

## I. PHYSICAL ELECTRONICS

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### A. PHYSICAL ELECTRONICS IN THE SOLID STATE

#### 1. Hall Effect in Lead-Sulfide Films

Direct-current measurements were made at room temperature on six samples cut from the same lead-sulfide film sheet, provided by the Electronics Corporation of America. The measurements, made with an accuracy of 10 per cent, gave a carrier concentration of negative sign and a concentration of  $10^{16}$  carriers per  $\text{cm}^3$ . This concentration was calculated on the basis of a thickness determined by the manufacturers from a weight analysis. It was shown on two separate samples that the Hall voltage was proportional to the magnetic field strength. Preliminary studies show that contact noise is the usual troublesome factor. Contact materials of silver paste, aquadag, and evaporated gold were used and all proved unsatisfactory several hours after application. Silver paste provided good contact for short intervals of time shortly after application. At present, good permanent contacts are being sought.

D. H. Dickey

#### 2. Surface States on Semiconductors

Construction of a tube for measuring the photoconductivity and contact potential of germanium is nearing completion. The rectangular 5 mm  $\times$  25 mm germanium sample will be fastened across the undersides of two kovar cups that are sealed to the bottom of a cup-like depression in the top wall of the tube. This depression will hold coolant to lower the sample temperature. The sample will be illuminated from below; the bottom wall of the tube is a flat sheet of glass.

The two kovar cups will also serve as electrical terminals for the sample. To assure good, noise-free contacts, it is planned to evaporate metal on the two ends of the sample. Metal clips attached to the kovar cups will make contact with the metal coating of the germanium. If the contacts are adequately noise-free, we may be able to dispense with additional probe contacts for measuring the voltage drop across the sample.

Retardation of an electron beam will be used to measure the changes that occur in the sample contact potential during the experiment. (The absolute work-function will not be of prime importance in this case.) The electron accelerator consists of a tantalum sheet, 8 cm  $\times$  4 cm, "folded" to form two square sections with a right angle between them. One square will be placed horizontally below the germanium sample; a hole drilled in its center will admit both light and electrons to the sample. The other square section

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will be located vertically beside and below the horizontal section, and a fine hole drilled in its center will discharge electrons from the emitter behind it. A small box section (with another fine hole), which is welded to the back of the vertical square, serves as a simple collimator for the electrons. Behind this box section a tungsten filament will emit the required electrons; they will be accelerated toward the vertical square and through the two fine holes. The beam of electrons will then be deflected upward by an electrode placed in the plane that bisects the angle between the two squares; it will then pass through the hole in the horizontal square and be retarded by the germanium. The light emitted by the filament through the fine holes will not be deflected, but will continue in a straight line; precautions to absorb it will be taken if necessary. The tungsten filament will be enclosed by a tantalum cover; this enclosure also contains a labyrinth of baffles through which the filament leads will pass, in order to prevent as much undesirable light as possible from escaping. Here, too, further precautions may be necessary.

E. Ahilea

## B. GASEOUS DISCHARGES

### 1. Ion Generation, Electron Energy Distributions, and Probe Measurements in a Low-Pressure Mercury Arc

The mercury vapor discharge tube will soon be in operation. A method has been developed to permit measurement by an ionization gauge of the partial pressure of residual gases while the discharge tube is in the water bath. A pulsed "getter" tube is also included in order to facilitate the clean up of contaminating gases. The water bath is completed and is ready to regulate the mercury vapor pressure to better than 1 per cent.

The three simple probes were completed and sealed into the discharge tube. The components of the two multiple probes were fabricated and outgassed by electron bombardment in special glass envelopes. They were then sealed off from the system at a pressure of approximately  $7 \times 10^{-9}$  mm Hg for temporary storage until we were ready for probe assembly.

The assembly of the multiple probes constituted a problem, since they consist of four concentric cylinders with a radial separation of approximately 0.025 inch. An angular displacement of approximately  $1^\circ$  at the press is sufficient to cause a short circuit. This problem was solved on a sample probe by using aluminum foil spacers and heavy nickel supports. The aluminum spacers were then dissolved by hydrogen chloride, leaving the nickel supports to maintain the clearance.

The problem of attaining stable measuring and regulating equipment appears to be solved.

