Kerf-less Wafering for Cost-Effective Silicon PV

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Agenda

- Company Overview
- PolyMax™ - kerf-free wafering technology
- Thickness range and expanded applications
- Cost Reduction Analysis
- PolyMax™ - Materials and Equipment Review
- Conclusion
Company Overview

- Founded in 1997
- Employees: 60 + external contract Eng/Mfg
- Headquartered in San Jose, California (Silicon Valley)
- Develops and licenses engineered substrate technology for semiconductor, optoelectronics and display markets
- Company’s proprietary technologies
  - NanoCleave® (Layer-transfer)
  - NanoBond (Plasma-activated bonding)
  - NanoSmooth (Epi Smoothing/Epi Thickening)
- SiGen has extended its layer transfer expertise to the cleaving of mono-crystalline PV wafers for the solar industry
  - PolyMax™
1. Lower overall demand for PV with a drop in all value chain pricing – cost pressure
2. Oversupply scenario – market demand for high quality and high efficiency
3. Poly price reduction – benefit capacity
4. Continue drive for thinner wafers – lower cost
5. Leveling field for growth – differentiation is key
PolyMax technology provides the transformational solution to wafering process
SiGen PolyMax Process

Two Step Process
(1) Implant
(2) Cleave

What kerf less represents
- Eliminates Consumables and Waste
  - SiC, Slurry, Wire
- Eliminates Other Systems
  - Gluing
  - Singulation
  - Cleaning
- Reduces Upstream CapEx
  - Less poly feedstock
  - Less CZ pullers
- Develops thin wafer market
  - Removes the sub-150µm wafer barrier
  - New applications (i.e. BIPV)
High Efficiency c-Si Foil: 20/20

- THIN-FILM CELLS
- c-Si KERF-FREE FOILS
- PolyMax F-Series 20µm 20%

CdTe or CIGS
- 20µm

20µm

0.1 gm/Wp 1 gm/Wp 10 gm/Wp

Includes Kerf
# Achieving Low-Cost PV Efficiency

<table>
<thead>
<tr>
<th>Si PV Thickness (µm)</th>
<th>Cell Power Conversion Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mono c-Si</td>
<td><strong>“Conventional” Solar Cells</strong></td>
</tr>
<tr>
<td>2008</td>
<td>50-150µm</td>
</tr>
<tr>
<td>c-Si KERF-FREE WAFERS</td>
<td>20%</td>
</tr>
<tr>
<td>2010?</td>
<td>20µm</td>
</tr>
<tr>
<td>PolyMax W-Series</td>
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* Includes Kerf

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Example: 20/20 Thin Foil

156mm x 156mm - 20um
1.26 gm/wafer
0.29 gm/Wp

36 x 1.26gm = 45gm

Compared to 150um Wiresaw wafer → PolyMax
20um foils provide 15X material savings
Future opportunities for thinner wafers

Thinner wafers opportunities

- Further cost reduction
- Enhanced rear illumination
- Lightweight
- Flexibility

Wafer Thickness

300um  200um  180um

150um  100um  50um  20um

c-Si Wafers  c-Si Foil
What if…

“Black hole” of the solar silicon business is removed
PolyMax will cover the wafer thickness roadmap with reduced gm/wafer and $/Wp

Assumptions: Poly price: $100/kg; wafer size: 156mm x 156mm; CE:16%; WS thickness 150um baseline
Potential of Kerf-free Wafering

Standard Upstream Process Line

- Poly Plant
- Growing
- Block cutting
- Cropping
- Grinding
- Gluing
- Slicing wafers
- Pre-Cleaning
- Final Cleaning

*10,000MT → $1B

* Photo Courtesy of REC

PolyMax Plant

- Poly Plant
- Growing
- Block cutting
- Cropping
- Grinding
- Cleaving wafers

Poly Plant Capacity Needed: ~1/3
CZ Puller Capacity Needed: ~1/3

~50% Reduction
Potential of Kerf-free Wafering

Standard Upstream Process Line

**Poly Plant**

*10,000MT → $1B

* Photo Courtesy of REC

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300MW Wafering

**Feedstock:** 3,300 metric ton

**Price:** $70/kg

**Total:** $231M

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**PolyMax Plant**

**Feedstock:** <1,000 metric ton (150um)

**Price:** $70/kg

**Total:** $70M

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$161M less Poly

Feedstock Payments per year

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Assumptions: Poly price: $70/kg; wafer size: 156mm x 156mm; CE:18%; WS thickness 180um baseline
PolyMax™ Wafers & Foils
PolyMax™ 150um Wafer
PolyMax™ 20um Foil
TTV/Roughness – Key to Thin PV

WS – TTV is almost independent of thickness → worse TTV for thinner wafers

PolyMax™ – TTV is a % of the wafer thickness → thinner wafer better TTV
PolyMax Material Results

TTV, RMS Roughness

Thickness

20µm

50µm

100µm

150µm

PolyMax™
PolyMax Material Results

PolyMax™ 20μm thick wafer
RMS 59.1nm
Z range: 493.1nm
X 5.00 μm/div
Z 1000.00 nm/div

PolyMax™ 50μm thick wafer
RMS 97.6nm
Z range: 796.3nm
X 5.00 μm/div
Z 1000.00 nm/div

PolyMax™ 100μm thick wafer
RMS 386.8nm
Z range: 3.2μm
X 10.00 μm/div
Z 2000.00 nm/div

PolyMax™ 150μm thick wafer
RMS 386.8nm
Z range: 3.2μm
X 10.00 μm/div
Z 2000.00 nm/div

TTV, RMS Roughness

Thickness

20μm 50μm 100μm 150μm
PolyMax Material Results

TTV, RMS Roughness

Thickness

Minority-Carrier Density (cm⁻³)

PolyMax™

Tau = 38.6 µs at 2.9E+15 cm⁻³

Tau = 205.4 µs at 5.7E+15 cm⁻³

Tau = 129.0 µs at 1.6E+15 cm⁻³

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PolyMax Equipment

20µm 50µm 150µm
Dual Endstation System
Platen & Tray
The configuration consists of the following elements:

- Propagation is caused by beam-induced cleaving
- Expected Propagation Process Time < 10 seconds per wafer
- No tile handling/tray disassembly
- Cleaved film pick up is from top
PolyMax Roadmap

20µm  

50µm  

150µm
PolyMax Roadmap

**Beta PolyMax™**
- First Shipment – Early/Mid 2010

**Alpha PolyMax™**
- 50um-150um
- Installation later '09

**PolyMax™**
- Ramp up Manufacturing

- **150um PolyMax Wafer**
- **50um PolyMax Wafer**
- **20um PolyMax Foil**
Kerf-less wafering equipment is real and practical
- High-Volume manufacturing equipment on target for 2009
- Development of automation concepts & factory equipment compatibility with REC

Direct Film Transfer is the enabling technology
- Implant technology applied to low-cost production
- Cleave technology for high productivity
- Maintaining high material quality
Conclusions – PV Industry

- Kerf-free benefits are aligned with PV Industry demand

  1. Lower overall cost through entire PV value chain
     - Poly feedstock savings
     - Upstream equipment savings (CZ pullers, cropping, etc.)
     - Lower Opex costs
     - Thinner & higher strength form factors

  2. Green footprint & waste reduction
     - Free of wire and slurry consumables
     - Smaller energy footprint
     - Free of recovery/waste treatment infrastructure

  3. New Applications
     - Effective across residential to commercial to utility
     - Enables high-efficiency BIPV
     - Flexible high-efficiency PV
Thank you!

For more information visit
www.sigen.com