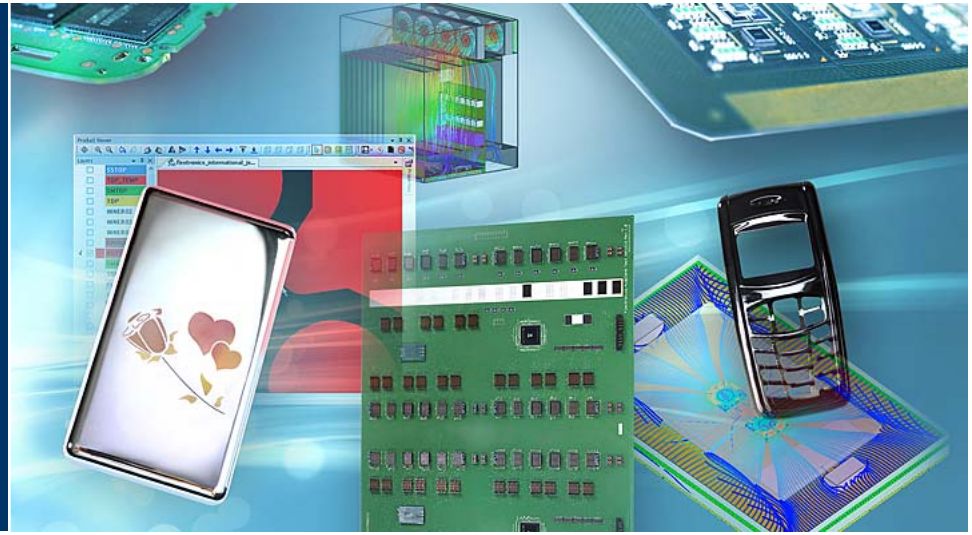
FLEXTRONICS

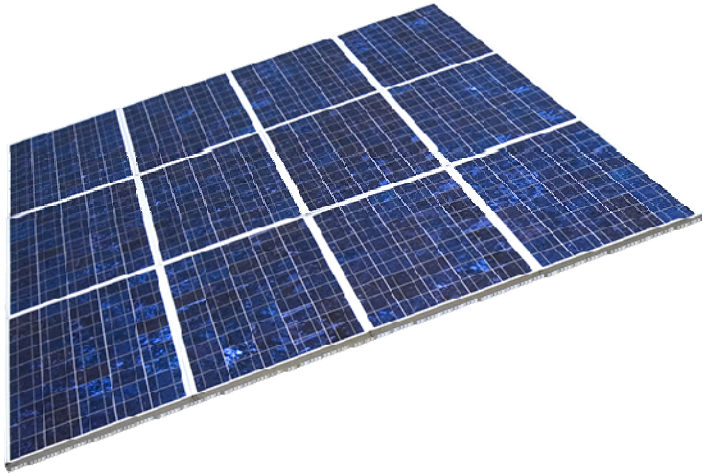
Advanced Technology Group

Solar PV Module Assembly

Dr. Dongkai Shangguan

April 2011





Continuous Momentum

evertiq
online european electronics

Enphase works with Flextronics over Clean Tech

Enphase Energy, a solar microinverter systems specialist, today announced a new microinverter, which will be produced by EMS provider Flextronics.

Pythagoras Solar partners with Flextronics

Pythagoras Solar plans to commercialise its energy efficient, transparent and high power density photovoltaic glass unit (PVGU). It has partnered with Flextronics to quickly scale its operations.

PV-tech.org
Daily News

solarbuzz

SolarEdge partners with Flextronics for manufacturing of distributed PV power harvesting systems

The top EMS companies apparently bid on the contract, but Flextronics won the gig because of its "in-depth, long-evolved knowledge in reliable production of power electronics, global supply chain operation, and most importantly, factories in all geographies," he explained. "This enables SolarEdge to manufacture close to the market, and provides manufacturing back-up in case of factory issues and all with global procurement and logistics."

