### Technology
- Single crystal ribbon growth

### Report Date
- 10/3/84

### Approach
- Silicon dendritic web growth
- Contractor: Westinghouse Electric Corp.
  - Advanced Energy Systems Division
  - JPL Contract 955843

### Goals
- For 1984
  - Demonstrate 10 meter length of continuously melt replenished web crystal growth
  - Demonstrate 10 square centimeters per minute steady-state web growth

### Status
- 6 1/4 meters of uninterrupted, continuously melt replenished web growth has been achieved with three different growth configurations
- Steady-state web growth of 8 cm²/min has been achieved
- Major improvement in web growth reproducibility has been achieved
- Concepts for higher growth rate have been developed

### Principal Activities This Period
- Grow Long Web Crystals From Continuously Replenished Melt
- Develop Temperature Distribution In Web And Melt
- Improve Reproducibility Of Growth
- Develop Configurations For Increased Growth Rates (Width And Speed)
- Develop New Growth System Components As Required For Improved Growth
- Evaluate Quality Of Web Grown
Continuously Melt-Replenished Web Growth

Three Web Growth Configurations Have Achieved Long Growth (Approx. 6 Meters)

- J435  (3.3 cm width)
- J460L  (4.1 cm width)
- J460LS (5.1 cm width)

Critical Regions of Temperature Distribution in Silicon Web Growth

- Between Crucible Compartments (Growth And Melt Replenishment Compartments)
- Within The Growth Compartment
- Vertical Profile Within The Growing Web
- Horizontal Profile Within The Growing Web
Melt Temperature Distribution

\[ T_M + 14 \quad T_M + 4 \quad T_M \]

\[ \Delta T = 0.4 \pm 0.2^\circ C \]
\[ \Delta T = 1.2^\circ C \]
\[ \Delta T = 2.5^\circ C \]

Principal Methods for Control of Melt Temperature Distribution

- Stationary Shield Configuration
- Dynamically Positionable Shield Configuration
- Dynamically Positionable Work Coil
- Design Of The Barrier Which Separates Crucible Compartments
Susceptor Shields

For Control Of Melt Temperature Distribution Includes Both Fixed And Adjustable Shields

Temperature Distribution Within the Growing Web

- Determined By Design Of The Susceptor Lids And Top Shields
- Predicted By Computer Model
- Lid And Shield Temperatures Measured In Growth System
Reproducibility of Web Growth

Improvements This Period

- Crucible Re-Designed For Better Susceptor Fit And Improved Thermal Transfer
- Rectangular Work Coil Fabricated With Precision Dimensions
- Perimeter Shields Re-Designed For Reproducible Spacing
- Mated Parts Fitted For Uniform Thermal Transfer

Configurations for Increased Growth Rates (Width and Speed)

- Concepts Are Generated Through Computer Modeling
- Initial Design Specification Derived From Models
- Design Is Verified Through Experimental Web Growth
- Experimental Web Growth And Measurements Provide Data For Additional Input To Model

Growth System Component Development

Major Examples Of Component Development In This Reporting Period:

- New Crucibles
- Improved Crucible Barriers
- New Induction Heating Work Coils
- New Furnace Cover Plate For Higher Growth Rate
- Improved Feeder For Polysilicon Pellets
- Thermal Elements For New Growth System Designs
- Instrumentation For Monitoring Dendrite Thickness (Incomplete)
Web Quality Evaluation

Sources

From This Program

- Residual Stress Via Web Split Width Measurements
- Dislocation Density Via Etch Pit Counting
- Defect Type, Distribution And Structure Via X-Ray Topography

From Associated Programs

- Impurity Evaluation
- Electrical Properties
- Solar Cell Data

WEB SAMPLES FOR STRUCTURE ANALYSIS

[Diagram of web samples with measurements: 33 cm and 25 cm]
SILICON SHEET

J435 Lid Configuration

Etch Pit Density
($10^3 \text{cm}^{-2}$)

Residual Stress
($\text{Mdyn/cm}^2$)

Position, cm

J460 Lid Configuration

Etch Pit Density
($10^3 \text{cm}^{-2}$)

Residual Stress
($\text{Mdyn/cm}^2$)

Position, cm
Problems and Concerns

Calendar Schedule Of Goals Is Tight

Summary

- Technology And Direction Of Development Sufficient To Surpass Goals When Fully Developed
- Major Improvement Achieved In Length Of Continuously Melt Replenished Crystal Growth