I. PHYSICAL ELECTRONICS

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A. ELECTRON EMISSION PROBLEMS

1. A Magnetic Analyzer Investigation of Thermionic Emission from Tungsten

The new magnetic velocity analyzer structure, which includes an electron lens for retarding the electrons, has been designed. The precision parts of this structure and the jig for its assembly have been machined. Some additional filaments are being crystallized in an improved projection tube.

A. R. Hutson

2. Photoelectric Investigation of Surface States on Insulators

Preliminary measurements of photoemission have been made on a single crystal of magnesium oxide (obtained from the Norton Company). Effects of photoconductivity and space-charge polarization of the sample have been observed and have been found to be many times larger than in quartz, where these effects were not observed. No determination of the photoelectric threshold has been made because of the intensity problems in the far ultraviolet. This measurement should be possible with a more intense source, which will be available in the near future.

R. N. Noyce

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

The apparatus necessary for this experiment has been nearly all assembled and tested. Three field-emission projection tubes are now being coated with conducting glass and phosphor anodes. Electron microscope shadowgraphs are now being made of the tips of specimen tungsten points from which field-emission currents will be drawn. An optical photomicroscopy apparatus for photographing the grosser point geometries has been constructed and satisfactorily tested. A study is now being made of the optics of the 931 A photometer used to measure the light emitted from the phosphor. An effort will be made to increase the light-gathering efficiency of the photometer.

J. M. Houston

B. PHYSICAL ELECTRONICS OF THE SOLID STATE

1. Temperature Gradients Across Ionic Crystals

Work has continued on the electrical effects of temperature gradients imposed across the system, silver — silver chloride — silver. For unit temperature gradient
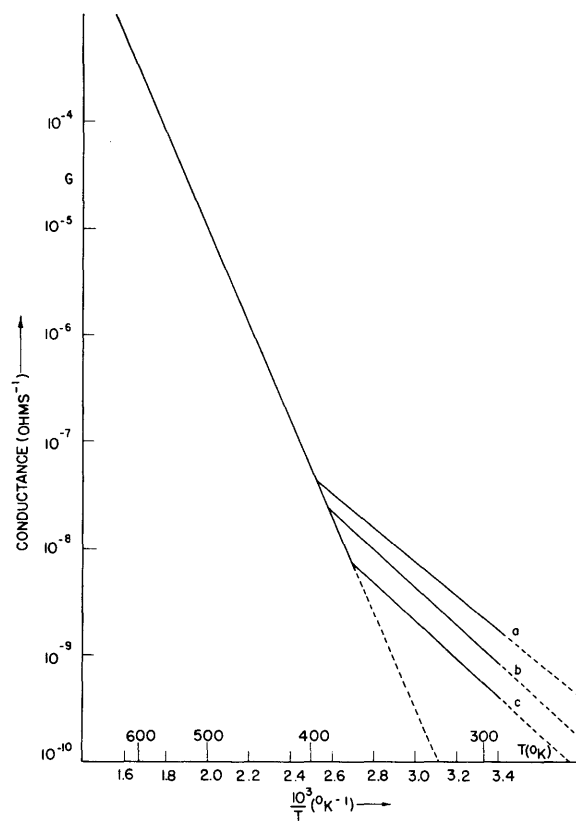
Fig. I-1

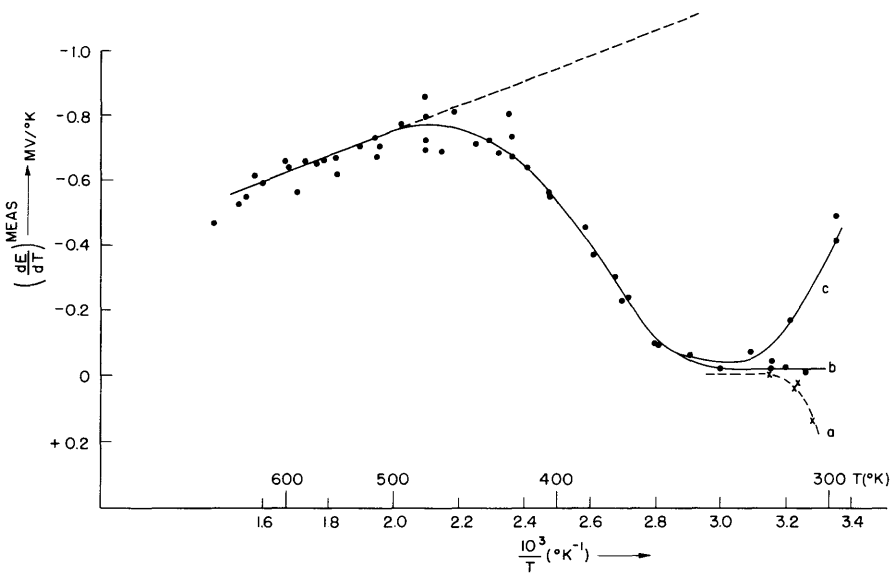Conductance G of AgCl as a function of reciprocal temperature.