EE Times Asia

Q-Cells Selects Flextronics to Manufacture 200 Megawatts of Solar Modules

Deal represents one of the largest solar manufacturing contracts awarded in the industry to date

Flextronics to build clean tech plant in Malaysia site

facility in Port of Tanjung Pelepas (PTP) for Clean Tech Super Site, in a move that strengthens its position in manufacturing of solar modules. The facility aims to reach an annual production volume of 1GW of solar modules in two years. This complements the company's clean tech strategy that includes providing services to global OEMs of inverters, wind power, smart grid, smart metering and energy-

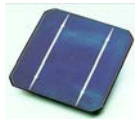
YAHOO! FINANCE

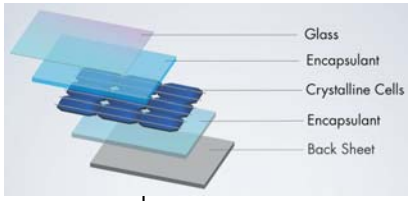
SunPower, Flextronics to run solar panel factory

SunPower, Flextronics join forces to run California solar panel factory

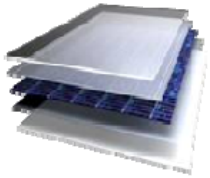
SAN JOSE, Calif. (AP) -- Solar power products company SunPower Corp. said Thursday it is teaming with Flextronics International Ltd. to build solar panels by the end of this year.

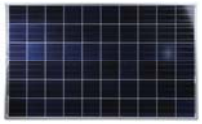
Solar Module Assembly vs. PCBA

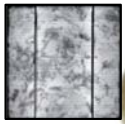


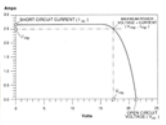


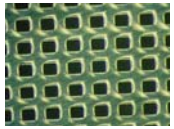
tab & string → lay-up → lamination → assembly → testing (structural/functional)

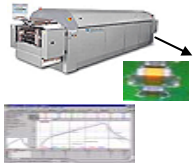




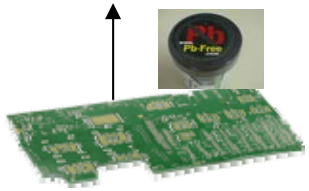


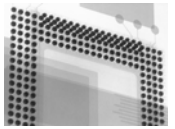






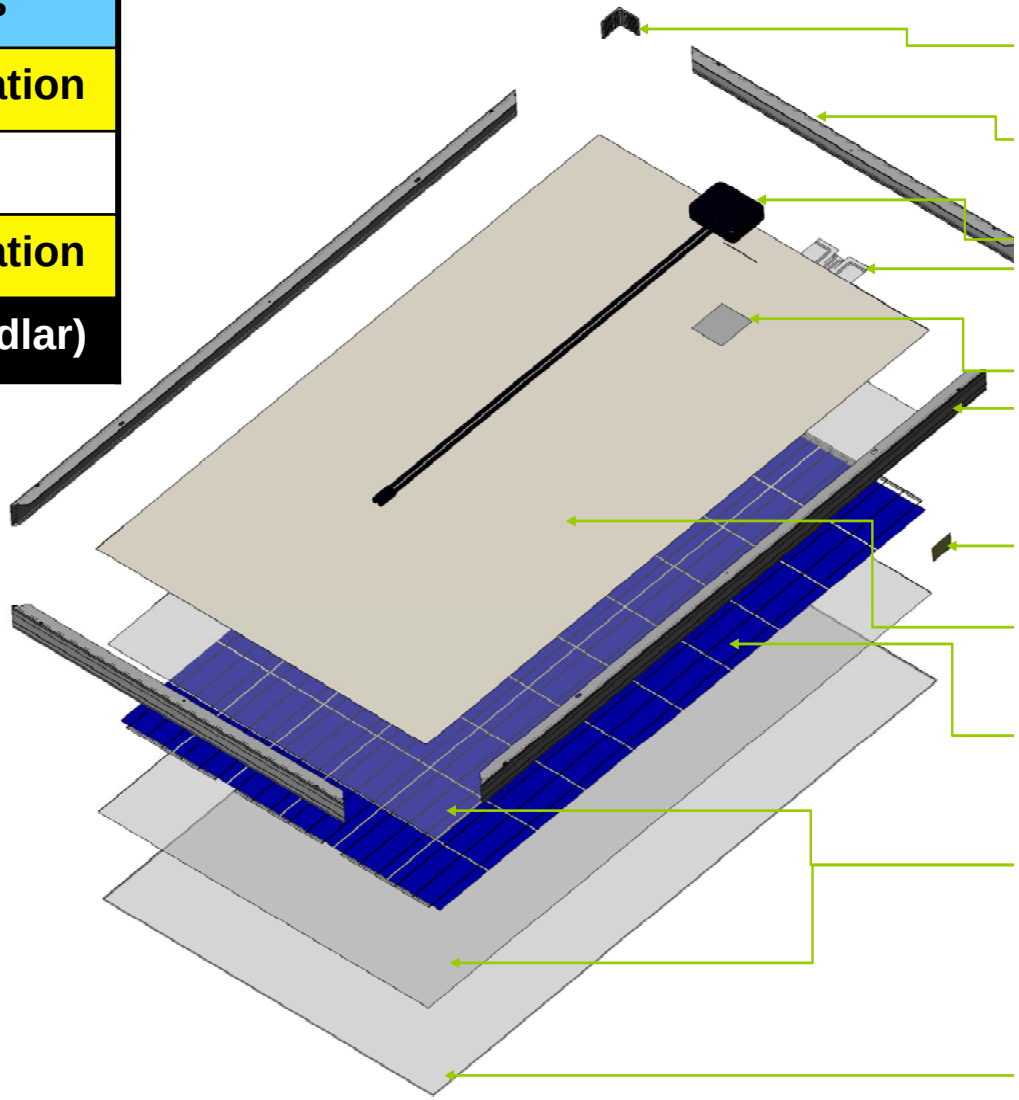
solder paste printing → pick & place → reflow → assembly → testing (structural/functional)





