

Lessons Learned from Development of Silicon CPV Modules

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PV Module Reliability Workshop, March 2012

RELIABILITY MATTERS



29 February 2012

The warranty issues are a **BIG DEAL (to us at least)**. We are very disappointed that FSLR has now taken a cumulative \$253mm of warranty and related charges as its panels are underperforming in the field – these issues we think are **VERY** concerning. Field reliability of thin film panels are less proven as is – and high temperature degradation of CdTe panels is a known issue (ask us for an NREL study on this topic). We have confirmed FSLR is building the Topaz project to 586MW AC, above the 550MW specified in the contract – we think there is some risk that this “over spec” is to provide protection given the minimum energy performance specs that FSLR has committed to in the project given the lower confidence on field performance.

First Solar, Inc. (Public, NASDAQ:FSLR) [Watch this stock](#)

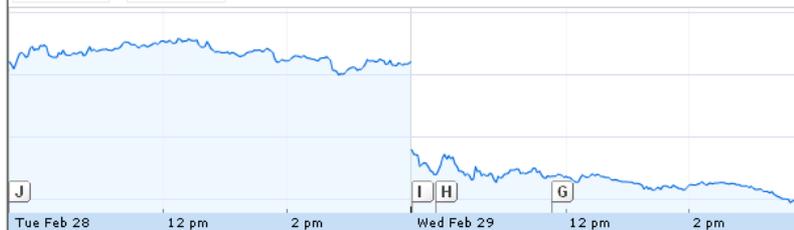
31.92 -0.38 (-1.18%)

Real-time: 9:43AM EST
NASDAQ real-time data - [Disclaimer](#)
Currency in USD
Range 31.71 - 32.55
52 week 29.87 - 163.00
Open 32.55
Vol / Avg 134,800.00/5.35M
Mkt cap 2.77B
P/E 5.27
Div/yield -
EPS 6.08
Shares 86.42M
Beta 1.37
Inst. own 89%

Compare: Dow Jones Nasdaq SPWR ASTI DSTI ESI

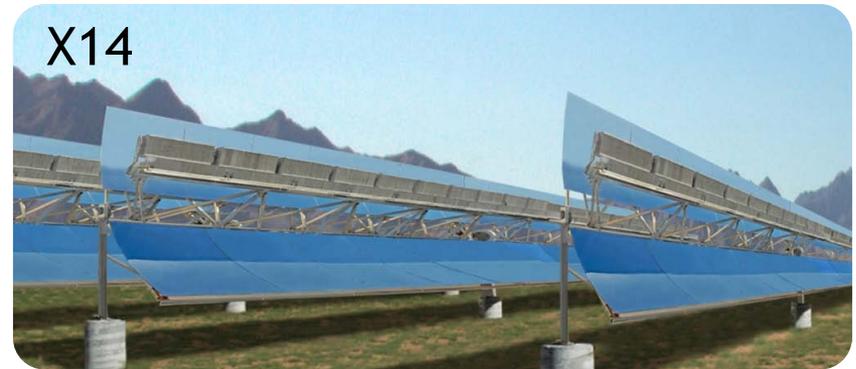
Zoom: [1d](#) [5d](#) [1m](#) [3m](#) [6m](#) [YTD](#) [1y](#) [5y](#) [10y](#) [All](#)

Feb 28, 2012 - Mar 01, 2012 -4.1 (-11.33%)



