I. PHYSICAL ELECTRONICS

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A. ELECTRON EMISSION PROBLEMS

1. Magnetic Velocity Analyzer Investigation of Thermionic Emission from Tungsten

The improvements in construction technique described previously (1) have been realized in practice. Figure I-1 shows the analyzer held in its adjustable jig, the manipulatable welding jaws, and the derrick for lowering the crystallized filament into place. Figure I-2 is a close-up showing the filament yoke, bearings, and anode in more detail.

The method used for welding the filament into place on the axis of the rotating filament yoke is shown in Fig. I-3. The filament subassembly, consisting of the 0.002-inch diameter crystallized tungsten filament welded between two 0.010-inch diameter tantalum wires and the tungsten spring for maintaining the proper tension in the filament, was prefabricated. It was then lowered into place through the 0.015-inch diameter holes on the axes of the filament yoke bearings and welded above the upper bearing and below the lower bearing.

The experimental tube was completed and vacuum-processed. An M.I.T.-designed Bayard-Alpert ionization gauge indicated that the equilibrium pressure in the tube after seal-off was 3×10^{-9} mm Hg. The weld holding the bottom of the filament subassembly under tension broke during the processing, but it was found that heating current could be maintained, though it tended to fluctuate. The broken weld also allowed the filament to bow out from the axis of rotation. In spite of these two difficulties it proved possible to test the operation of the analyzer. The tube was operated with the anode and analyzer grounded, and the filament biased negatively with respect to ground by a variable potential -V. The filament was pulse-heated from a mercury vapor thyratron inverter. This heating circuit automatically cuts off the emission current during the heating half-cycle by applying a positive bias to the filament.

For electrons originating from a single crystal surface, the relation between filament potential -V and the perpendicular magnetic field B required for maximum transmission through the analyzer is

$$B^2 = \frac{2}{R^2\left(\frac{e}{m}\right)}\left(V + \Delta V + \frac{kT}{2e}\right)$$

where R is the radius of maximum transmission in the analyzer, $(kT/2e)$ is the most probable energy of emission, and ΔV is the contact difference of potential between the analyzer chamber and the crystal surface supplying the electrons to the analyzer. The
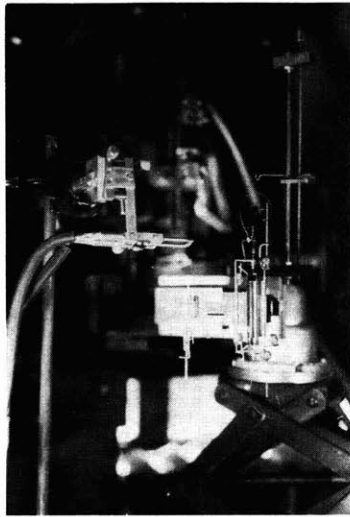
Fig. I-1

General view of con-
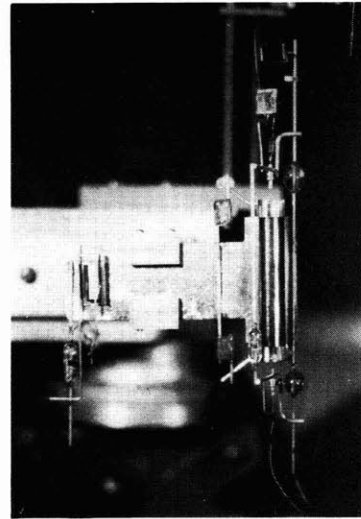struction of analyzer.
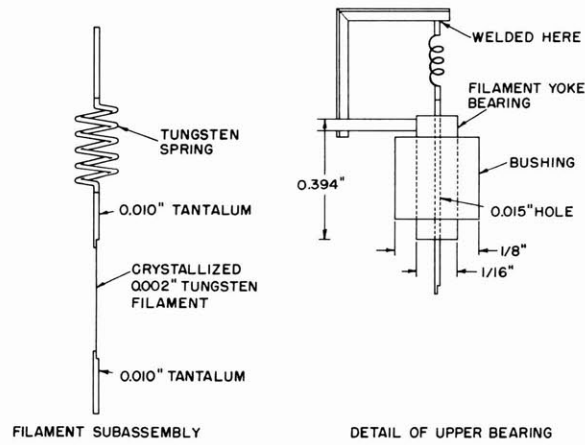

Fig. I-2

Detail of filament yoke
and anode structure.

TUNGSTEN
SPRING

0.010" TANTALUM

CRYSTALLIZED
0.002" TUNGSTEN
FILAMENT

0.010" TANTALUM

FILAMENT SUBASSEMBLY

WELDED HERE

FILAMENT YOKE
BEARING

BUSHING

0.015"HOLE

0.394"

1/8"

1/16"

DETAIL OF UPPER BEARING

Fig. I-3

Structural details of rotating
filament assembly.

differences between observed ΔV's for different crystal faces should be the differences in work-function between these faces. If one measures the value of V for maximum transmission at a number of magnetic field strengths and makes a plot of V vs B^2, one can obtain $\left[\Delta V + (kT)/(2e)\right]$ as the intercept on the V axis.