Crystalline Silicon Module (c-Si) Construction

Solar Glass
EVA Encapsulation
Cell Matrix
EVA Encapsulation
Back sheet (Tedlar)



Corner Joint (4)

Frame Ends (2)

Junction Box & Cables
Insulating Sheet

Product Label

Frame Sides (2)

Barcode Label

Backsheet

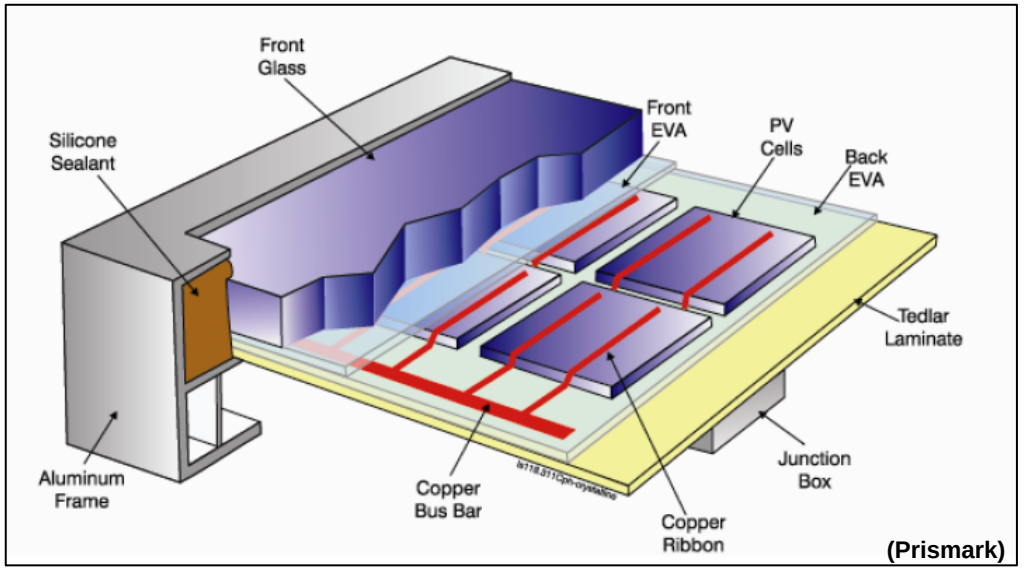
Cell Interconnect Matrix

EVA

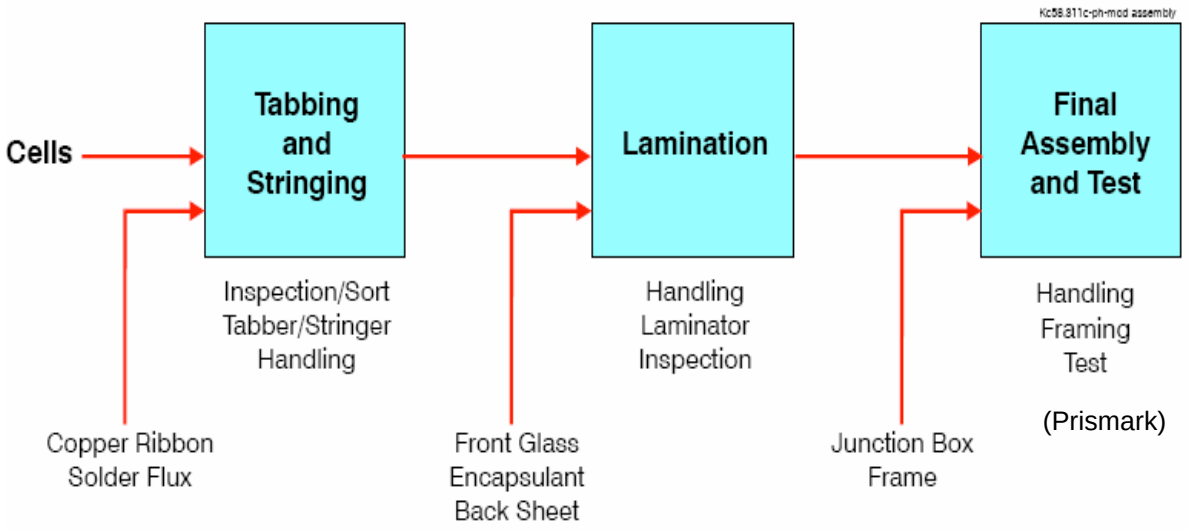
Glass

