

I. PHYSICAL ELECTRONICS

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A. ELECTRON EMISSION PROBLEMS

1. Magnetic Velocity Analyzer Investigation of Thermionic Emission from Tungsten

The operation of the magnetic velocity analyzer tube requires an accurately known magnetic field. Two Helmholtz coils have been set up in order to provide the known field and cancel the earth's field. In order to make an exact cancellation of the earth's magnetic field, a small air-driven dc generator was placed at the center of the two Helmholtz coils. The generator consists of an armature of approximately 4000 turns connected to a split commutator. Since it has no field coil, its output is directly proportional to the magnetic field in which it finds itself. By observing the generator's output voltage on a galvanometer, one can vary the orientation and current of the earth-cancelling Helmholtz coil until the generator shows no output in three mutually perpendicular directions. This method achieves cancellation of the earth's field to within 0.5 percent.

A. R. Hutson

2. Photoelectric Study of Surface States on Insulators

Preliminary study on the heating of the quartz crystal in order to clean the surface has shown that it is impossible to pass through the transition from α to β quartz (573°C) without fracturing the crystal. Other methods of cleaning the surface of the sample are being considered. It has been found that this difficulty does not exist in using a fused quartz sample, and a tube using a fused quartz disk is now under construction.

Since the study of fused quartz will give no conclusive evidence about surface states on a crystalline surface, consideration has been given to the use of another crystalline substance which may be heated. Mica seems to be a good substance for many reasons: it is readily available in thin sheets having fracture planes exposed; its resistivity is 2×10^{17} ohm-cm; and its forbidden band as shown by optical transmission is 4.15 eV, as compared with 6.5 eV in quartz. With this more narrow band it is thought that the radiation necessary to remove electrons from the surface will be in a more accessible region of the spectrum. A tube using mica is being planned, with provision for heating the crystal to a high temperature.

A vibrating reed electrometer has been ordered from Applied Physics Corporation for use in the measurement of the photocurrents.

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A modified Baird-Alpert ionization gauge has been constructed, similar in design to that described in the Quarterly Progress Report, January 15, 1952. This gauge was assembled on a single press, greatly simplifying construction and glassblowing, with no appreciable loss in sensitivity.

R. N. Noyce

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

A research is being planned to recheck the experimental dependence of field emission current density on applied electric field and surface work-function, against the theoretical dependence predicted by the Fowler-Nordheim equation. Also, it is hoped to be able to determine relative values of field emission work-function for the various crystallographic directions of tungsten.

In 1949-50 Wilkinson measured the crystallographic variation of electron field emission from a tungsten point by photometering light from a phosphor-coated sphere around the point. He showed that the variations in field emission current with applied voltage agrees with the Fowler-Nordheim equation. He also showed, less definitely, that the three-halves power of work function in the exponential factor of the Fowler-Nordheim equation is correct. However, he was not able to determine accurately the electric field present at his point; nor did he report measurements of the importance of scattered light in introducing error, especially in the high work-function regions.

In the present research, measurements will be made of the importance of scattered light to determine whether photometering a phosphor is a suitable method for measuring field emission from high work-function areas of the tungsten point. Also, it is planned to take electron microscope shadowgraphs of the points used and then measure the electric field from large-scale models of the points.

Once the electric field is known, one can determine a value of the field emission work-function, which can then be compared to other work-function determinations such as the Richardson work-function. It will be interesting to compare these results with those of Mr. A. R. Hutson who is now attempting to measure the crystallographic variation of thermionic work-function.

J. M. Houston

4. Conduction Mechanism in Oxide-Coated Cathodes

Currently in the literature there are two theories concerning the conduction mechanism in oxide-coated cathodes. One regards the crystals of the porous aggregate as simple n-type semiconductors with the conduction current passing electronically through the crystals. The other maintains that the conduction current at the higher operating temperatures is carried by the electron gas in the pores of the aggregate. One possible

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method that has been proposed for distinguishing between these two mechanisms is to fill the envelope containing the cathode with pure helium gas under pressure, thereby reducing the mobility of any electrons in the pores. Although it is understood that this experiment has been tried, no clear-cut results have been published. One difficulty lies in the uncertainty of information regarding the mobility of electrons in helium for values of E/p much less than one volt/cm-mm Hg.

As a preliminary approach to this problem the following experiment will be carried out. Two button-type cathodes similar to those used in cathode-ray tubes will be mounted facing each other in such a manner that one can be moved along their axis to bring their surfaces together for making conductivity measurements, or they can be separated at various spacings at the discretion of the operator. With the heated cathodes separated, pure helium gas will be admitted at various pressures and from its influence on the flow of current between the two cathodes, the mobility of the electrons in helium will be determined under conditions operationally similar to those existing in the pores of the cathode. From these data it should be possible to predict the pressures of helium which will be required to influence any current present in the pores.