Data of this type were taken on the present tube, though the bowing of the filament severely limited the crystallographic directions which could be measured. About fifteen points ranging from V = 5 volts to V = 30 volts were taken for each V vs B^2 plot, and the best straight line fit to these points, obtained by the method of least squares, was used to determine the intercept $\left[\Delta V + (kT)/(2e)\right]$ and slope $2\left[R^2(e/m)\right]^{-1}$. The residuals obtained from the least-squares line of regression permitted the calculation of the standard deviation of the intercept which was always found to be 0.01 volt or less. From the slope of the line of regression, the charge/mass ratio of the electron, and the magnetic field computed from the Helmholtz coil current, the radius of maximum transmission in the analyzer was found to be 3.50 cm. Microscopic measurement of the entrance-slit-to-exit-slit distance gave a value of 2R = 7.007 cm. This agreement is well within the accuracy to which the Helmholtz coils can be measured.

Evidence from the data obtained in this tube for emission as a function of crystal orientation and from the work of Nichols and Smith (2) indicates that surface field strengths of the order of 25,000 volts/cm may be necessary in order to resolve the emission from high work-function directions at the anode slit.

The requirement of high surface field strengths is not imposed by the patch fields of the single crystal (which are of the order of 300 volts/cm). Rather, one must be sure that the emission from a high work-function direction is not blanketed by electrons emitted from neighboring low work-function directions with sufficient tangential velocity to carry them to the anode slit. In order to obtain a surface field of 25,000 volts/cm at the filament, the anode-filament potential must be at least 300 volts. The electrons leaving the anode slit must then be retarded so that they may enter the analyzer with about 10-ev energy in order to maintain 0.01-ev resolution. The electron-optical problem of retarding the electrons between the anode and analyzer is now being studied.

A very simple solution to the problem of the theoretical resolution of the 180° velocity analyzer has been obtained which will be of value in determining the energy distribution of the emission current.

A. R. Hutson

References

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

2. M. H. Nichols, G. F. Smith: Thermionic and Crystal Properties of Tungsten and Tantalum, ONR Final Report N6-onr-24433, Dept. of Electrical Engineering, California Institute of Technology, June 1952

2. Photoelectric Study of Surface States on Insulators

The first tube using a fused quartz sample has been completed. This tube had provision for heating the sample in a radiation oven as described in the Quarterly Progress Report, July 15, 1952, and it was assumed that the surface being studied could be cleaned by suitable heat treatment. The total pressure in the tube is approximately 2×10^{-9} mm Hg, and it is felt that the pressure of active gases is far lower, since the ion gauge, which is operated continuously, serves to "clean up" active gases.

The background currents in this tube were of the order of magnitude of 10^{-16} amp, and the lowest detectable current was limited to this value. When the sample was illuminated with the 2537A and 2654A lines from a mercury arc (type C-H3), no increase in current could be detected. The work of D. Jeffries (Master's Thesis, Dept. of Physics, M.I.T. 1951) on crystalline quartz showed currents of the order of magnitude of 10^{-14} amp at these wavelengths, with what is believed to be comparable light intensities.

Another tube is now being processed which employs a crystalline quartz sample. Shielding has been improved to cut the background current as much as possible. It is hoped that Jeffries' work can be checked with this tube.

R. N. Noyce

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

The past quarter has been spent designing the field-emission projection tube to be used to measure the magnitude of scattered light and soft x-rays resulting when field-emitted electrons strike a phosphor laid down on a hemispherical anode of conducting glass. (See the Quarterly Progress Report, July 15, 1952.)

The tungsten hairpins which will be used to support and heat the tungsten point have been made and tested. They are designed so that the hairpin and point can be removed from the projection tube and the point then shadowgraphed in an available electron microscope. The hairpin and point can then be replaced in the projection tube.

After numerous trials, an electrode has been designed which is suitable for casting an electron "shadow" on the phosphor screen. This electrode consists of a piece of tantalum approximately 0.1 inch × 0.2 inch × 0.002 inch supported by two 0.020-inch tungsten wires. The entire structure can be heated to 2000°C for outgassing by passing a current of 16 amp through the support leads. Thorough outgassing is necessary in order to achieve the vacuum of around 10^{-11} mm Hg necessary for this research.

A study is now being made of the techniques of etching tungsten wires into very sharp but symmetrical points and the techniques of depositing a uniform layer of phosphor on the inside of a glass hemisphere.

