63-2-4

LEAR SIEGLER, INC.

RESEARCH LABORATORIES

SANTA MONICA, CALIFORNIA

SEMICONDUCTOR THIN FILMS

Contract No. NObsr 87634
Bureau of Ships
Department of the Navy
Washington, D. C.

Quarterly Report No. 2
October 1, to December 31, 1962

LEAR SIEGLER, INC. RESEARCH LABORATORIES
3171 S. BUNDY DR. • SANTA MONICA, CALIF. • EXmont 1-7211

TABLE OF CONTENTS

1.0 PREVIOUS PLANS FOR THE SECOND QUARTER

1.1 To locate or construct an ultra high vacuum system, 10^{-8} torr, for use in trial depositions of silicon on silicon and beryllia.

1.2 To set up Hall measurement apparatus for testing deposited films.

1.3 To use the new flash evaporation source.

1.4 To arrange for a formal, reliable source of beryllia crystals.

1.5 To assemble and/or construct a plasma torch for growing refractory crystals by a Verneuil technique.

1.6 To deposit n and p type silicon.

2.0 PROGRESS

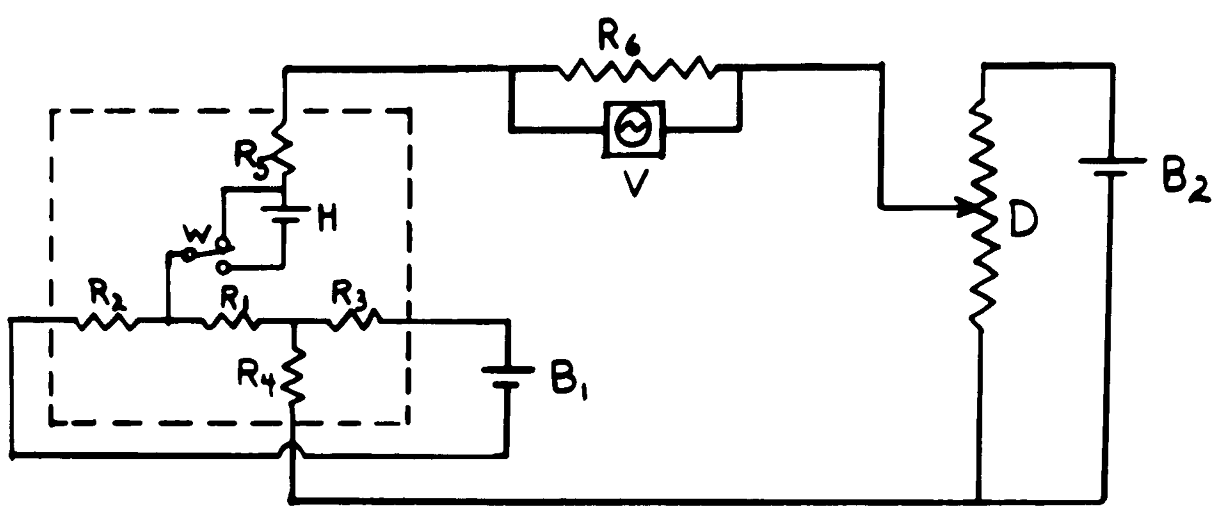
Most of the work planned for the second quarter was carried out. However, some projects have been deferred and some changes made.

2.1 Ultra High Vacuum Deposition

We could not arrange for the temporary use of an ultra high vacuum system, so we shall build a small sealed off system for testing. If deposits are better than in the 10^{-6} torr system, we shall build or buy a demountable system. Parts for the sealed off system have been received and will be assembled and tested in January.

2.2 Electrical Measurement

Hall measurement apparatus has been set up according to the following scheme:



Slight electrical misalignment of the contacts which receive the voltage for V is practically unavoidable because the films do not have a uniform thickness. $R_2 + R_1 + R_3$ represents the resistance of the sample to the generating current driven by B_1, R_1 being the resistance along the sample between misaligned contacts; $R_4 + R_1 + R_5$ is the resistance across the sample in series with the generated Hall voltage represented by battery H. W is a switch which, with H, represents the effect of turning on the magnetic field. B_2 is a battery which, with Decavider, D, balances the misalignment and/or Hall voltages. The null readings are taken across the 1 megohm resistor R_6 by oscilloscope V. D is adjustable to 10,000 ohms in 0.01 ohm steps; V has a maximum sensitivity of 200 microvolts per centimeter. The magnet is being calibrated now by measurement of the Hall voltage generated by a calibrated Beckman Model 350 indium antimonide thin film Hall generator and by measurement of the nuclear magnetic resonance of protons in an aqueous solution. Contacts are made with air drying silver suspension; the contacts are ohmic but have high resistance and capacitance.

Measurements on three gallium arsenide samples shown in Table 1 were made in a field of 8200 gauss between 4 inch flat pole pieces 1-1/2 inches apart.

Table 1

Sample	Type	Resistivity	R	Mobility	Thickness
J546-2P	p	4.5	21	4.7	3000A
J556B	p	2.5	63	25	3000A
J549A	p+	0.56	34	61	3000A

A sample with leads is shown in Figure 1.