Fig. I-2

Measured thermoelectric electromotive force per degree
of AgCl as a function of reciprocal temperature.

imposed, an emf is generated across the crystal, and this has been measured as a function of the average temperature under the condition of zero current flow. The conductance of the crystal has also been measured over the same temperature range (20° to 370°C). The conductance was determined by first measuring the zero current flow or open-circuit emf generated by the crystal, and then placing a resistor of known value in parallel with the crystal and remeasuring the emf.

Figure I-1 shows the logarithm of the conductance as a function of reciprocal temperature. In the high-temperature region the measurements are reproducible and thermal equilibrium obtains. The slope of the line in this region gives U, the approximate value 0.8 ev in the relation $\ln G = A - \epsilon U/kT$, in agreement with previous work (1). In the low-temperature region of the curve the general level of the conductivity depends markedly on the past history of the specimen as shown by the three curves a, b, and c. Curve c is obtained when the crystal is cooled down very slowly to allow the annealing out of the defects created by the previous high temperatures applied. Curve a, although not an intentional quench, involved a much faster cooling process which resulted in a higher level of conductivity. Curve b represents an intermediate rate of cooling. The slopes of all these curves are about the same, approximately 0.3 ev. It should be noted that the location of the break point in the curve at a temperature of 370°K for the well-annealed case indicates that the purity of the crystal is fairly high.

The corresponding thermoelectric data are indicated in Fig. I-2 where the emf generated per degree temperature difference dE/dT is plotted as a function of the reciprocal of the average temperature. Each value of dE/dT is obtained by measuring the emf produced for various temperature differences between approximately $\pm 10°C$. with the mean temperature remaining constant. It will be seen that there are three regions to this curve: a high-temperature region in which dE/dT varies linearly with 1/T, a transition region in which dE/dT decreases as the temperature decreases, and a third region for which the behavior may be of type a, b, or c.

Type c indicates an increase of dE/dT with further decrease in temperature, and this occurs for a well-annealed crystal exhibiting conductivity behavior of type c in Fig. I-1. For a quenched specimen, as indicated by curve a in Fig. I-1, the value of dE/dT in the low-temperature region actually changes sign and increases positively with decreasing temperature. For a temperature of 303°K, that is, $10^3/T = 3.3$, the analysis of several runs shows that the condition of the sign of dE/dT as a function of conductance G for this sample is

for $G > 1.3 \times 10^{-9}$ ohm^{-1} dE/dT is ve negative

for $G < 1.3 \times 10^{-9}$ ohm^{-1} dE/dT is ve positive.

The emf per degree produced in such a silver — silver chloride — silver system may

be divided into two parts, a homogeneous part $(dE/dT)^{hom}$ and a heterogeneous part $(dE/dT)^{het}$. The homogeneous part is that produced across the silver chloride itself, resulting from the temperature gradient, and the heterogeneous part is that resulting from the silver — silver chloride interfaces being at different temperatures.

At any temperature,

$$\left(\frac{dE}{dT}\right)^{het} = \frac{s^{Ag}_{Ag^+} - s^{AgCl}_{Ag^+}}{F}$$

where

$s^{Ag}_{Ag^+}$ = partial molar entropy of silver positive ions in metallic silver

$s^{AgCl}_{Ag^+}$ = partial molar entropy of silver positive ions in silver chloride

$\quad$ F = charge of 1 faraday.

For the calculation of $(dE/dT)^{het}$ it is further assumed that

$$s^{Ag}_{Ag^+} = s^{Ag} \tag{1}$$

that is, that the electronic contribution to the molar entropy is negligible;

$$s^{AgCl}_{Ag^+} = \frac{1}{2} s^{AgCl}. \tag{2}$$

If we use the tabulated values of the specific heats and their temperature dependence, the partial molar entropies may be calculated and $(dE/dT)^{het}$ obtained.

Then

$$\left(\frac{dE}{dT}\right)^{hom} = \left(\frac{dE}{dT}\right)^{meas} - \left(\frac{dE}{dT}\right)^{het}$$

and over most of the temperature range the $(dE/dT)^{het}$ correction amounts to approximately 10 percent.