J. M. Houston

4.   Conduction Mechanism in Oxide-Coated Cathodes

It has been shown (E. B. Hensley: ONR Technical Report No. 11, Univ. of Missouri, April 1952) on the basis of the pore conduction theory that the ratio of conductivity to thermionic emission for oxide-coated cathodes should be approximately $\sigma/J = e\ell/kT$ where ℓ is a mean value of the diameters of the pores. For oxide cathodes ℓ is believed to be approximately 3 microns and thus, at a temperature of $1000°K$, this ratio should be approximately 3.5×10^{-3} cm/amp ohm. Geometric factors relating the specific values of σ and J to their apparent values will of course modify the above value to some extent. Relatively few values for σ/J have been published but all of these have been larger than the above by at least one or two orders of magnitude. At first sight this would appear to be serious evidence against the pore conduction hypothesis as this discrepancy seems to be too large to be accounted for by the geometric corrections alone. However, there is another consideration which may be of prime importance. It is well known that free barium is evaporated from the surface of a hot cathode. Also the activation of a cathode is believed to depend upon a stoichiometric excess of barium. Since barium evaporated from the exterior surface of the cathode will be lost while barium evaporated from the interior walls of the pores will not be lost, it is very probable that the exposed surface of a cathode will be in a lower state of activation than is the interior of the cathode coating.

A special tube is being constructed to investigate the state of activation of a cathode surface relative to that of its interior. Two button-type cathodes are mounted such that their coated surfaces are parallel and in contact with each other. One of these cathodes is movable so that the surfaces may be rapidly separated to a predetermined spacing. The conductivity is measured while the cathodes are in contact, and the thermionic emission can be obtained from an analysis of the current voltage characteristics after the cathodes are separated. The cathodes will be processed with the two surfaces in contact as much as is possible. In this manner the loss of free barium from these surfaces will be avoided. Particular attention will be paid to any decay in the thermionic emission during the first few seconds after the cathodes have been separated.

Progress on the experiment involving the effect of pure helium gas induced into the pores of an oxide cathode has been delayed because of repeated failures of certain brazed vacuum seals in the metal valves employed. It appears that these problems are being solved by making certain changes in the alloys used in the construction of these valves.

E. B. Hensley

B.   PHYSICAL ELECTRONICS OF THE SOLID STATE

1.   Temperature Gradients Across Ionic Crystals

Work has continued during this quarter on the measurement of the emf produced across the system silver—silver chloride—silver on establishment of a temperature

gradient. The emf is measured by means of a vibrating reed electrometer, and the temperature of each of the silver terminals is measured by a molybdenum-nickel thermocouple. The outputs of the electrometer amplifier and the thermocouples are fed via a selector switch into a Brown recorder (25 mv full scale). In measuring the temperature difference, it is not possible to join the two thermocouples in opposition and measure the out-of-balance voltage as this would short circuit the silver chloride crystal and cause high currents to flow in the specimen. Thus, each thermocouple voltage must be measured separately and the subtraction performed later. An input circuit is being constructed which uses an auxiliary millivolt source and the Brown recorder to indicate the thermocouple voltage. The full-scale readings of the Brown recorder are modified to ranges of 1 mv, 5 mv or 10 mv, and the recorder indicates the differences between the thermocouple voltages and the voltage of the auxiliary millivolt source. The voltage difference between the thermocouples is then read from the chart. A zero-shift circuit has also been fitted to the recorder.

It was noted in the previous Quarterly Progress Report that the silver chloride crystal turned a yellowish-green in color whenever it was heated above about 150°C. Experiments performed by M. A. Gilleo in the Laboratory for Insulation Research here at M.I.T. show that in the range from very low temperatures up to room temperature, there is a continual shift with temperature in the absorption edge of silver chloride. Extrapolation above room temperature would appear to explain the yellowish-green color observed without the production of any specific absorption band.

W. Grattidge

C. EXPERIMENTAL TECHNIQUES

1. Further Studies in Vacuum Technique

A simplified control circuit has been designed and constructed for use with the Bayard-Alpert ionization gauge. It was found that the stability of the circuit was affected by normal power line variations. A regulated power supply has therefore been developed for this circuit.

The characteristics of this power supply are:

At 150 Volts Output at 25 Milliamperes

Relative Speed of Line Variations	Line Variations	Output Change
slow over approximately 10 seconds	+10 percent -10 percent	-90 mv[*] +90 mv[*]
fast	+10 percent -10 percent	+80 mv -80 mv

[*]These output changes are due to filament temperature change in the dc amplifier.

also

> Ripple voltage less than 1 mv
>
> Microphonics approximately 10 mv
>
> Output resistance approximately 5 ohms
>
> 48-hour drift approximately 50 mv

The omegatron which was reported in the previous report has not yet produced the desired results. Ion current has been obtained but the resonant ion peaks have not yet appeared. Numerous tests on the external parameters have been made which indicate the problem may be one of geometry of the tube. If this can be definitely verified another omegatron of altered design will be constructed.

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