Module Assembly Process (c-Si)

- Cell Inspection, Test and Sort
- Glass Wash
- Tab and Stringing
- Prep Buss Bars, EVA & Backsheet
- Matrix Assembly and Lay Up
- EVA and Back sheet
- Inspection
- Lamination
- Edge Trimming
- Framing
- Junction Box Installation
- Sun Simulator & Hi-Pot Test
- Label Application
- Package and Ship



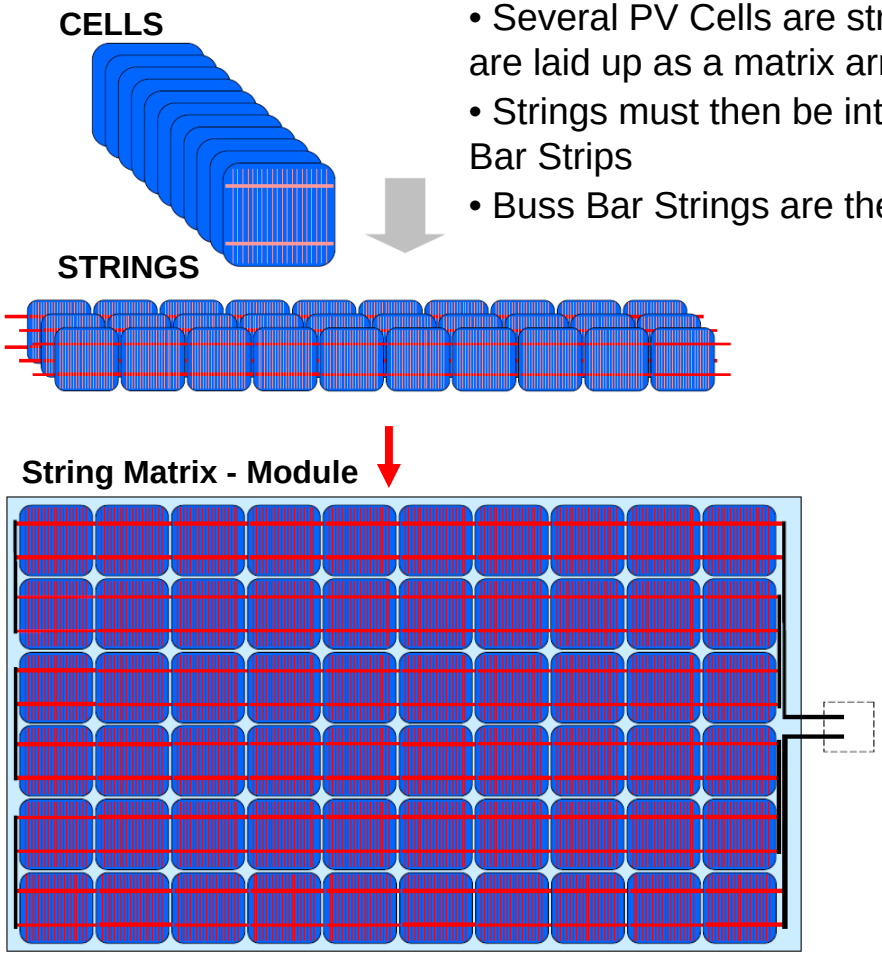
(Prismark)



