

I. PHYSICAL ELECTRONICS

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A. PHYSICAL ELECTRONICS IN THE SOLID STATE

1. Conduction in Zinc-Sulphide Single Crystals

By means of recent additions to the apparatus for measuring the dc electrical properties of single acicular zinc-sulphide (ZnS) crystals, the crystals are irradiated with red plus infrared light (all wavelengths between 6500 Å and 12,000 Å) or with ultraviolet light (that portion of the light of a mercury lamp transmitted by a Wratten 18A filter which passes wavelengths between 3000 Å and 4000 Å). In addition, a small oven housing can be placed over the crystal and its electrode mount for measurements at temperatures up to 300° C. The heater is supplied with regulated dc power from a temperature regulator whose sensing element is a glass-beaded thermistor located inside the oven. The temperature is controlled within $\pm 0.05^\circ$ C.

The red plus infrared light is used to relax the crystal after application of a voltage, and the ultraviolet is used to observe the luminescence. However, all conductivity measurements are made in the absence of external radiation.

Recent measurements on a ZnS:Cu, Cl crystal with painted silver electrodes indicate large instability in the nature of the silver-zinc sulphide contact. It was observed, however, that after a baking period of 15 hours at 150° C, the contacts stabilized, but the crystal passed much less current. With 50 volts applied, the crystal resistance was 2×10^{14} ohms at 100° C. The slope of the log of conductance versus $1/T$ curve (expressed in electron volts) between two points at 150° C and 100° C is 0.22 ev; between two points at 100° C and 50° C it is 0.40 ev. The value of 0.22 ev agrees approximately with the reported value for the chlorine trap depth; the larger slope at lower temperatures indicates, possibly, that the current is limited by an entrance barrier at the contact.

Upon removal of the applied voltage, there is a reverse current. It has been reported elsewhere that red plus infrared light will relax ZnS phosphor particles suspended in a dielectric medium. This has been only partially true with the reverse currents observed here. Indeed, in some circumstances, the red plus infrared light stimulates a forward current. The current waveform in the absence of irradiation during this relaxation is not a simple exponential, but can be reasonably well represented by a sum of two exponentials, or by a power curve.

Additional crystals containing no added impurities have been obtained from Dr. F. Koury, of Sylvania Electric Products, Inc., Salem, Massachusetts.

D. A. Berkowitz

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2. Low-Voltage Characteristics of Germanium Diodes

Measurements at low voltages of the characteristics of rectifying germanium junctions are being continued with the measurements of the complete characteristics of five new junctions of indium fused to n-type germanium of various resistivities. These data are being analyzed.

It is becoming increasingly evident that a detailed analysis of the junction characteristics can shed much light on the conduction processes of these devices. A new method of Professor W. B. Nottingham for determining the base resistance from a study of the shape of the characteristic in the region of voltage close to that given by $V_T = T/11,600$ separates the ohmic from the rectifying part of the diode characteristic. Detailed data on one unit for this voltage region are now being obtained.

In order to permit measurements at lower temperatures, the possibilities of a new photoconductive chopper are being explored. Present performance of the device indicates a noise level in the microvolt region with an input impedance of 10^7 ohms. This is close to the theoretical limit imposed by Johnson noise.

J. F. Campbell, Jr.

B. ELECTRON EMISSION PROBLEMS

1. Effect of a Magnetic Field and of a Unidirectional Heating Current on Thermionic Emission from Molybdenum

This study has been completed. Measurements taken with the modified tube described in the Quarterly Progress Report of April 15, 1958, page 2, showed that an applied magnetic field of 6000 gauss (or less) has no effect on the saturation current density from a clean metal surface. All variations observed earlier were shown to be spurious; they were caused either by faulty design of collectors in the earlier tube or by the effects of ac heating of the filament.

No difference in the saturation current density from opposite sides of the ribbon filament was noted after 200 hours of dc heating at roughly 1800° K. This negative result may arise from the small grain size of the recrystallized filament, which would tend to cancel any individual differences between adjacent grains. There was evidence of extensive dc etching of the surface, but optical observation could not distinguish any differences in etching between adjacent crystals or between opposite sides of the same crystal.

The results are more completely described in a Master's thesis presented by the author to the Department of Physics, M.I.T., June 1958.

J. Greenburg

C. EXPERIMENTAL TECHNIQUES

1. A Sensitive dc Amplifier, Battery-Operated

Two subminiature tubes and a transistor have been combined to make a dc amplifier that operates from a 22.5-volt dry cell battery, Burgess type 5156. The filaments of the two tubes operate from Mallory cells, type RM-42-R. The power drain is so small that battery life of 600 to 1000 hours is anticipated. The tubes used are a type CK 5886 for an input tube and type CK 6088 for a tube to drive the 2N43A transistor.

