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PHASE I OF THE AUTOMATED ARRAY ASSEMBLY TASK OF THE LOW
COST SILICON SOLAR ARRAY PROJECT

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MASTER

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Motorola, Incorporated
Semiconductor Group
Phoenix, Arizona

U.S. Department of Energy

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Solar Energy

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1.0 SUMMARY STATEMENT

Studies on definition of solar cell design and solar cell variables, selection of processes and process sequences, definition of process variables, relationships between primary process variables and cell variables, selection of evaluation techniques, and primary variable evaluation have progressed according to plan during this period.

Studies reported here include solar cell design and solar cell variables, the presentation of three process sequences and attendant process steps, the definition of process variables, and discussion of the selection of evaluation techniques.

2.0 INTRODUCTION

Phase I of the Automated Array Assembly Task, LSSA Project, is concerned with a comprehensive assessment of the improvements in existing technology that may be needed to develop, within a period of no more than 10 years, an industrial capability for low cost, mass production of very durable silicon solar photovoltaic modules (and arrays).

This portion of the Phase I study involves the definition and analysis of control parameters of individual process steps as well as the integrated process sequence, and of the effects of these control parameters on the final solar cell (and module) structure, performance, and cost effectiveness.

3.0 TECHNICAL DISCUSSION

This is the first report on the extension to this contract. The scope of the extension is to define and study variables present in the manufacturing of solar cells.

3.1 STUDY XII: DEFINITION OF SOLAR CELL AND SOLAR CELL VARIABLES

An optimally designed solar cell for both wafer and ribbon geometries will give maximum efficiency, but may not be the most cost-effective. Options, wherein cost is traded for efficiency, must be considered to derive the most cost-effective result. However, because of the relatively high cost of support structures (about 35% in 1985) it is expected that the higher efficiency cells will be the most economically favorable and that the cell design, starting material, and process sequence must not be inherently efficiency limiting. N/P and P/N solar cells must also be considered in the overall study.

Solar cell variables will be defined; this will include both operational and diagnostic parameters. How these cell variables relate to the effects of process variables and the starting silicon material will be formulated.

3.2 STUDY XIII: SELECTION OF PROCESSES AND PROCESS SEQUENCES

Solar cell fabrication processes with a high probability of meeting the long range LSSA Program objectives are listed in Table 1, and three powerful process sequences are listed in Tables 2, 3, and 4. The selection of processes and process sequences will be refined through experimental and analytical means, resulting in a list of processes having no more than two choices for each step, and a list of process sequences numbering no more than 10.

1. Starting Condition
 - a. Sawed and Etched Surfaces
 - b. Texture-Etched Surfaces
2. In-Process Surface Cleaning or Etching
 - a. Wet Chemical
 - b. Texture-Etching
 - c. Scrubbing
 - d. Plasma
 - e. Gas Stream Drying
 - f. Gravity (Centrifuge) Drying
3. Junction Formation
 - a. Ion Implantation
 - b. Diffusion
4. Metallization
 - a. Plating
 - b. Solder Coating
5. Antireflection Coating
 - a. Chemical Vapor Deposition
 - b. Spray (Spin) On
6. Annealing
 - a. Resistance Furnace Heating
 - b. Low Temperature Radiant Heating
7. Patterning
 - a. Proximity Photolithography
 - b. Projection Photolithography
 - c. Ion Implantation Shadow Masking

TABLE 1: PROMISING SOLAR CELL FABRICATION PROCESSES

1. Perform P+ diffusion over entire wafer, simultaneously growing layer of SiO_2 . This forms the back surface field.
2. Apply photoresist to one side, remove SiO_2 on opposite side, remove photoresist.
3. Texture etch exposed silicon surface.
4. Deposit silicon nitride (CVD) over wafer surfaces.
5. Pattern metal grid into silicon nitride on textured surface using photolithographic techniques, simultaneously cleaning dielectric from back surface.
6. Ion implant front (textured) surface with N-type dopant to form N-P junction. Ions are mechanically shadow masked from wafer edge to form planar junction.
7. Anneal wafers to activate ions. P-N junction in metal grid openings is deeper than beneath nitride.
8. Plate and sinter metallization.
9. Solder coat.

TABLE 2: ION IMPLANTED N/P JUNCTION SOLAR CELL PROCESS

1. P+ Diffusion, Oxide Growth
2. Photoresist, Planar Junction Pattern, Protect Back
3. Texture Etch
4. Diffuse Planar Junction
5. Remove Diffusion Oxide, Deposit Silicon Nitride
6. Photoresist Metallization Pattern, Protect Back
7. Metal Contact Diffusion
8. Strip Back, Clear Contact
9. Plate and Sinter
10. Solder Coat

TABLE 3: SOLAR CELL DIFFUSION PROCESS SEQUENCE 1.

1. P+ Diffusion, Oxide Growth
2. Photoresist, Planar Junction Pattern, Protect Back
3. Texture Etch
4. Diffuse Planar Junction
5. Remove Diffusion Oxide, Deposit Silicon Nitride
6. Photoresist Metallization Pattern
7. Plate and Sinter
8. Solder Coat

TABLE 4: SOLAR CELL DIFFUSION PROCESS SEQUENCE 2.

3.3 STUDY XIV: DEFINITION OF PROCESS VARIABLES

For each of the process steps finally chosen in Study XIII, the process variables will be defined. The result will be a tabulation that will serve as the basis for completion of this study. This work is in process and will be presented in the next report.

3.4 STUDY XVI: SELECTION OF EVALUATION TECHNOLOGIES

Once the primary variables have been selected and related to the cell variables, it will be necessary to select the techniques through which quantitative information can best be obtained. In many cases, analytical techniques can be used, based on previous experience with solar cell fabrication and semiconductor component manufacture in general. However, there are important cases where direct experimental evaluation techniques are necessary, and their investigation will constitute a part of this study.

The importance of effective evaluation techniques cannot be overemphasized. They must be capable of accurately describing the primary variables and the results of a process step; they must, however, also be economical, implying minimizing unnecessary or overly-precise tests.

4.0 CONCLUSIONS

The program is in its initial stages, making it too early to draw significant conclusions.

5.0 RECOMMENDATIONS

No specific recommendations are given this month.

6.0 CURRENT PROBLEMS

No specific problems have occurred to the date of this report.

7.0 WORK PLAN STATUS

The work plan is on schedule.

8.0 LIST OF ACTION ITEMS

No items requiring unusual action have come to light during this report period.

9.0 MILESTONES

Status of the program is shown in the Milestone Prediction and Accomplishment Chart Figure 1 .

FIGURE 1

MILESTONE ACCOMPLISHMENT AND PREDICTION CHART

PREDICTED

ACCOMPLISHED

	A	M	J	J	A	S	O	N	D	J
Financial Management and Cost Reports	▲	△	△	△	△	△	△	△	△	△
Monthly Technical Progress Reports		△	△		△			△		
Quarterly Reports	▲					△	△			
Annual Report	▲									
Final Report										△
Progress Meetings		△					△			
Task Integration Meetings		△			△				△	

FIGURE 1 (continued)
MILESTONE PREDICTION CHART
REPORTS AND DOCUMENTATION

△ SCHEDULE

▲ DELIVERED