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CONTINUOUS CZOCHRALSKI GROWTH

Silicon Sheet Growth Development of the Large Area Silicon Sheet Task of the
Low Cost Silicon Solar Array Project

First Quarterly Progress Report, October—December, 1977

December 31, 1977

Work Performed Under Contract No. NAS-7-100-954888

Kayex Corporation
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Rochester, New York

U.S. Department of Energy

MASTER

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Solar Energy

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CONTINUOUS CZOCHRALSKI GROWTH

SILICON SHEET GROWTH DEVELOPMENT
OF THE LARGE AREA SILICON SHEET TASK
OF THE LOW COST SILICON SOLAR ARRAY PROJECT

FIRST QUARTERLY PROGRESS REPORT
COVERING PERIOD: OCTOBER - DECEMBER, 1977
PROGRAM MANAGER: DR. R. L. LANE

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DECEMBER 31, 1977

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ABSTRACT

This project is directed toward the development of equipment and processes to produce single crystal solar silicon by a continuous Czochralski method. "Continuous" is defined as the ability to produce 100 kilograms of crystal from only one melt container.

The equipment to be used is a Hamco CG2000 Production Crystal Grower. Certain modifications will be made to the grower to enable periodic replenishment of silicon into the crucible and removal of grown crystals.

During the reporting period, the crystal grower was constructed and installed in a separate room designated and prepared for the project. It was adapted with a modified throat, a vacuum-tight isolation valve, an enlarged pull chamber to hold a supply of poly material, and a modified automatic diameter control (ADC) optical system. It was fully tested and made ready for trial runs.

Additionally, designs are under way for other modifications to the equipment, including a recharge system, a polysilicon attachment device, and a modified bead-chain pull mechanism capable of pulling and simultaneously weighing a 30-40 Kg growing crystal.

An economic model was developed for batch CZ as a base-line reference, and for two methods of continuous CZ. Preliminary analysis indicates a cost (value added by crystal growth) of approximately \$13 to \$17 per kilogram of usable crystal for continuous CZ versus \$33.00 for state of art methods. This model will be updated as additional data, process parameters and equipment requirements are obtained.

CONTENTS

	<u>PAGE</u>
ABSTRACT	1
1.0 INTRODUCTION	1
2.0 PROGRESS	1
2.1 CRYSTAL GROWER CONSTRUCTION	1
2.2 CRYSTAL GROWER MODIFICATION	2
3.0 ECONOMIC MODEL	3
4.0 PROBLEMS	4
5.0 PLANS	4
6.0 COSTS	4

FIGURES & TABLES

FIG. 1 HAMCO JPL/FACILITY	6
FIG. 2 CONTINUOUS CZ FACILITY	7
FIG. 3 POLY ATTACHMENT DEVICE	8
FIG. 4 PROGRAM PLAN	9,10
FIG. 5 COSTS AND MAN-HOURS	11,12

1.0 INTRODUCTION

The production of several crystals from one container by the Czochralski (CZ) method requires equipment and process modifications not commonly used in the semiconductor device industry. In general, these modifications are required for the purpose of permitting some method of silicon replenishment without cooling the residual melt and container or contaminating the silicon.

Although a number of methods of accomplishing continuous CZ growth can be devised, it is very important that the chosen method be suitable for a production environment and that it is attractive in terms of safety, reliability, and cost. In a production-type process, variables should be well-controlled and equipment should not require operators with great skill or technical ability.

It is the purpose of this project to develop equipment and process to achieve low-cost continuous CZ production of silicon single crystal ingot by repeated refilling (recharging) of the vitreous silica crucible and subsequent crystal growth cycles.

2.0 PROGRESS

2.1 CRYSTAL GROWER CONSTRUCTION

During the reporting period, a new CG2000 production crystal grower was completed with special modifications to the throat, pull chamber and isolation valve to make it suitable for recharging. The pull chamber is enlarged to permit polysilicon to be stored within the furnace in a ready condition for recharging. (The initial effort will utilize polysilicon rods for recharging. A subsequent design will be suitable for powdered or nugget silicon).

Other initial modifications to the chambers include a redesigned throat and

vacuum-tight isolation valve, larger viewports, and a longer pull length capacity.

Figure 1 is a photograph of the Hamco CG2000 after initial installation in the room specially prepared and designated for the project. Modifications (other than those described above) required for continuous CZ growth are not shown in this photograph.

2.2 CRYSTAL GROWER MODIFICATION

Figure 2 is a schematic drawing of the modified CG2000 grower with additional modifications indicated.

2.2.1 ADC OPTICAL SYSTEM

The redesigned vacuum-tight isolation valve precluded the use of the Hamco standard ADC Optical System. It was necessary to relocate the ADC sight port in the pull chamber door, and the mirror and lens system required redesign.