In the design of the experimental apparatus, particular emphasis is being placed on the purity of the helium gas to insure that possible chemical effects do not obscure the results. This will be accomplished by utilizing a technique devised by Biondi (M. A. Biondi: Rev. Sci. Instr. 22, 535L (1951)). This method depends on the ability of the superfluid component of liquid helium, which is below the λ -point (2.18°K), to penetrate a minute opening or superleak. The superleak consists of a platinum wire sealed into a pyrex capillary which connects a liquid helium bath to a highly evacuated vacuum system. The imperfect seal between the platinum and pyrex is too small a leak to admit normal fluids; however, superfluid helium is able to penetrate the leak at a usable flow rate.

The construction of the apparatus is nearing completion. A new vacuum system employing mercury vapor pumps and equipped with bakable metal valves for handling the gas is in operation. Kinetic vacuums of better than 10^{-9} mm Hg are readily obtainable. A new ion gauge control circuit to be used with the Bayard-Alpert ionization gauges has been designed and has proved to be quite satisfactory for monitoring these high vacuums. A manometer of the differential-diaphragm type for measuring the pressure of the helium without contaminating the system is under construction.

E. B. Hensley

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B. PHYSICAL ELECTRONICS OF THE SOLID STATE

1. Studies of Thermoelectric Power and Conductivity of Ionic Conductors

Measurements of thermoelectric power and conductivity of barium oxide over a wide temperature range have recently been reported (J. R. Young: Technical Report No. 10, Contract N7onr-292, Task Order 5, University of Missouri). It was found that the temperature dependence of the thermoelectric power was different in the high and low temperature regions, these regions having been previously defined for the conductivity behavior of barium oxide. In the high temperature region the slope of the temperature dependence of the thermoelectric power correlated with the slope of the temperature dependence of the conductivity. In the low temperature region there was no such agreement; the thermoelectric power was apparently almost independent of temperature.

Any explanation of such behavior in the two temperature regions appears to have to be given in terms of two mechanisms, with one or the other of them dominant in each region. For the high temperature region, there are two proposed mechanisms: electron transport within the pores of the porous material; electron transport through the material itself acting as an n-type semiconductor. Both proposals indicate a basis for the correlation of slopes noted above. For the low temperature region no completely satisfactory mechanism has been indicated.

It is suggested that the thermoelectric power in this region might be explained in terms of the thermoelectric power of an ionic conductor, and with this in mind a study of the thermoelectric power and conductivity of ionic conductors is being established. Silver chloride is the first material chosen for study and it is planned to investigate it in single-crystal and other forms.

The measurements will be taken on specimens held between two electrodes in vacuum; each electrode, whose temperature can be measured by attached thermocouples, will be heated independently. The emf generated as a result of a temperature difference established across the specimen is measured by a type K potentiometer and the emf per degree temperature difference, the thermoelectric power, is found as a function of temperature for the range from room temperature to temperature close to the melting point. The conductivity of the specimens for different temperatures will also be investigated and polarization effects will be studied.

At the present time the vacuum system has been constructed and tested and is capable of producing pressures lower than 10^{-9} mm Hg. The initial electrical equipment for thermoelectric power and conductivity studies has been assembled and preliminary measurements have been made on a silver chloride single crystal.

W. Grattidge

C. EXPERIMENTAL TECHNIQUES

1. Ionization Gauge Studies

Further study is being carried out with ionization gauges. Three gauges were sealed off with neon gas at a pressure of about 10^{-9} mm Hg. The history of these tubes had included separate calibrations with nitrogen, argon, and neon gases. According to earlier indications with nitrogen gas, the gauges were expected to clean up the residual gases by electron pumping when operated after seal-off. After two months time, however, the gauges indicate no clean up. At this time, this result can be accounted for only by reasoning that the noble gases do not clean up while nitrogen probably does clean up.

Gas appears in these sealed-off tubes following the removal of the electron accelerating voltage. The observed increase in pressure was from 10^{-9} mm Hg to 2.5×10^{-7} mm Hg in about twenty-four hours. Clean-up studies indicate that this gas was probably helium which had diffused out of the glass. The identification of the gas depended on earlier studies (1949). The hot filaments were run continuously during the period.

A gauge was constructed in which the ion collector was decreased in length by 30 percent from our standard design. Although we previously believed that our electron collector design was such that the ionization volume was an ion trap, the gauge with the shortened ion collector was found to be about 30 percent less efficient an ion capture than the standard design. Additional work on this subject is underway at the present time and a more complete report will be made when the results are conclusive.

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

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

The problem to be considered is the design and construction of a radiation pyrometer which will utilize nearly monochromatic radiation of about 2μ . The radiation will be pulsed at 90 cps and focused on a PbS photoelectric cell, the output of which will be fed into a tuned amplifier. After amplification and rectification the current will be read on a suitable meter which can be calibrated for temperature by means of a fixed standard source of radiation that can also be directed onto the photocell. This standard source will be calibrated with an attached thermocouple.

The initial construction of the amplifier is under way.

W. M. Bullis