SILICON DENDRITIC WEB GROWTH
WESTINGHOUSE ELECTRIC CORP.
S. Duncan

<table>
<thead>
<tr>
<th>Technology</th>
<th>Report Date</th>
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<tbody>
<tr>
<td>Single crystal ribbon growth</td>
<td>10/3/84</td>
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<table>
<thead>
<tr>
<th>Approach</th>
<th>Status</th>
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<tbody>
<tr>
<td>Silicon dendritic web growth</td>
<td>• 6 1/4 meters of uninterrupted, continuously melt replenished web growth has been achieved with three different growth configurations</td>
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<tr>
<td>Contractor</td>
<td>• Steady-state web growth of 8 cm²/min has been achieved</td>
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<tr>
<td>Westinghouse Electric Corp.</td>
<td>• Major improvement in web growth reproducibility has been achieved</td>
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<td>Advanced Energy Systems Division</td>
<td>• Concepts for higher growth rate have been developed</td>
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<tr>
<td>JPL Contract 955843</td>
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Goals
For 1984
• Demonstrate 10 meter length of continuously melt replenished web crystal growth
• Demonstrate 10 square centimeters per minute steady-state web growth

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
Continuous 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
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 Lds
  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
**SILICON SHEET**

**J435 Lid Configuration**

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

<table>
<thead>
<tr>
<th>Density</th>
<th>ZC25-3</th>
<th>2248-3</th>
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<tr>
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<td>▲</td>
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<tr>
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Residual Stress
(M\(\text{dyn/cm}^2\))

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<tr>
<th>Stress</th>
<th>ZC25-3</th>
<th>2248-3</th>
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<tbody>
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**J460 Lid Configuration**

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

<table>
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<th>Density</th>
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<tr>
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<tr>
<td>8</td>
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</tr>
<tr>
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Residual Stress
(M\(\text{dyn/cm}^2\))

<table>
<thead>
<tr>
<th>Stress</th>
<th>R461-5</th>
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<tbody>
<tr>
<td>0</td>
<td>▲</td>
</tr>
<tr>
<td>-10</td>
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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