In the high-temperature region the variation of $(dE/dT)^{hom}$ with temperature is of the form

$$\left(\frac{dE}{dT}\right)^{hom} = - \frac{Q^{*AgCl}_{Ag^+}}{TF}$$

where

$$Q^{*AgCl}_{Ag^+}$$

is the average heat of transport of the silver ions in silver chloride and T is the

absolute temperature. For pure silver chloride, transport processes occur by two mechanisms: interstitial silver ions moving through the lattice and the movement of cation vacancies in the opposite direction. Each of these processes will have energies of transport $Q^*_{Ag(i)}$, $Q^*_{Ag(h)}$ associated with them, and so

$$Q^{*AgCl}_{Ag^+}$$

will be some average value of each of these heats.

Wagner (2) has given the more general relation

$$Q^{*AgCl}_{Ag^+} = \frac{1}{2}\left(Q^{*AgCl}_{Ag(i)} + Q^{*AgCl}_{Ag(h)}\right) + \left(t^{AgCl}_{Ag^+(i)} - \frac{1}{2}\right)\left(Q^{*AgCl}_{Ag^*(i)} - Q^{*AgCl}_{Ag^+(h)} + \Delta H\right)$$

where

$t_{Ag^+(i)}$ = relative fraction of process due to movement of interstitial silver ions

ΔH = energy of disorder.

Thus, if one assumes that the two defects contribute equally to the transport process

$$Q^{*AgCl}_{Ag^+} = \frac{Q^{*AgCl}_{Ag(i)} + Q^{*AgCl}_{Ag(h)}}{2}$$

and there is reason to believe this applies at high temperature. However, for further progress it is necessary to consider materials in which the two contributions may be separated, and this is possible by a method of introducing such impurities as $PbCl_2$ into AgCl as indicated by Koch and Wagner (3). The preparation of such materials is now being planned.

W. Grattidge

References

1. W. Lehfeldt: Z. Physik 85, 717, 1933
2. Private communication from C. Wagner
3. E. Koch, C. Wagner: Z. Physik. Chem. B38, 295, 1937

C. EXPERIMENTAL STUDIES

1. Further Studies in Vacuum Techniques

Construction has begun on needed equipment for further studies in vacuum technique. To make possible the accurate measurement of the small currents observed in these studies (which may be as low as 10^{-13} amp), a new Compton quadrant electrometer set-up is being installed. A vacuum system that incorporates the better features of previous

systems is being designed. We plan, upon completion of the new equipment, to make studies which will result not only in improvements in the design of an ionization gauge of the Bayard-Alpert type but also in a better understanding of its operation.

D. H. Dickey, J. D. Hobbs, L. E. Sprague

2. Ionization Gauge Control Circuit

The simplified ionization gauge control circuit described in the previous progress report has been constructed and tested. In addition, the flexibility and usefulness of the circuit has been increased by means of minor circuit changes which also permit the control circuit to be used directly as a vacuum-tube electrometer. The performance of the control circuit was found to agree closely with the expected behavior.

It was found, however, that an additional control was necessary in order to adjust the electron emission current to the approximate value required for the pressure range. Design and construction of a simple electron-emission stabilizer is under way. This control will serve to compensate partially for slight variations in filament resistance from gauge to gauge, for changes in surface conditions on the tungsten filament, and for slight variations in line voltage.

S. Aisenberg

3. Development of the Omegatron

A new omegatron, intended to increase the uniformity of the rf field, has been constructed. The designs with which we are working are simplified ones of the original omegatron (Thomas, Sommer, and Hipple: Phys. Rev. 82, 697, 1951). It is hoped that the more simple design will perform comparably with the original. The sharpness in tuning this type of mass spectroscope, together with the many parameters involved, leads to difficulties in utilizing its sensitivity. Expected resonance ion currents at moderate vacua are very low, necessitating extreme care in order to obtain the lowest possible background and detection of resonance peaks.

W. J. Lange

4. An Infrared Radiation Pyrometer: 90-CPS Peaked Amplifier

During the past quarter we have been working out the details of the 90-cps peaked amplifier for use with the infrared radiation pyrometer reported in previous reports (1).

The amplifier consists of a preamplifier, which utilizes feedback through a twin T filter (2) to restrict the output to the desired 90-cps signal, and three succeeding stages, the first of which also utilizes a similar feedback network to increase the stability. It is powered by a 220-volt regulated supply of conventional design and draws about 10-ma plate current.

Voltage amplification at 90 cps is about 3100 compared with 50 at 60 cps and 70 at

120 cps. If a 10 megohm input resistor and the present rectifier output are used, the current amplification is about 10^7 at 90 cps. Currents down to 10^{-11} amp may be measured.

It is hoped that sharpening the twin T filters will improve the response in addition to allowing increased gain at 90 cps. Revisions of the output network should enable the measurement of currents of the order of 10^{-12} amp.

W. M. Bullis

References

1. Quarterly Progress Reports, Research Laboratory of Electronics, April 15, 1952; July 15, 1952

2. H. H. Scott: Proc. I.R.E. 26, 226, 1938