SOLA2020 PV Manufacturing

Topic: Manufacturing Trends

Stuart Wenham

21st April, 2011

UNSW
Market Trends – Where is the Market Heading?

1. Applications
2. Price and Market Trends
3. Trend to higher Performance
4. Wafer Types
5. Cell Technology
6. Environmental Trends
7. Encapsulation
8. Balance of System

UNSW
1. Application Trends

- Rooftop Systems
- Utility Scale Systems
- Stand-alone Systems
  - developing countries

Elecnor Solar Power Plant

35 MW – Trujillo, Spain

Alamosa Solar Power Plant - Colorado
Future Energy Sources and Current Consumption

Photovoltaics - Electricity from Sunlight

UNSW

Energy usage per person (Source: IEA, 2003)
Market Trends – Where is the Market Heading?

1. Applications
2. **Price and Market Trends** – Grid Parity?
3. Cell Efficiencies
4. Wafer Types
5. Cell Technology
6. Encapsulation
7. Balance of System

UNSW
Industry Growth vs Cost

- $100 billion/year industry
- Doubling every 1-2 years
Cost Trends for the Next 10 Years

UNSW

Photovoltaics - Electricity from Sunlight
Predicted Cost Reductions

- Polysilicon Feedstock

Scenario parameters:
- Learning rate = 20%
- Average CAGR = 35%
- Cell efficiency gain: according to ITRPV
Market Trends – Where is the Market Heading?

1. Applications
2. Price and Market Trends
3. **Cell Efficiencies**
4. Wafer Types
5. Cell Technology
6. Encapsulation
7. Balance of System
Leading Laboratory Technologies

UNSW – 25% PERL cell
ISFH – 22.4% RISE cell
Sanyo – 23% HIT cell
Stanford – 24% Rear Point Contact
Challenge to Upgrade Technology

- Compatibility with multi wafers essential for success
- J0 reduction from 1600 to 400fA/cm² gives +40mV in Voc

UNSW
Challenge to Upgrade Technology

- 150-200 μm patterned metal contact
- 3 mm
- phosphorus
- p-type
- bulk of wafer
- rear metal contact
- p +
- metal

Photovoltaics - Electricity from Sunlight

UNSW

Graphs showing changes in finger width and [ohm/square] from 2010 to 2020.
Market Trends – Where is the Market Heading?

1. Applications
2. Price and Market Trends
3. Cell Efficiencies
4. Wafer Types
5. Cell Technology
6. Encapsulation
7. Balance of System

Typical COGS Structure-Cell

- Wafer: 84%
- Dep: 2%
- Others: 8%
- Direct Labor: 1%
- Other RM: 5%

Photovoltaics - Electricity from Sunlight
Wafer Trends

- Wafer costs now $0.8/W and falling
- Current wafering bottleneck
- Thinner wafers and touch free processing
- Trend towards multicrystalline silicon
- New wafer types
  - N-type
  - Seeded casting
  - Range of low cost wafers (incl UMG silicon)
- Module costs now <$2/W
- <$1/W Si module cost price within 2 years

UNSW
Wafer thickness reduction has the following implications:
1. Cost reduction through reduced wafer pricing by reduction of poly-silicon use.
2. Need for innovative handling concepts for thinner wafers to reduce wafer breakage.
3. Need for new cell concepts suitable for achieving high efficiencies on thin wafers.
4. Need for new interconnection and encapsulation concepts suitable for thin wafers.

*Fig. 5: Trend of minimum wafer thickness processed in mass production of solar cells.*
Cell Technology Trends

1. Applications
2. Price & Market Trends
3. Cell Efficiencies
4. Wafer Types
5. **Cell Technology**
6. Encapsulation
7. Balance of System

UNSW

*Photovoltaics - Electricity from Sunlight*
Trends in Cell Technology

1. Selective emitters
2. Narrower metal lines
3. Low temperature processes
4. Rear contacts
5. Processes for thin wafers
   - Improved surface passivation
   - Touch free
   - Simple
   - Laser/inkjet technology
   - Supporting substrates

Photovoltaics - Electricity from Sunlight
Challenge for Thin-Films

- low efficiencies
- durability
- abundance of materials
- stability
- toxicity
- limited history

Cell technology shares (%)

<table>
<thead>
<tr>
<th>Year</th>
<th>mono C-Si</th>
<th>multi c-Si</th>
<th>CdTe</th>
<th>a-Si/µc-Si</th>
<th>CIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>40.8</td>
<td>42.1</td>
<td>17.9</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>37.4</td>
<td>48.2</td>
<td>0.8</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>34.6</td>
<td>30.2</td>
<td>0.5</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>36.4</td>
<td>51.6</td>
<td>17.9</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>32.2</td>
<td>57.2</td>
<td>11.1</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>36.2</td>
<td>54.7</td>
<td>14.1</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>38.4</td>
<td>52.3</td>
<td>14.1</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>43.4</td>
<td>46.5</td>
<td>14</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>42.2</td>
<td>45.2</td>
<td>14</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>38.3</td>
<td>47.7</td>
<td>14</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>

Photovoltaics - Electricity from Sunlight

UNSW
Thin Film Design Rules

Increasing $E_g$

Decreasing $E_g$

Kesterite: $\text{Cu}_2\text{ZnSnS}_4$

UNSW
New Generation Solar Cells (>50%)
Market Trends – Where is the Market Heading?

1. Applications
2. Price and Market Trends
3. Cell Efficiencies
4. Wafer Types
5. Cell Technology
6. Environmental Trends
7. Encapsulation
8. Balance of System
Environmental Trends in Cell Manufacturing

1. Lead free
   - Pastes
   - solders

2. Banning of toxic materials eg Cd

3. Zero waste??

4. Recycled waste water
Market Trends – Where is the Market Heading?

1. Applications
2. Price and Market Trends
3. Cell Efficiencies
4. Wafer Types
5. Cell Technology
6. Environmental Trends
7. Encapsulation
8. Balance of System

Typical COGS - Module

- Wafer: 74%
- Other RM: 14%
- Direct Labor: 1%
- Others: 9%
- Dep: 2%

Photovoltaics - Electricity from Sunlight

UNSW
Trends in Cell Encapsulation

1. Pb free solders need higher temperature
   - Thinner interconnects due to thermal stress
   - Problem for thinner wafers
   - Glued interconnects
2. EVA no good for selective emitters
3. Glued interconnects
4. Rear contacts preferred.
5. PCB approach to interconnection
4. Manufacturers very conservative (25yr warranty)

UNSW

Photovoltaics - Electricity from Sunlight
1. Applications
2. Price and Market Trends
3. Cell Efficiencies
4. Wafer Types
5. Cell Technology
6. Environmental Trends
7. Encapsulation
8. Balance of System