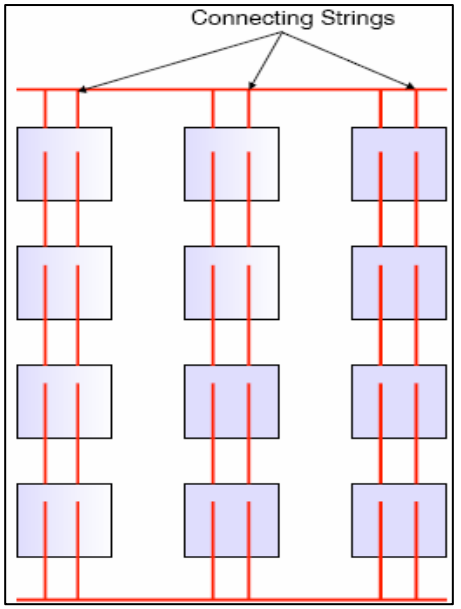
(Prismark)

PV Cells – String - Array - Module

- PV Cells are typically connected in series: Connect back contact of one cell to the front contact of the next cell
  - Backside Contact cells have connections only on the bottom of the cell
- Several PV Cells are strung together using ribbon wires and then the strings are laid up as a matrix array
- Strings must then be interconnected via conductive tape or solder to the Buss Bar Strips
- Buss Bar Strings are then connected into the Junction Box



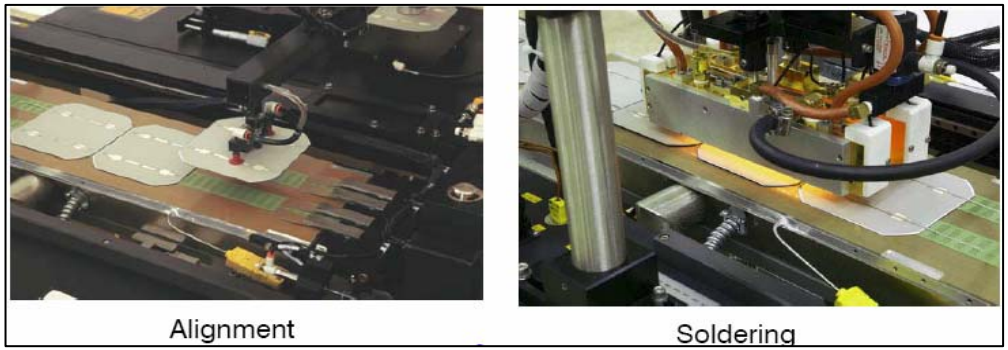
Source: Komax 2009



Source: Primark 2009

Tab & String Process

- Process Steps
  - Flux copper ribbon, cut to size, bend
  - Align cells and ribbon
  - Solder ribbon onto front / back bus bars of cell
  - Repeat on all cells of string
- Process can be manual or automatic
  - Automated soldering is typically done by IR Light, Touch Induction or Heated Contact methods
- Critical Parameters
  - Breakage
  - Alignment
  - Throughput