INTRODUCTION

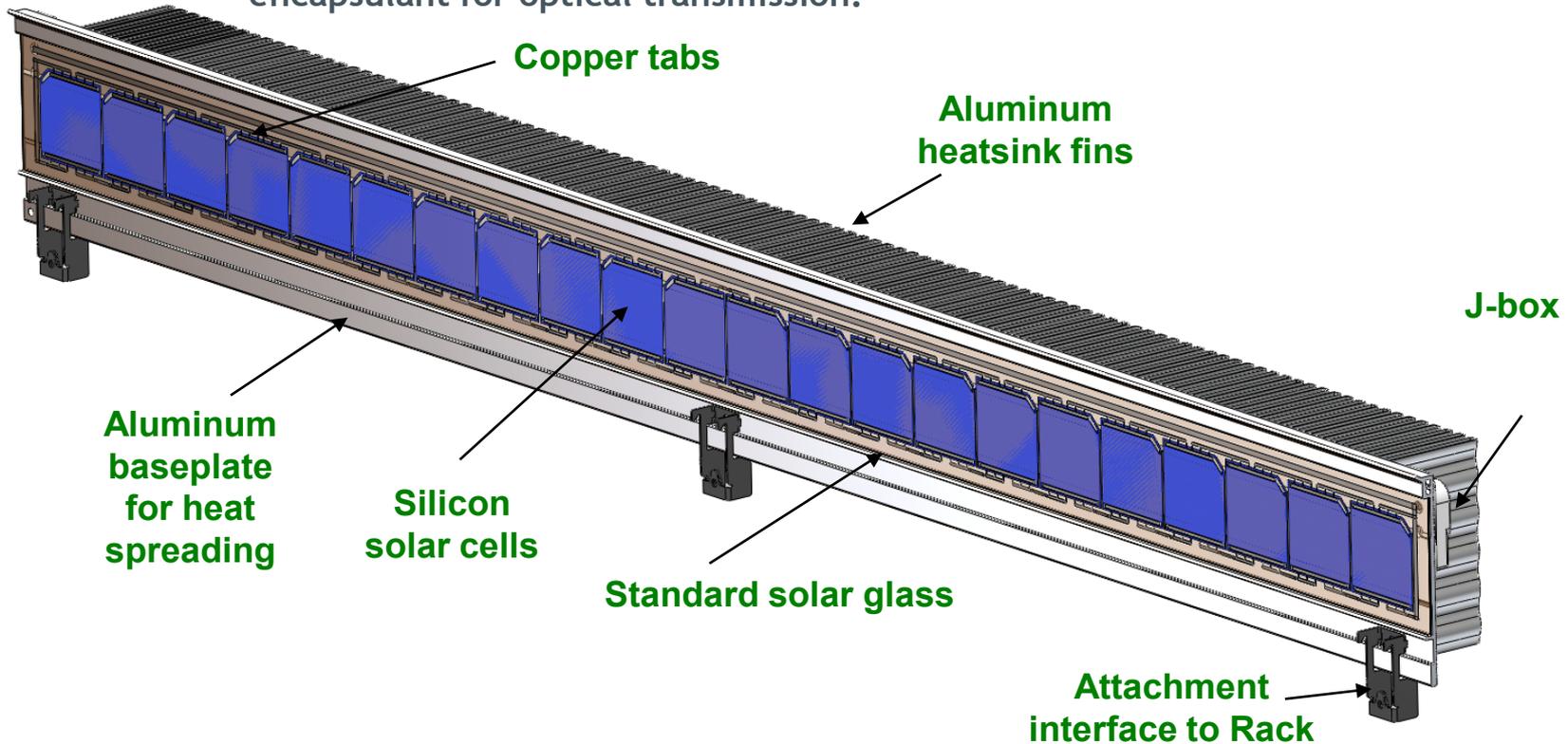
- Skyline Solar has commercialized CPV products using silicon PV cells in a linear concentrator



- Key design challenge for Skyline and predecessors (e.g. Euclides): receiver package
- Multiple, conflicting design drivers
 - High durability vs Low materials cost
 - Low thermal resistance vs High electrical resistance

GEN1 RECEIVER DESIGN

- Design goals:
 - Leverage standard solar panel packaging, processes, and manufacturing partners
 - Common components to standard panels - Examples: Cell processing, stringing/tabbing, encapsulents, glass, Jbox, cables
 - Adapt where required for our application - thermal optimization and optical flux.
 - Aluminum baseplate and heatsink fins in place of Tedlar backsheet
 - Adaptation of backsheet encapsulant for thermal dissipation and frontsheet encapsulant for optical transmission.