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Theoretical calculations were made that will permit the measurement of these, and other, properties: ionization frequency (averaged over cylinder radius), electron mobility (averaged over cylinder radius), and electron velocity distribution function.

In addition, a model was developed to explain the variation (with various discharge parameters) of the ratio of saturation ion current to saturation electron current. This model permits extra ion current through the trapping of ions generated in the potential well near the negative probe and the increased ion collection area associated with the potential well. Data on the dependence of saturation current ratio on discharge parameters will help to test this model and to determine which component (trapped ions or collected ions) is predominant.

S. Aisenberg

### C. EXPERIMENTAL TECHNIQUES

#### 1. Measurement of the X-Ray Limit in Ionization Gauges

In the Quarterly Progress Report of April 15, 1956, page 6, a theory of equilibrium pressures in a Bayard-Alpert ionization gauge was proposed. Although a tentative experiment seemed to confirm the theory, a more rigorous experiment was initiated. A modified Bayard-Alpert ionization gauge (1), which is equipped with a vacuum jacket that covers approximately 80 per cent of its pyrex envelope, was built. This jacket offers two main advantages:

a. The helium permeation ought to be cut down by a factor of 5, approximately, thus achieving lower equilibrium pressures and enabling a closer approach to the "X-ray limit" (2).

b. Since, in the course of the experimentation, it is necessary to vary the electron current over comparatively wide limits by changing the electron emitter temperature, the portions of the glass envelope near the electron emitter are subject to temperature variations and consequently variable helium permeation rate. In the present design, all portions of the glass envelope susceptible to such temperature variation are within the vacuum jacket and thus do not contribute to helium permeation.

The gauge was sealed off the vacuum pumps at a total pressure of approximately  $2 \times 10^{-9}$  mm Hg,  $N_2$  equivalent. Data for testing the present theory are being collected.

R. D. Larrabee

#### References

1. W. B. Nottingham, Design and properties of the modified Bayard-Alpert gauge, Vacuum Symposium Transactions, 1954, p. 76.
2. L. J. Varnerin and D. White, J. Appl. Phys. 25, 1207 (Sept. 1954).

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### 2. Use of Evaporated Metals as Getters

Tantalum evaporated on the glass walls of a tube from a hot filament is a common getter material for reducing the partial pressure of absorbable gases below  $10^{-11}$  mm Hg. Mr. H. Shelton found that molybdenum is easier to outgas, evaporates at a lower temperature, and serves the purpose as well as tantalum (1). However, by utilizing the two following techniques, it is possible to use almost any refractory metal as a getter without having it (or its supporting posts) outgas appreciably in operation:

a. Make the hairpin getter filament about 0.5 inch longer than is desired and rigorously outgas it in high vacuum. The lower half-inch, which was not properly outgassed owing to heat conduction to the mounting posts, is then cut off, and the hairpin is remounted. In this way, a filament that is "completely" outgassed is obtained.

b. In order to keep the getter filament posts from becoming hot enough to outgas appreciably while the getter material is being evaporated, pulsed heating of the getter filament is recommended. A duty cycle of 0.5 sec on, followed by 3 to 6 sec off, was found to be quite satisfactory. A microswitch activated by a motor-driven cam serves as a convenient pulser.

R. D. Larrabee

### References

1. H. Shelton, Quarterly Progress Report, Research Laboratory of Electronics, M. I. T., Oct. 15, 1955, p. 9.

### 3. The Spectral Emissivity of Tungsten

In the Quarterly Progress Report of April 15, 1956, page 9, an experiment was described that indicated how well a finished tungsten specimen could be purified by differential evaporation at high temperatures ( $2750^{\circ}\text{K}$ ). With these data and the annealing schedules recommended by DeVos (1) in mind, the tungsten specimen, which will be used in subsequent emissivity measurements, was given the following heat treatment:

- |  |  |
|--|--|
| a. $2750^{\circ}\text{K}$ for one-half hour; | c. $2800^{\circ}\text{K}$ for one-half hour; |
| b. $2500^{\circ}\text{K}$ for 30 hours;      | d. $2500^{\circ}\text{K}$ for 20 hours.      |

During the first stage of the heat treatment, the specimen was covered coaxially by a quartz shield to protect the pyrex envelope window from the evaporated material. During the later three stages, the quartz shield was removed, and the optical transmission of the window was monitored by measurements of the apparent temperature (pyrometer wavelength,  $6450 \text{ \AA}$ ) of the source (for a constant power input). The voltage across the source was also monitored during the last three stages with a potentiometer