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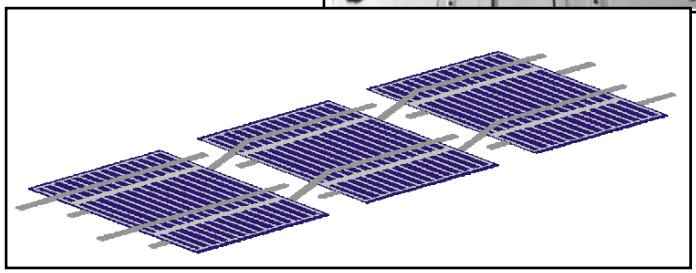
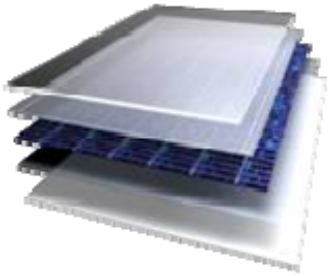


Source: Komax 2009

Lamination Process



- **PV Cells are laminated between a Glass Front and Protective Backsheet using an encapsulant**
  - **Encapsulation provides mechanical protection, moisture protection and electrical insulation**
  - **The encapsulant must be low cost, easy to process, optically clear and have no degradation after 30 years of UV and weather exposure**
- **Standard encapsulants are based on EVA (Ethylene-Vinyl Acetate)**
  - **EVA material requires vacuum, heat and pressure allow to allow polymerization**
    - **The Lamination Cycle usually takes 15-25 minutes for cross linking polymerization**
    - **New Fast Cure EVA materials can reduce cycle time**
- **Key Process Parameters: T, t, P**

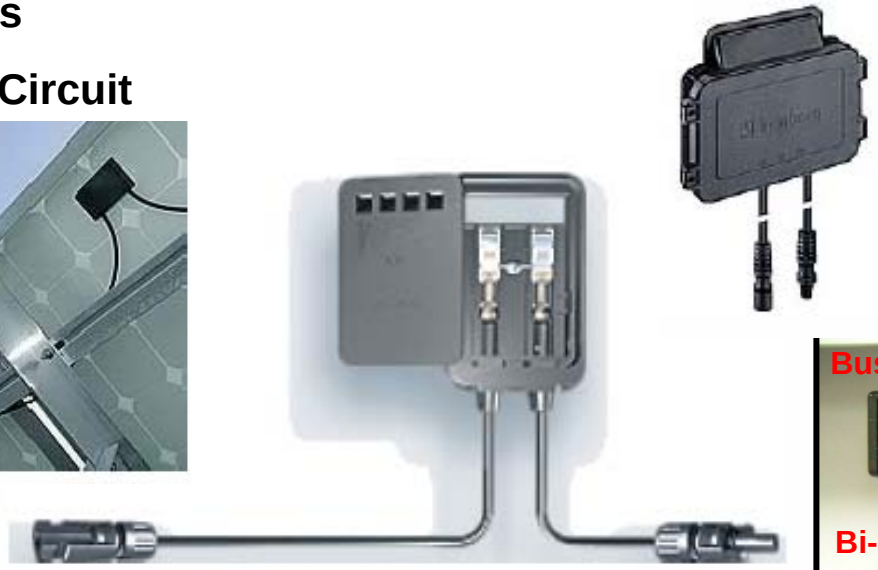
Ethylene-Vinyl Acetate (copolymer of 10%-40% ethylene and 10%-40% vinyl acetate)

DuPont™ *Tedlar*® polyvinyl fluoride (PVF) -(CH2CHF)n- thermoplastic fluoropolymer with the repeating vinyl fluoride unit:

Junction Box Attach

Junction Box (J-Box)

- **Collects input and transfers output current from Module Cells to external cables for interconnection to adjacent Modules and inverters**
- **Serial Circuit**

