeout, but the solution to this problem is now well in hand.

E. B. Hensley

5. Nonspace-Charge to Space-Charge Transition as a Function of Temperature in Test Diodes

The solution to the generalized problem of space-charge limited emission formulated by Langmuir (Phys. Rev. <u>21</u>, 419, 1923) many years ago has been adapted to answer some of the following questions as applied to the idealized diode which has a parallel plane geometry and a uniform distribution of electron emission characterized by a specific work-function and temperature.

a. How does the depth of the space-charge potential minimum vary with the temperature?

b. How far away from the cathode is the potential minimum, and upon what factors does it depend?

c. For a given temperature, for what voltage range, both positive and negative, does space charge influence the emission current?

d. For a given applied voltage, how does the current change with temperature over the entire range of observable values, including both the nonspace-charge and the space-charge regions?

The new analysis, now being prepared for presentation as a technical report, answers these questions and many others and becomes readily adaptable to practical applications. It allows the experimenter to establish certain "effective" values of the noncontrollable parameters in practical tubes, by relating the answers to the above questions to a temperature relation that is divided into two regions at the critical value T_a for a given specimen. At the temperature T_a space charge first shows its effect.

W. B. Nottingham

B. PHYSICAL ELECTRONICS OF THE SOLID STATE

1. Temperature Gradients Across Ionic Crystals

It is known that electrical conduction in ionic crystals is possible because of imperfections in the crystal lattice. From the work of Wagner and Koch (Z. physik Chem. B38, 295, 1937-8) these imperfections in silver chloride are silver ions in interstitial positions, together with vacancies in the regular silver lattice sites. Two temperature regions are found; at high temperatures these imperfections are in equilibrium with the crystal, whereas at low temperatures the imperfections become frozen in and their number therefore depends on the past history of the specimen.

Work has continued on the measurement of emf's set up whenever a temperature gradient is established across a silver chloride crystal. It has been noted that at room temperature the AgCl crystal is without color, but as the temperature is raised and a temperature gradient is established, the crystal turns a greenish-yellow. After being cooled and left overnight, the crystal returns to its original state. A special tube is now being constructed for a more detailed study of this effect.

W. Grattidge

C. EXPERIMENTAL TECHNIQUES

1. Ionization Gauge and General Vacuum Studies

An investigation was made of the effect of ion-collector potential upon the ionization and collection efficiency, as well as the effect of change of ion-collector length upon the ion-collection characteristics and the gauge sensitivity. A shorter ion collector with reduced surface area would imply a reduction in the electron emission caused by the soft X-ray and photoelectric effect. This emission of electrons results in a limitation on the measurement of very low pressure. In Fig. I-1 a comparison is made of the gauge sensitivity vs ion-collector potential characteristics for a full-length ion collector, and for a gauge with an ion collector 30 percent shorter. The sensitivity of the gauge with the shortened collector was found to be about 30 percent lower. The drop in the characteristic curve for the full-length collector can be ascribed to the reduction of ionization volume as the depth of the potential well is increased. The hump in the

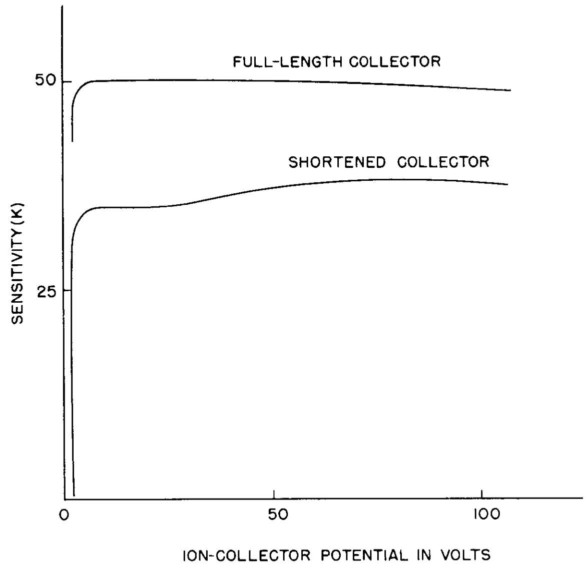

Fig. I-1

Comparison of gauge sensitivity vs ion-collector potential for full length and shortened ion collector.

characteristics for the shortened collector can be explained in the following way: at about 25 volts all of the ions are not being collected; but, as the collector potential is increased, more of the ions in the end of the electron collector cage not occupied by the ion collector are attracted to the ion collector and the gauge sensitivity is increased. For larger potentials the sensitivity decreases because of the reduction of ionization volume.