The design and the construction of this modification is complete and it is now installed on the grower. Also included in this design was an enlarged viewport in the pull chamber to allow visual confirmation that the crystal clears the valve before it is closed for removal of the crystal.

2.2.2 POLY WEIGHT/RECHARGE SYSTEM

The key factor in continuous CZ growth is the reliable and controlled addition of polysilicon to the hot crucible.

The first approach on this project will be to develop process and equipment for handling polysilicon that is in rod form. Rods of 30-40 Kg are available in the industry now.

The proposed method is to grow large crystals (using presently well-established methods) with a subsequent crucible recharge after each crystal. A separate mechanism capable of lowering the poly into the crucible while simultaneously weighing the rod will serve to make the process efficient and controllable.

The design layout for the Poly Weight/Recharge mechanism is complete and the detail drafting will begin shortly. Certain long lead items have been ordered. The fabrication will be performed at the Hamco/Kayex facility.

2.2.3 POLY ATTACHMENT DEVICE

A convenient and reliable method of attaching heavy poly rods is required. This design is complete (See Figure 3) and fabrication is under way.

2.2.4 MODIFIED BEAD CHAIN/CABLE MECHANISM

The Hamco standard bead chain pull mechanism requires certain modifications for the purpose of this project. For improved accuracy of weight measurement, a cable instead of a bead chain will be used. Additionally, the pull mechanism will be strengthened to increase its pull capacity from 20 to 40 kilograms.

This portion of the design program is complete and modification of the unit will commence in January.

3.0 ECONOMIC MODEL

An economic model is being developed based on (1) time-cycle data to get throughput information and (2) cost estimates for each cost item for crystal growth. It will be updated throughout the life of the project.

The results will be expressed primarily as kilograms per hour throughput and as add-on cost per kilogram of crystal grown. From these figures, other calculations can be easily made (with certain assumptions relating to slicing), such as cost per meter² for crystal growth, and number of crystal growers required in a production facility to produce silicon sheet at a given rate.

Comparisons have been made between state of the art batch CZ growth (one 10 cm diameter crystal per crucible) and two methods for achieving continuous CZ growth. The batch method will be used as a base line condition. The three growth methods are as follows:

Method	Batch	Continuous CZ Method #1	Continuous CZ Method #2
Crucible Size	12" x 9" high	12" x 9" high	14" x 10-1/2" high
Crystal Size	14.4 Kg	20 Kg	33 Kg
No. of Crystals/Crucible	1	5	3
Diameter of Crystal	10 cm	10 cm	12.5 cm

Preliminary calculations indicate the following:

Method	Batch	Continuous #1	Continuous #2
Throughput Kg/hr	0.93	1.2	1.7
Add-on Cost/Kg	\$33.09	\$16.79	\$13.15

The details of this model will be included in a later report.

4.0 PROBLEMS

No major problems exist which would prevent meeting the objectives at this time, and the project is on schedule. (See Program Plano, Figures 4a and b).

5.0 PLANS

During the next quarter, a dopant fixture will be designed and built. A crystal/poly transfer device will be designed to allow the safe handling of hot crystals and heavy rods of poly.

The design and construction of the Poly Weight/Recharge device will also be completed in the next reporting period.

6.0 COSTS

The program started October 1 and the following costs and man-hours have

been expended in the first quarter:

Total Man Hours: 1050

Total Costs: \$28,235

For a month by month breakdown, please see Figures 5a and b.

FIGURE 1
HAMCO/JPL FACILITY

FIGURE 2

SIMILAR TO

PART NO.

ITEM NO.	PART NO.	DESCRIPTION	QTY
1	021-0065-201	HOOK - R.C. HOLDING FIXTURE	2
2	024-0079-201	ROD - R.C. HOLDING FIXTURE	1
3	027-0000-101	WASHER - R.C. HOLDING FIXTURE	1
4	026-0001-438	NUT - 1"-Ø STD. S.S.	1

PLAN VIEW

SIDE VIEW

GROOVE DETAIL FOR ALL RECHARGE MATERIAL
SCALE: 2X

POLY ATTACHMENT DEVICE
FIGURE 3

UNLESS OTHERWISE SPECIFIED

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QTY		LEV.		DESCRIPTION OF CHARGE		DATE		BY		CHK	
<p align="center">HAMCO DIV. OF THE KAYEX CORP. ROCHESTER, N. Y.</p>											
MACHINE				PART NAME				PRODUCT CODE			
FRACTIONAL ± 1/100				DECIMAL ± .005				ANGULAR ± 1/2°			
DES. BY		DATE		APPROV.		DATE		MATERIAL		FINISH	
CHK. BY		DATE		SCALE		FULL		PERIOD			
SUPERSEDES				EXP. NO.							
MIL. ASSY.				300-0101-2				PART NO.			
				C				361-0054-201

FIGURE 4 -a

FIGURE 4 -b

ERDA/JPL 954888

DIRECT LABOR HOURS

Figure 5-b

Figure 5-a