KEY COMMERCIAL CONSTRAINTS: RELIABILITY & COST

- Reliability considerations: akin to flat-plate c-Si modules* + high UV

Failure Modes of Crystalline Si Modules



- Broken interconnects
- Broken Cells
- Corrosion
- Delamination and/or loss of elastic properties
- Encapsulant discoloration
- Solder bond failures
- Broken glass
- Hot Spots
- Ground faults
- Junction box and module connection failures
- Structural failures

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- Cost
 - Limits material choices: e.g. no sapphire substrates
 - Limits manufacturing processes: high throughput, wide tolerances

*Wohlgemuth Cunningham, Nguyen, Kelly and Amin, PV Module Reliability Workshop 2010, Golden, CO

SKYLINE'S EXPERIENCE

Encapsulant Options

- EVA
- PVB
- Silicones

Discoloration, broken cells

Thermal Expansion Effects

- Metal + glass
- Long panels
- Cu + Si joints
- Lamination

Junction Box Considerations

- Small footprint
- Case material composition
- Potting and sealing
- Supplier quality

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ENCAPSULATION: GLASS TO ALUMINUM LAMINATION

Robust design

- Low laminate stress during life cycle
- Geometry chosen to manage CTE mismatch
- Minimize material usage

Well matched materials

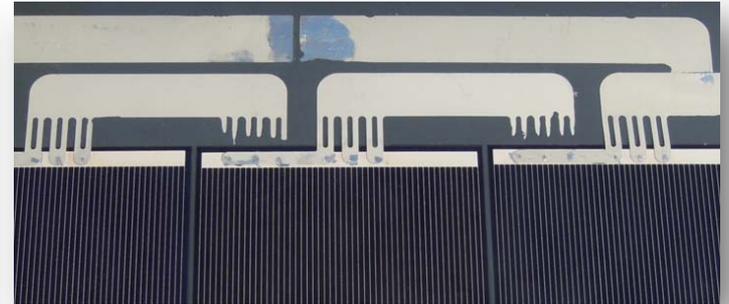
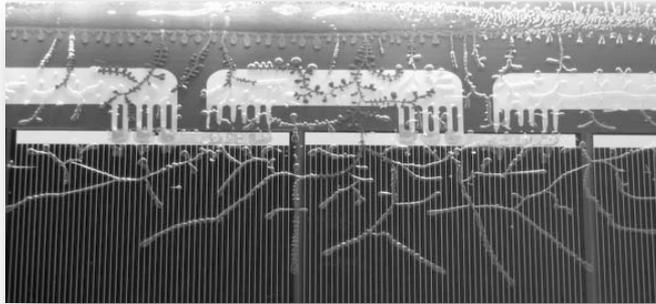
- Chosen for high adhesion between layers
- Low modulus change across temperature range
- Suitable for high UV and thermal management

Robust process

- Stable and safe chemistry
- Process speed + high yield
- Low risk of string damage

ENCAPSULATION: WHAT CAN GO WRONG

Delamination or Voiding



Interconnect Failure



CELL STRING SOLDER JOINTS

Wide Process window

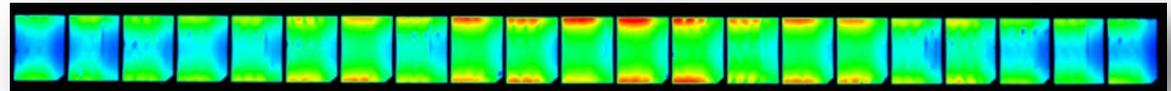
- Proper choices of solder material and thickness
- Proper choices of manufacturing equipment
- Extensive testing and characterization

Tolerant of temperature extremes

- From solder reflow temperature down to -40°C
- Daily temperature cycles
- Optimized tab geometry

