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THIN FILMS OF SILICON ON LOW-COST SUBSTRATES

QUARTERLY PROJECT REPORT NO. 1
QUARTERLY REPORT NO.1

1 JULY 1976 30 SEPTEMBER 1976

Contract No. E(04-3)-1287

PREPARED FOR

UNITED STATES

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
SAN FRANCISCO OPERATIONS OFFICE

PREPARED BY

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Motorola Project No. 2283

AC03-76ET20410

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ABSTRACT

The objective of this research program is to investigate the deposition of silicon on low-cost or temporary substrates using an Energy Beam. The Energy Beam consists of a central stream of partially ionized gas coupled to a source of RF energy. Thus a silicon bearing compound, injected into the gas stream, will decompose, either in the plasma or at the deposition substrate.

The designs for the deposition chamber and the gas panel have been completed. We have received a five kilowatt Energy beam system and initiated a study of the Energy Beam plasma. Some preliminary experiments using a scanned laser beam for grain enhancement have been carried out. The construction of the deposition chamber and gas panel are now underway.

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1.0 INTRODUCTION

The designs for the Energy Beam deposition chamber and the gas panel have been completed; their construction is presently underway. We have received the Energy Beam system, and have initiated a study of its plasma. Some preliminary experiments using a scanned laser beam for grain enhancement have also been carried out.

2.0 INITIAL EXPERIMENTS

Preliminary experiments are being conducted to establish the boundary conditions for Energy Beam Deposition (EBD). We are using a Cary spectrometer to study the line spectra emitted by the Energy Beam plasma. We have also studied the effectiveness of grain enhancement using a scanned CO₂ laser beam in both the Temporary and Permanent Substrate methods:

Temporary Substrate: Polycrystalline silicon sawed from a polycrystalline cylinder prepared by float-zone crystal growth was used as the feedstock for this experiment. Figure 1 is a Laue X-ray photograph of the material prior to grain enhancement; Figure 2 is an x-ray photograph of the sample after recrystallization using a scanning CO₂ laser beam. Figure 3 is a photograph taken through an optical microscope (magnification: 55X) of the area x-rayed.

Permanent Substrate: Approximately 10 mils of silicon was deposited on a "Grafoil" graphite substrate. Figure 4 is a Laue X-ray of the deposition silicon. After recrystallization using the CO₂ laser, the grain size was significantly increased, as shown in Figure 5. However, recrystallization is more effective with the Temporary Substrate method.

FIGURE 1 Sample 234
Original Material

FIGURE 2 Sample 234
Re-crystallized
Material

FIGURE 3 Optical Microscope
Photo of Area X-rayed in
in Figure (55X)

FIGURE 4 Sample 238
Silicon Deposited
on grafoil
Original Material

FIGURE 5 Sample 238
Re-crystallized
Material

3.0 THE GAS SYSTEM

The first experiments conducted with the Energy Beam will be aimed at determining the optimum parameters of the deposition process, exclusive of the choice of substrate for ultimate utilization. Parallel experiments, using vacuum deposition, will be carried out testing possible substrates.

3.1 PLASMA AND SHEATH GASES

The Energy Beam consists of a central plasma surrounded by a sheath of non-ionized gas. Decomposition of the silicon bearing gas may occur in the central plasma, the outer sheath, or at the deposition substrate.

A mixture of $\text{SiH}_n\text{Cl}_{4-n}$ and a carrier gas will be used in the plasma and sheath inlets to the Energy Beam. Although silane will be the first gas chosen for experimentation, the gas panel has been designed to accommodate SiCl_4 and the Chloro-silanes. In addition, provision will be made for introduction of "dopant" gases.

The choice of the carrier gas will depend on the dominant mechanism for silicon deposition. Two such mechanisms are possible:

A; Dissociation at the Substrate: In this case, the Energy Beam serves a dual role. It heats up the substrate, and introduces the silane (or other $\text{SiH}_n\text{Cl}_{4-n}$) to the heated substrate. Thus, the silane is transported by the carrier gas without decomposing until it reaches the substrate. In this case the carrier gas would be chosen to maximize the transfer of heat and silane to the substrate, while allowing good temperature control. Because of the confinement attained through the effects of the sheath gases, this mode alone should offer increased efficiency over conventional techniques.

B; Silane Excitation in the Plasma/Sheath: In this case the microwave energy is transferred to the $\text{SiH}_n\text{Cl}_{4-n}$ molecules through the carrier gas. Thus the $\text{SiH}_n\text{Cl}_{4-n}$ arrives at the substrate either in a highly excited vibrational state or already completely disassociated. A good carrier gas will then satisfy three requirements:

- . High coupling efficiency to the Energy Beam's RF field.
- . Close matching of vibrational levels with an $\text{SiH}_n\text{Cl}_{4-n}$ to allow for high pumping efficiency.
- . It will not introduce electrically active contaminants to the silicon.

