PV Vendor Survey Results & Research Priorities

February 1-2, 2006

Manufacturing Research Center
Georgia Institute of Technology
Atlanta, GA
Workshop Objectives

• Introduce Georgia Tech Manufacturing Research Center’s PV Manufacturing Initiative
• Discuss vendor survey results
• Prioritize current and next-generation PV manufacturing needs
• Vision for PV manufacturing program at MARC
• Prioritize research agenda of the PV Mfg Initiative
• Recruit industry partners for collaborative R&D on priority needs
Introduction

PV Manufacturing Initiative
at Georgia Tech

Equipment Manufacturers

Cell/Module Manufacturers
PV Industry Needs Survey

• Survey objectives
  – Identify and prioritize key R&D needs of equipment vendors and manufacturers of crystalline Si solar cells/modules
  – Assist in prioritizing university research agenda for current and next generation PV manufacturing technologies
PV Industry Needs Survey

• Survey sent to
  – PV equipment vendors (December 2005)
  – PV cell and module manufacturers (January 2006)

• Vendor survey sent to
  – AKT, Spire Solar, Manz Automation, RENA, OTB Solar, Xerox PARC, NPC, GT Equip
PV Industry Needs Survey

• Cell/Module survey sent to
  – BP Solar, Schott Solar, Advent, GE, Sun Power, Evergreen

• Follow-up workshop with PV cell manufacturers in March-April 2006

• Summary of manufacturers’ survey results to be publicized at a later date
PV Vendor Survey Results

Wafer Thickness of Interest

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Short Term</th>
<th>Long Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 microns</td>
<td>6.3</td>
<td>7.5</td>
</tr>
<tr>
<td>200 microns</td>
<td>7.5</td>
<td>8.8</td>
</tr>
<tr>
<td>150 microns</td>
<td>8.8</td>
<td>8.8</td>
</tr>
<tr>
<td>100 microns</td>
<td>6.2</td>
<td></td>
</tr>
</tbody>
</table>

Degree of Importance (Response Average)
PV Vendor Survey Results

- Wafer Characterization
  - Wafer Stress Management
  - Cracks in Wafers
  - Saw/Etch Damage Impact
  - Robot Transfer Forces
  - Robot Transfer Rate
  - Equipment Specific Handling
  - Belt Transfer
  - Thermal Interconnects
  - Mechanical Interconnects
  - Lamination Pressure
  - Low Cost Wafer Interconnects
  - Auto Wafer Assembly
  - Back contact Interconnects
  - Wafer Assy Stress Management
  - Panel Construction from Wafers

- Generic Handling
  - Air Conveyors
  - Soldering Nonuniformities
  - Texturing Damage Impact
  - AR Coating
  - Monitor Process Parameters
  - Track Manufacturing Data
  - Factory Communication

- Interconnect Technology
  - Panel Construction from Wafers
  - Low Cost Wafer Interconnects
  - Auto Wafer Assembly
  - Back contact Interconnects
  - Wafer Assy Stress Management

- New Methods
  - Air Conveyors
  - Soldering Nonuniformities
  - Texturing Damage Impact
  - AR Coating
  - Monitor Process Parameters
  - Track Manufacturing Data
  - Factory Communication

- Information Technology
  - Panel Construction from Wafers
  - Low Cost Wafer Interconnects
  - Auto Wafer Assembly
  - Back contact Interconnects
  - Wafer Assy Stress Management

Degree of Importance (Average of Responses)

- Short Term
- Medium Term
Discussion of Survey Results

- Comments?
- Issues?
Vision for PV Manufacturing Research Program at MARC

• PV manufacturing line overview

• Proposed/Ongoing research program
PV Manufacturing Vision

Information Technology Based Process/Machine Monitoring, Optimization and Control

Raw Material Supply
Bulk Quality Inspection & Characterization

Wafer Production
- Ingot casting/sawing
- Boule growth/sawing
- Sheet/Ribbon growth
- Etching & Cleaning

Automated In-Line Monitoring & Control
- Defect characterization
- Wafer planarity
- Stress characterization
- Inspection of crucibles and heaters, etc.

Cell Production
- Robot handling
- Conveyor transport
- Screen printing

Automated In-Line Monitoring & Control
- Cracks/Chips
- Metal cosmetics
- Handling force/stress
- Bulk electronic quality

Module Assembly
- Interconnect handling/heating
- Laminate heating/pressure
- Cell string handling
- Glass handling

Automated In-Line Monitoring & Control
- Cracks
- Cosmetics
- Handling force/stress
- Electrical continuity
Current R&D Focus

• Emphasis on development of scientific methods and tools for:
  – stress and crack detection in Si wafers
  – modeling, analysis and optimization of thin wafer handling methods
  – Real-time factory information technology (data exchange, process monitoring and control)
Current R&D Focus

- **Wafer stress measurement**
  - Development of methods for measuring in-plane residual and applied stresses in as-grown/processed Si wafers

- **Thin wafer handling**
  - Analysis and optimization of forces/stresses acting on thin wafers handled by Bernoulli and other grippers

- **Factory information systems**
  - Development of web-based process/machine monitoring, data exchange and control software
CAMX Message Broker

CAMX API
Database Interface

Java Beans
Java Servlets
JSP Pages
Apache Tomcat
Application Server

Camera

Water Inspection and Handling

Controller

Optics and Stage

Controller

Robot

Controller

Sensor

Robot Handling
Current Hardware Capabilities

Information Technology Based Process/Machine Monitoring, Optimization and Control

**Raw Material Supply**
- Bulk Quality Inspection & Characterization

**Wafer Production**
- Ingot casting/sawing
- Boule growth/sawing
- Sheet/Ribbon growth
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**Cell Production**
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**Module Assembly**
- Interconnect handling/heating
- Laminate heating/pressure
- Cell string handling
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**Polariscope**

**4-axis SCARA robot with Bernoulli gripper**

**Future Plans**

- Ongoing work
- Planned work
Collaborative Mechanisms

• Acquire PV manufacturing equipment on consignment from vendor(s) to extend current hardware capabilities in MARC
• Develop company-specific R&D project(s) funded by one or more companies
• Carry out ongoing R&D on consignment equipment and share results with company
Summary

• Vendor survey
• PV Manufacturing Initiative
  – Vision
  – Research focus
• Mechanisms for collaboration
• Opportunity for industry feedback in afternoon session (Industry Feedback)