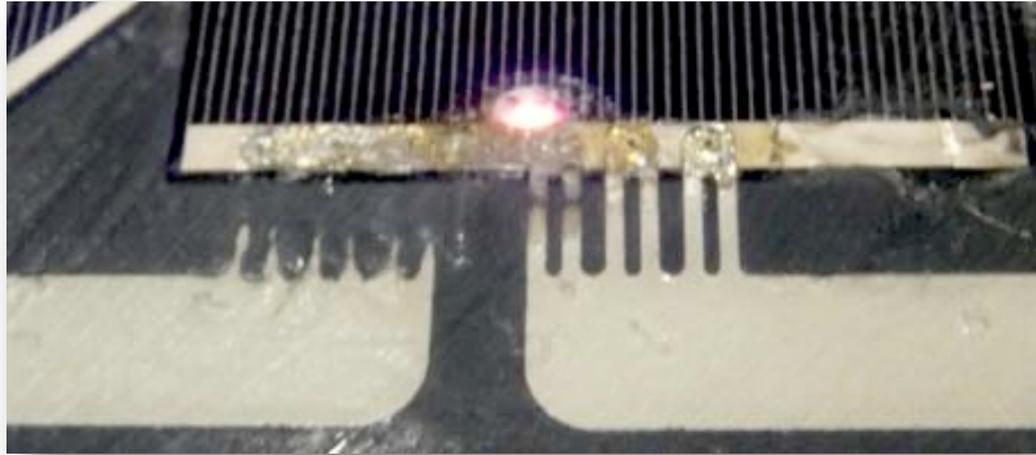
Direct reliability and performance impact

- Poor solder joints can cause high local heating
- Good solder joints will reduce string resistance
- Proper solder joints will not degrade with T/C.

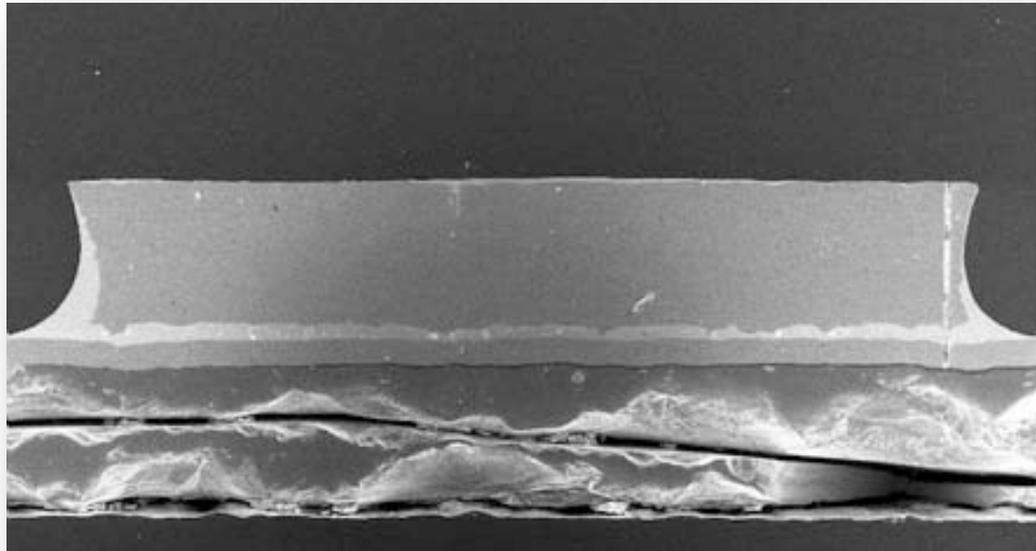


CELL STRING: WHAT CAN GO WRONG

Localized Heating



Cell Cracking



JUNCTION BOX

Early in-house testing

- Screened several suppliers
- Uncovered fundamental design and materials issues
- Developed simplified J-Box design



Reliability impact

- Many material systems interact in J-Boxes
- J-Box failures caused the largest panel headaches
- J-boxes can be single point of failures

Cost impact

- Too high \$\$ for a plastic & copper component
- J-Box manufacturing yield issues are expensive
- Poor electrical joints cost in performance and system reliability

J-BOX: WHAT CAN GO WRONG

Bulk Material



Adhesion