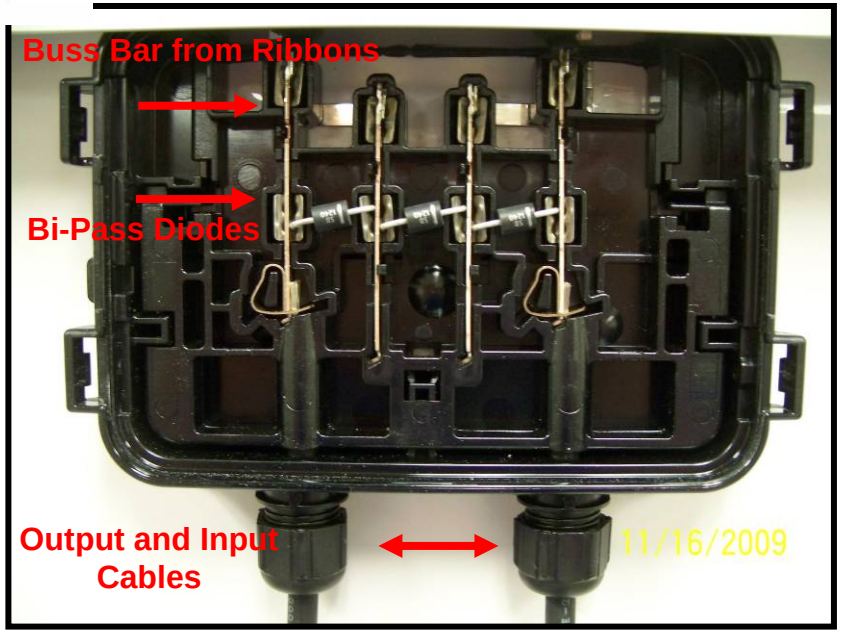


J-Box Mounting Machine

Source: 2BG Mounting Machine

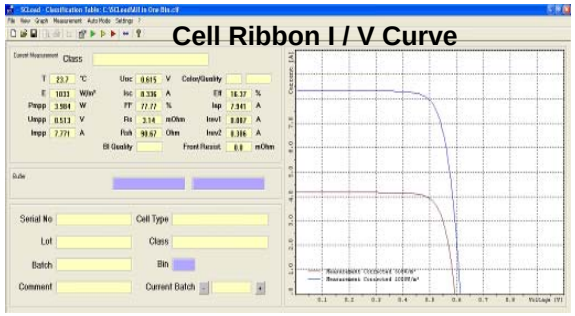
BOS

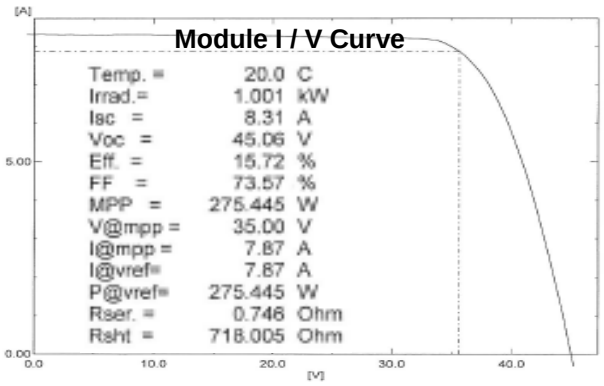
- **Junction Box**
- **Frame**
- **Racking**
- **Tracking**
- **Connectors and cables**
- **Inverters**
- **Grid connect hardware & software**

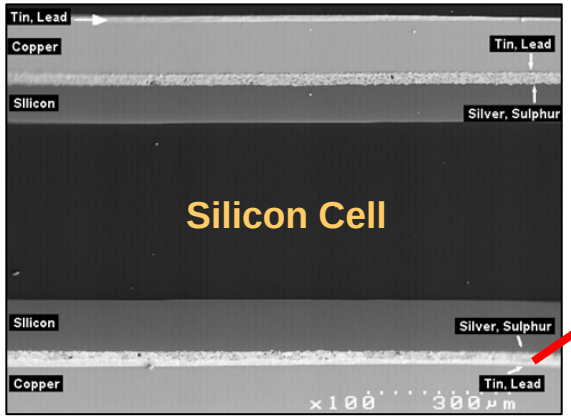


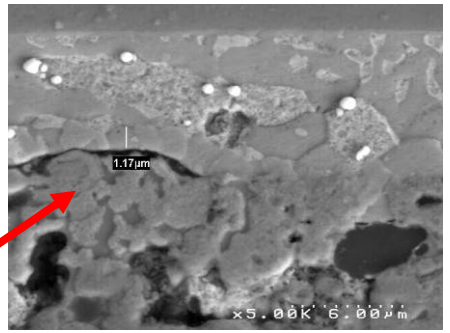
Quality Verifications

- **Cell Inspection**
  - Machine Vision and Alignment
- **Ribbon – Buss Bar Soldering Verifications**
  - Visual, Metallurgical, Pull Tests, Solder Area
- **Mechanical and Electrical Testing**
  - Electroluminescence Testing
  - Hi Pot Testing
  - Flash Testing