3.2 GAS HANDLING SYSTEM

The gas panel for the energy beam deposition of silicon has been designed. The flow schematic is shown in the Appendix, Figure A.5. The gas panel allows the carrier gas to be chosen from He, H_2 , Ar or N_2 (or a mixture of these gases). The carrier gas can be fed into both the sheath and plasma inlets to the energy beam. The active gas can be chosen from SiH_4 , SiHCl_3 , and SiCl_4 . Mass flow controllers will be used with the active gas. We must still design an electrical control panel for the solenoid valves. It will include automatic sequencing of pre-purge, post-purge and failure mode cycles.

The lay-out and assembly of the gas panel was started this week.

4.0 DEPOSITION CHAMBER DESIGN

Design of the reactor chamber has been completed. Quotes for the fabrication of the chamber and its associated accessories have been obtained, and purchasing orders are presently being initiated. The final chamber design is an enlarged version which will accommodate a working surface (movable quartz substrate) area of 10 cm by 25 cm. The enlarged version also allows

the use of a larger safety vent area (rupture disc) located at the bottom of the chamber. This provision has been incorporated to allow for rapid de-pressurization of the chamber in the event of an uncontrolled pressure build-up.

Sectional views of the current reactor assembly are presented in Figures A.1 through A.4. Figure A.1 depicts an end-view of the chamber. As can be observed in Figure A.1, the substrate deposition surface (quartz) can be viewed from either side, the chamber top and bottom surfaces. Figure A.2 (top view) gives a clearer definition of the arrangement of the various viewing and utility ports with respect to the energy beam nozzle. Figure A.3 shows a side view of the chamber with utility port details. Figure A.4 is provided to indicate the TV viewing apparatus which is external to the chamber.

Fabrication of the deposition chamber is scheduled to be completed by mid November, at which time, assembly of the various add-on fixtures will proceed. It is presently anticipated that a check-out of the completed chamber assembly will occur during the later portion of November, and initial growth experiments (in the chamber) will proceed during the month of December. Samples of the EBD approach should then be available at the end of the second quarter.

APPENDIX

FIGURE A.1 DEPOSITION CHAMBER, END VIEW

FIGURE A.2 DEPOSITION CHAMBER, TOP VIEW

FIGURE A.3 DEPOSITION CHAMBER, SIDE VIEW

FIGURE A.4 TV VIEWING APPARATUS, SIDE VIEW

FIGURE A.5 GAS PANEL

NOTES:

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THIRD ANGLE PROJECTION

MATERIAL SPEC.

HEAT TREAT

APPLIED FINISH

DRAWN BY

CHECKED BY

SCALE

DATE

REV

REDD

ITER NO
REV D

UNLESS OTHERWISE SPECIFIED

✓ RMB ALL MACHINED SURFACES

DEC TOL .001

MM TOL .001

ANGULAR TOL .001

FEATURE CONTROL SYMBOLS PER USAS 14.5-1972 CURRENT

BREAK ALL SHARP EDGES & CORNERS. REMOVE BURRS

UNDERLINE DIMS NOT TO SCALE

MATERIAL SPECIFICATION LIST

TITLE
EBSO GAS CONTROL
FLOW SCHEMATIC

MOTOROLA INC.
Semiconductor Products Division

DWG NO

THIN FILMS OF SILICON ON
LOW-COST SUBSTRATES
PROGRAM EXPENDITURES

Quarterly Report No. 1
Contract No. E(04-3)-1287

PROGRAM EXPENDITURES

The following are the manhours and costs expended in the performance of the program through the month of September.

1. MANHOURS

<u>Previous Expenditures</u>	<u>Current Month Expenditures</u>	<u>Cumulative Expenditures</u>
147	248	395

2. FUNDS

<u>Previous Expenditures</u>	<u>Current Month Expenditures</u>	<u>Cumulative Expenditures</u>
7766	10078	17844

Figures 1 and 2 depict graphically the hours and costs expended by month.

HOURS EXPENDED BY THE MONTH

ERDA CONTRACT NO. E(04-3)-1287

MOTOROLA PROJECT NO. 2283

----- Scheduled Expenditures
----- Actual Expenditures

FIGURE 1

COSTS EXPENDED BY THE MONTH

ERDA CONTRACT NO. E(04-3)-1287

MOTOROLA PROJECT NO. 2283

----- Scheduled Expenditures
_____ Actual Expenditures

FIGURE 2

TOTAL COST (including Fee)

250K
200K
150K
100K
50K

J A S O N D J F M A M J J

MONTHS OF PROGRAM