A Bayard-Alpert type of ionization gauge was constructed of molybdenum instead of the usual tantalum, in order to compare the behavior of these two metals at very low pressures. Measurements are being taken and the results will be reported as soon as they are conclusive.

In our previous work the gas pressures measured and reported have been total pressures; that is, we have had no way of measuring partial pressures or analyzing the residual gases. In order to learn more about the actual limitations in vacuum studies, we are about to attempt to analyze the residual gases in vacuum systems and in sealed-off tubes. A modified omegatron has been designed and constructed. This tube can be thought of as a mass spectrometer which works on the cyclotron principle. An axial electron beam flows in the direction of a magnetic field and produces ions. An rf voltage is applied, perpendicular to the magnetic field, and causes charged particles to move in curvilinear orbits. When the radio frequency coincides with the "cyclotron frequency" of some particular gas, the ions move in orbits which are Archimedes' spirals. The spiral orbits take the ions outward from the electron beam and cause them to be incident on an ion collector. Off-resonant ions move in orbits which "beat;" that is, they successively travel in bigger, then smaller, circular orbits about the electron beam but never reach the ion collector. The electron stream is held in a concentrated beam by the magnetic field. This tube has been completed, but no results have been obtained.

S. Aisenberg, W. J. Lange, L. E. Sprague, W. B. Nottingham

2. Infrared Radiation Pyrometer for Temperature Measurements on Oxide-Coated Cathodes

Work on this problem has been concentrated on the construction of the amplifier to be used for the measuring circuit and the removal of the faults from the breadboard model.

The amplifier consists of six stages arranged in two sections as shown in Fig. I-2: the first stages consist of very sharply tuned 90-cycle amplifiers and the last three are standard amplifier stages, ending with a cathode follower which feeds into a milliammeter.

The next problem is to design the pyrometer head which will consist of the motor, lead sulfide cell, and preamplifier, in addition to the optical system and the two tubes under investigation: the standard tube and the unknown tube (see Fig. I-3).

W. M. Bullis

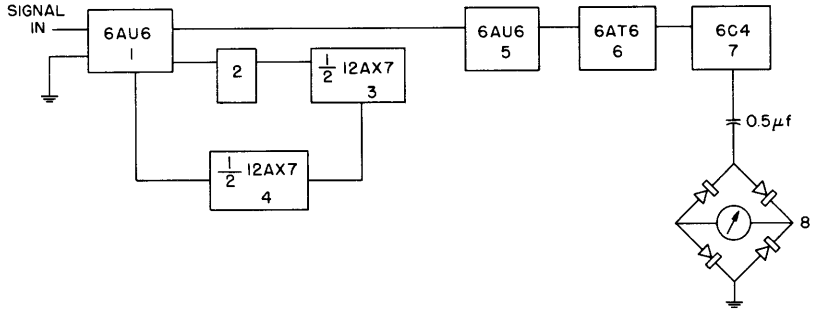

Fig. I-2

Block diagram of amplifier: (1) pentode amplifier; (2) 90-cycle reject filter; (3) triode amplifier; (4) triode cathode follower feedback stage; (5) pentode amplifier (90 cycles only); (6) triode amplifier (90 cycles only); (7) triode cathode follower output stage; (8) rectifier bridge and milliammeter.

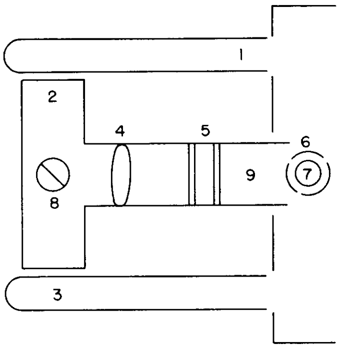

Fig. I-3

Diagram of optical system: (1) standard tube with thermocouple; (2) 3/4-inch square tube; (3) tube whose temperature is to be measured; (4) quartz lens (focal length - approximately 2 cm length to lead cell - 3.14 cm; (5) filters; (6) chopper mounted on 1800 rpm motor (90 cps); (7) lead sulfide cell; (8) two position mirror; (9) 3/4-inch round tube.