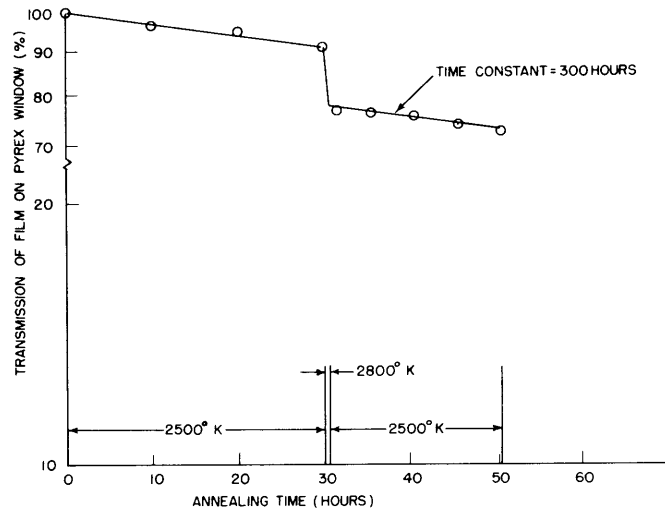


Fig. I-1. Transmission of film on window during annealing process.

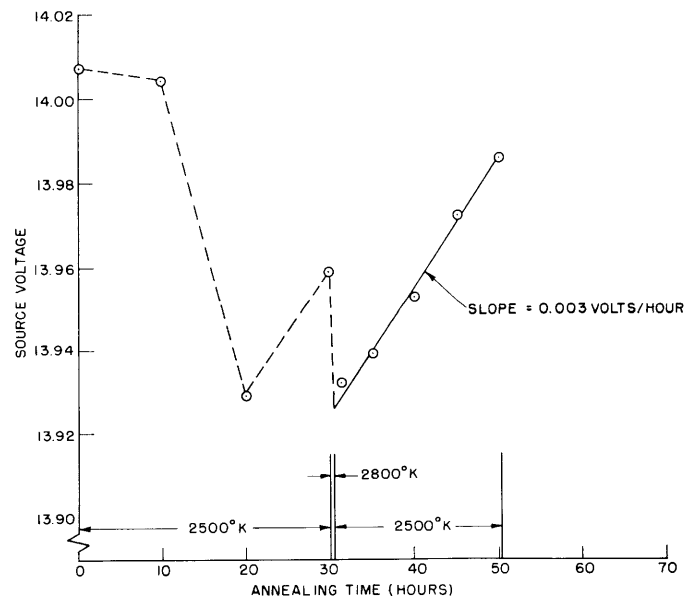


Fig. I-2. Variations in source voltage during the annealing process.

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(for a constant source current of 60 amp). These data are summarized in Figs. I-1 and I-2. The erratic fluctuations of source voltage during the second and third stages of heat treatment are probably caused by a combination of specimen purification (tending to lower the voltage) and metallic evaporation (tending to raise the voltage). During the last phase of heat treatment, the source voltage was observed to increase approximately linearly at a rate of 0.003 volt per hour; the transmission of the pyrex window was observed to decrease exponentially with a time constant of 300 hours. A tungsten evaporation rate of 21.8 monolayers per hour (2) explains the linear increase in source voltage if we assume that the effects of source purification are negligible. The number of monolayers falling on the window can be computed from geometrical considerations, since the mean-free path of the evaporated material is greater than the tube dimensions. In this way, the transmission of the metallic film on the pyrex window can be computed as a function of the number of monolayers of tungsten on it, with the following result:

Transmission of film =  $\exp[-N/128]$ , where N is the number of monolayers in the film. Using this relationship and the measured window transmission, we estimate that about 2100 monolayers of metal (approximately 2 per cent of the source material) were evaporated from the tungsten specimen during the last three stages of the heat treating schedule.

R. D. Larrabee

### References

1. J. C. DeVos, The Emissivity of Tungsten Ribbon, doctoral thesis (Vrue Universiteit Te Amsterdam, 1953).
2. A monolayer is defined here as a layer of tungsten with a density of  $4.84 \times 10^{-7}$  gram/cm<sup>2</sup>.