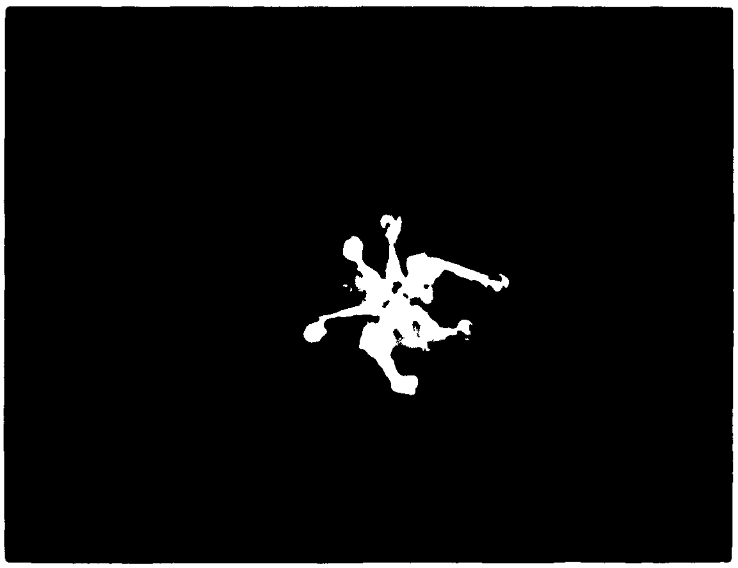


Figure 1

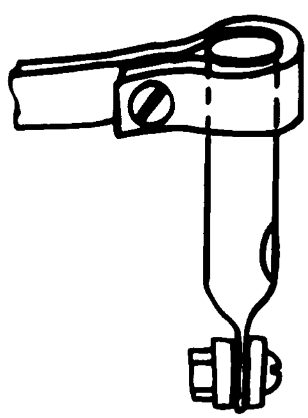
Bridge shaped sample of a gallium arsenide film on a half inch square fluorite substrate with leads attached for Hall measurement. The sample is attached with silver cement to an inch square glass plate and wires are soldered to the silver cement. The thermocouple measures the temperature near the film.

As the contacts do not stand up to repeated immersion in liquid nitrogen, improved contacts will be made. Fired silver enamel is expected to provide a rugged attachment to the substrate; vacuum deposition of suitable metals between the fired silver and the semiconductor films should form low resistance ohmic contacts.

A suitable cryostat will be built or purchased to allow measurement at temperatures between 77°K and 300°K in controlled atmospheres.

2.3 High Vacuum Deposition

The flash evaporation source shown in Figure 2 of Quarterly Report No. 1 was made and tried with gallium arsenide and silicon powders. The deposits were considerably thinner than were obtained with similar amounts of powder evaporated from an open boat. The new design shown below was then tried and gave improved efficiency.



2.4 Substrates

The only source we have found for beryllia crystals is Atomics International. However, they require that an additional facility for manufacture of crystals be built and paid for by LSi if they are to supply them. We would rather set up to manufacture crystals at LSi, but either way, there is no assurance of a supply in time for testing before the termination of this contract. We have, therefore, asked about getting beryllia crystals with approval of the AEC, for whom Atomics International is growing beryllia, through our respective contract offices.

Films of gallium arsenide have been deposited with some sharp preferred orientation on natural (hydroxyl) muscovite and on synthetic fluorphlogopite mica. There is thus a good chance that synthetic mica, which is usable to 1000°C, may serve as a substrate for deposition of silicon as well as germanium. We shall get samples of synthetic mica from Synthetic Mica Company and from Molecular Dielectrics, Inc. and test them as substrates for germanium and silicon deposition.

2.5 Plasma Torch

The power source for a plasma torch was installed and a torch tested. The silica tubing wall of the torch fused. A new torch is being constructed. Work on this project, inspired by the desire for ceric oxide crystals, has a low priority and will be continued only as time is available.

2.6 Deposition of Doped Silicon

P type silicon has been deposited many times but no experiments on deposition of doped silicon have yet been tried. Deposits of p type silicon on n type slices of silicon have shown no junction rectification.

2.7 Device Experiments

Because the films do show point contact rectification, an attempt was made to form a point contact using vacuum deposited thin films. The end of a fine iron wire (from steel wool) was held against a silicon deposit during deposition of a silicon monoxide layer and subsequently areas of aluminum were deposited using a 75 mesh screen as a mask. The experiment was unsuccessful in that the area with the proposed pinhole showed tunneling behavior indicating that there was no contact through the silicon monoxide.

Point contact rectification implies a surface barrier so an effort was made to properly condition the surface of a film and then form contacts which might give rectification. A 5000A film of silicon on beryllia was oxidized in air for one hour at 900°C. Then gold was deposited through a 200 mesh screen and aluminum deposited to one side as a large area. Rectification was obtained between the gold and aluminum contacts (Figure 2).

Figure 2

Characteristic curve of the configuration formed by a 6 square mil area of gold versus an approximately 10,000 square mil area of aluminum, both vacuum deposited on a 5000A p type deposit of silicon on a beryllia crystal after heating in air for one hour at 900°C. 0.05 ma/div vertically; 2.0 v/div horizontally.

However, similar rectification was obtained between small and large gold contacts (inside and outside the area covered by the 200 mesh screen). In a similar experiment with a gallium arsenide film on fluorite, rectification was shown between large and small areas of vacuum deposited tin.

Further work will be done with such devices in configurations designed to give useful triode action using contacts on both oxidized and unoxidized surfaces. Work will also be done with field effect transistor configurations.

3.0 PLANS FOR THE THIRD QUARTER

3.1 To test the small glass ultra high vacuum system for deposition of germanium.

3.2 To make Hall measurements at a series of temperatures from 77°K to room temperature and to at least plan for measurements of lifetimes.

3.3 To flash evaporate doped silicon in an effort to deposit n type films.

3.4 To continue work on device preparation using the films deposited in high and in ultra high vacua.

3.5 To deposit single crystal films on mica.

3.6 To start test depositions of conductors, resistors, and contact tabs on beryllia, fluorite, and mica.