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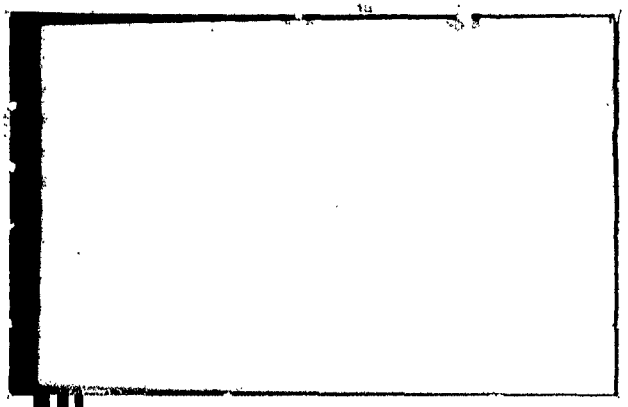

ELECTRICAL ENGINEERING RESEARCH LABORATORY
ENGINEERING EXPERIMENT STATION
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

STATUS REPORT
ON
RESEARCH ON SEMI-CONDUCTORS
AND
TRANSISTOR ELECTRONICS

Project No. NR 072 161
N6 ori-07140 Report No. 2

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Approved by.

John Bardeen
Professor

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1. GENERAL

The general aims of the research program, personnel involved and laboratory facilities are discussed in Report No. 1, dated January 15, 1953. Mr. Lloyd O. Brown resigned from the project as of February 1, 1953, and the work he was doing on impedance measurements of diodes has been suspended. Satisfactory progress has been made on the other problems; electrolytic transistor, surface effects, diffusion measurements and properties of small-area contacts. A new problem, an investigation of properties of germanium under ultrasonic oscillation has been started by L. Slifkin in cooperation with Dr. John Marx and Mr. George Baker of the Departments of Mining and Metallurgy and of Physics of the University. Internal friction associated with plastic flow and with motion of impurity atoms and effect of high amplitude oscillation on electrical resistivity will be studied.

Research in semiconductors at the University of Illinois has been aided by a research grant from Motorola, Incorporated. Part of these funds will be used for the construction of crystal-growing apparatus. It is expected that much of the work done with the aid of the grant will be closely related to that done under this project.

2. PROGRESS REPORTS ON SPECIFIC PROBLEMS

2.1 Electrolytic Transistor - H. Letaw, Jr.

Further experimental improvements leading to more reproducible data from the electrolytic transistor have been carried out during this report period. Values of $\alpha = (\partial I_c/\partial I_e)_{V_c = \text{const.}}$ equal to unity within the accuracy of the measurements have been obtained. As was expected, it has been found that α is a strong function of the distance of separation of the emitter and collector.

Successful experiments involving the use of the chloride-chlorine couple and the ferrous-ferric couple have been carried out. The initial experimental data outlined in the first progress report were misinterpreted in detail. The couple operating in the cell was thought at that time to be the cerous-ceric couple; however, subsequent experiments indicate that this was actually the chloride-chlorine couple.

In view of the favorably long time constants associated with the operation of this device, an investigation of the transient current effects encountered in this research will be carried out as soon as a suitable electro-mechanical recording instrument has been acquired. Extension of the operation of the electrolytic transistor to more diversified electrochemical couples is contemplated.

It is anticipated that a Technical Report will be issued within a reasonably short time to cover the research on the electrolytic transistor carried out to date

2.2 Surface Effects in Germanium - S. R. Morrison

As described in the previous progress report, small variations in the resistance of germanium filaments have been observed as the ambient atmosphere is cycled between wet and dry oxygen at constant temperature

In order to correlate these resistance changes with changes in the contact potential under similar conditions, as observed by Brattain and and Bardeen (Bell System Tech. J., January, 1953), measurements have been simultaneously taken of $(\Delta c.p)_L$, the change in contact potential with light. Also, in order to obtain a measure of how the lifetime of minority carriers is affected by the ambient atmosphere, measurements of the photoconductivity have been made.

It was found that, for a P-type sample of cross-sectional area the order of 0.01 cm^2, as the ambient was changed from dry to wet oxygen, the resistance increased by close to 1%, and $(\Delta c.p)_L$ changed from a magnitude of the order of 10^{-4} volts to the order of 10^{-3} volts. For an N-type sample, the reverse occurred for both measurements.

In general, the photoconductivity is roughly independent of ambient, although in some cases changes up to 40% have been observed.

A preliminary investigation into the dependance of the reverse resistance of a p-n junction has been made. The resistance change was of the order of a factor of five, the resistance decreasing under the influence of wet oxygen, increasing under the influence of dry oxygen

It is planned to attempt to increase the magnitude of the effects by using ozone or peroxide vapors instead of dry oxygen for one extreme in resistance and $(\Delta c\ p)_L$

2.3 Diffusion Measurements - H Letaw, Jr and L Slifkin

Procedures for the electroplating of germanium upon germanium surfaces have been further investigated by the use of radioactive tracer techniques involving Ge^{71} obtained from the Oak Ridge National Laboratory

The grinding machine to be used in connection with this investigation is at present being constructed in the machine shop ancillary to this laboratory

Further experimental work during the coming period will consist largely of efforts to perfect the method of electroplating germanium on germanium and the calibration of the grinding machine

2.4 Ultrasonic Experiments - L Slifkin

A study of the properties of germanium single crystals under ultrasonic oscillation is now in progress This work is being done in conjunction with Dr John Marx and Mr George Baker, both of the Departments of Mining and Metallurgy and of Physics, University of Illinois. The specimen is mounted on the 37 kc resonator described by Marx (Rev Sci Instr, 22, 503) and oscillated at 111 kc. Strain amplitude may be varied up to 3×10^{-4} and temperature up to the melting point of the germanium Proposed experiments are concerned with (a) the internal friction of germanium as a function of both strain amplitude and temperature, (b) work-hardening and annealing as shown by time dependence of the internal friction, (c) the effect of added Cu and of quenching on the internal friction and (d) the effect of high amplitude oscillation on the room temperature electrical resistivity

Preliminary results are as follows

(1) The room temperature logarithmic decrement is about 3×10^{-5}. This is too low to obtain reliable information concerning its dependence on strain amplitude at the present time.

(2) The value of Young's Modulus along the (100) direction obtained by us at room temperature agrees with that calculated from the data of Bond, et al (Phys Rev 78, 176) within the error due to uncertainty in the orientation of the crystal. It decreases linearly with increasing temperature, and is 87% of its 25°C value at 900°C. These requirements were performed at a strain amplitude of 4×10^{-6}. It is possible that a greater temperature effect might be seen at higher strain amplitudes.

(3) A strain amplitude of 2.7×10^{-4} does not break the crystal.

(4) At room temperature and up to strains of 2.7×10^{-4}, Young's Modulus is independent of strain amplitude.

2.5 Properties of Small-Area Rectifying Contacts - N. Holonyak, Jr.

It is planned to study the effect of ambient atmosphere on the rectifying properties of small area contacts. A furnace for making fused junctions has been designed and built. A small number of indium-germanium and gold-bonded diodes have been made, but the characteristics are not yet as satisfactory as desired.