A rugged 50- μ a meter is mounted on the box to serve as an indicator and provisions are made for the use of a more sensitive instrument externally. The circuit provides complete protection for these meters against excessive input voltages. Sensitivity can be expressed as a transconductance of 4 microamperes per millivolt. In our use of this instrument, "null" methods permit the accurate measurement of voltages that originate either in high-resistance circuits or low-resistance circuits with an uncertainty of less than 2×10^{-5} volt. Thus 10 mv can be measured with an accuracy of more than 1 per cent and with a current drain at the time of measurement of less than 10^{-14} amp. The measured grid current in our unit is 3×10^{-15} amp. There is no limit to the maximum voltage that can be measured as long as the unknown voltage is sufficiently constant to effect a balance with the required accuracy. The instrument is provided with input resistances of suitable quality so that currents covering the range from 1 μ a down to 10^{-11} amp can be measured with 1 per cent accuracy (or better). If need be, still smaller currents, down to less than 10^{-14} amp, can be measured with slightly decreasing accuracy as the currents get smaller. The method used in this range depends on charge accumulation. An input filter reduces the effect of 60-cycle ac pickup so that 0.1 volt rms can hardly be detected and one volt causes very little trouble. Circuit and constructional details will be presented later.

W. B. Nottingham

2. Photoelectrons Produced by Soft X-Rays

Work continues on a tube designed to determine the relative magnitude of soft X-ray production and the photoelectric emission caused by soft X-rays in tantalum, tungsten, and molybdenum electrodes. The electrodes used are 0.001-inch ribbons arranged symmetrically around, and parallel to, a central tungsten filament.

The tube has been calibrated as an ionization gauge against a modified Bayard-Alpert ionization gauge over a pressure range from 10^{-4} to 10^{-8} mm Hg. It was found that at a pressure of 10^{-9} mm Hg, the positive ion current equaled 1 per cent (or less) of the photoelectric emission current from the ion collector electrode.

Data taken at 6×10^{-10} mm Hg shows an apparent variation in photoelectric current

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with a change in electrode metal. However, other variations in the photoelectric current with changing electron current and ion collector bias are not yet understood; thus no definite conclusions can be drawn at this time.

D. S. Dunavan

3. Surface States on Semiconductors

The purpose of this experiment is to study the correlation between changes in the surface-trap density of germanium and changes in the contact potential of germanium. Both of these changes are caused by changes in the gases that surround the germanium sample.

The method of measuring changes in the contact potential has now been brought to an accuracy of 0.01 volt. It utilizes an electron retardation scheme whereby electrons are emitted by a tungsten ribbon, accelerated, deflected, and then retarded by the sample. The sample was mounted in an experimental tube in such a way that it could be cooled. After the tube was baked, the sample area was cooled with dry ice in acetone, and a retardation plot was taken. Some oxygen was then introduced into the vacuum system while a Tesla coil was sparking nearby in order to create ozone, and another retardation plot was taken. The work-function of the sample was found to increase by 0.37 volt.

Illumination of the sample by strong light decreased the electron current and indicated an apparent increase in work-function (observable with an accuracy of millivolts). This increase was somewhat greater after exposure to ozone. Whether this is the result of surface-barrier modulation or of the lowering of the Fermi level by heating is not yet known.

This sample exhibited negligible photoconductive response; apparently it had been etched improperly. The tube was cracked open, the sample re-etched and reinstalled in the tube. The cracked tube was sealed with Apiezon Q putty. The vacuum obtainable was approximately 10^{-7} mm Hg. The photoconductive response was much improved, but there was no evidence of trapping – the photoresponse was linear with light intensity, and its decay after the light was cut off was fast. Decreasing the resistance in series with the sample from 25,000 ohms to 10,000 ohms caused a slow but marked decrease in the voltage drop across the sample after the current through it was turned on; this decrease is believed to be caused by heating. The contacts to the sample were found to be noisy and rectifying at times. It is planned to repeat the photoconductivity experiment in Gebbie's original demountable brass tube (1), by using a sample with leads that are tin-soldered to the tube.

E. Ahilea

References

1. H. A. Gebbie and E. Ahilea, Surface studies on semiconductors, Quarterly Progress Report, Research Laboratory of Electronics, M.I.T., July 15, 1955, p. 3.