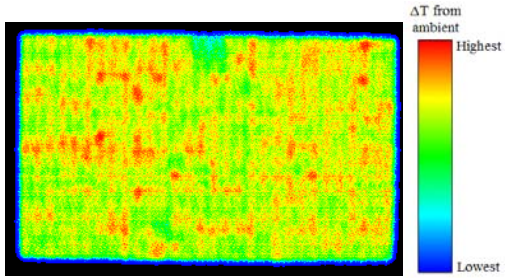






Cell – String Inspection Methods

- **Manual Visual Inspection**
- **Camera Inspection**
  - **ID Cell S/N and Lot Code**
  - **Provide alignment for Tab/String process**
  - **Verifies Conductive Grid Finger Pattern and Position**
  - **Detect Cell edge damage or chips**
  - **Able to detect major cracks where light shines through cell**
- **Infra Red Inspection**
  - **Power up method to look for hot spots on laminated modules**
    - **ID hot spots, poor connections or shorts between cells**
- **X-Ray Inspection**
  - **Use of traditional PCB X-Ray - Limitations on sample size**
  - **Good ability to see metal features**
- **EL Inspection**
  - **Electrical Bias applied to Ribbon-Cells to magnify Cell properties**
  - **Able to detect finite cracks, un-active areas and cell anomalies**
  - **Finite Crack acceptability limits unknown at this time**

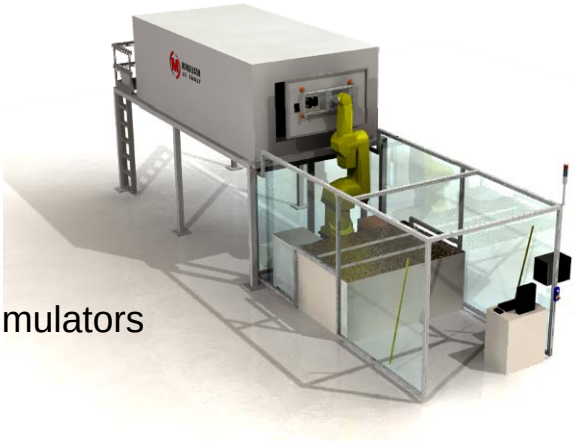


Source: Reltron

Source: HuBrain

Cell and Module Flash Testing

- Solar Cells and Modules can be Flash (Sun Simulator) tested in either Cell of Modular form
- Test Process can be automated or manual
- Test equipment is either a flat bed or solar tunnel or room type
- Use Solar Flash Simulators to present light
    - Cell/Module Flash response recorded
    - IEC-60904-9 STD International performance standard for solar simulators



Automated Module Tester

Semi- Automated Module Tester

Semi Automated Module Tester

Source: Spire, P-Energy, Berger and Mondragon

Technology Review
Mechanisms for Yield Improvement

- Improve encapsulation & metallization schemes
- Broken interconnects and solder bond failures
  - Thermomechanical fatigue, stress concentration
- Broken Cells
  - Requires better optical and mechanical handling test & inspection
- Corrosion
  - Requires improved moisture protection, optical and mechanical test & inspection
- Delamination
  - Improved adhesives
  - Material outgassing. Bubbles can form leading to loss of elastic properties.
  - Requires better material selection and robust accelerated testing
- Encapsulant discoloration
  - Requires better material selection and robust accelerated UV testing
- Broken glass
  - Hot-spot, arcs, improper mounting
- Ground faults
  - Avoid mounting behind the cell area
- Junction box and module connection failures
  - Workmanship (improper assembly), QC, qualified parts
- Structural failures
  - Follow manufacturer's recommendations, instructions, design to load

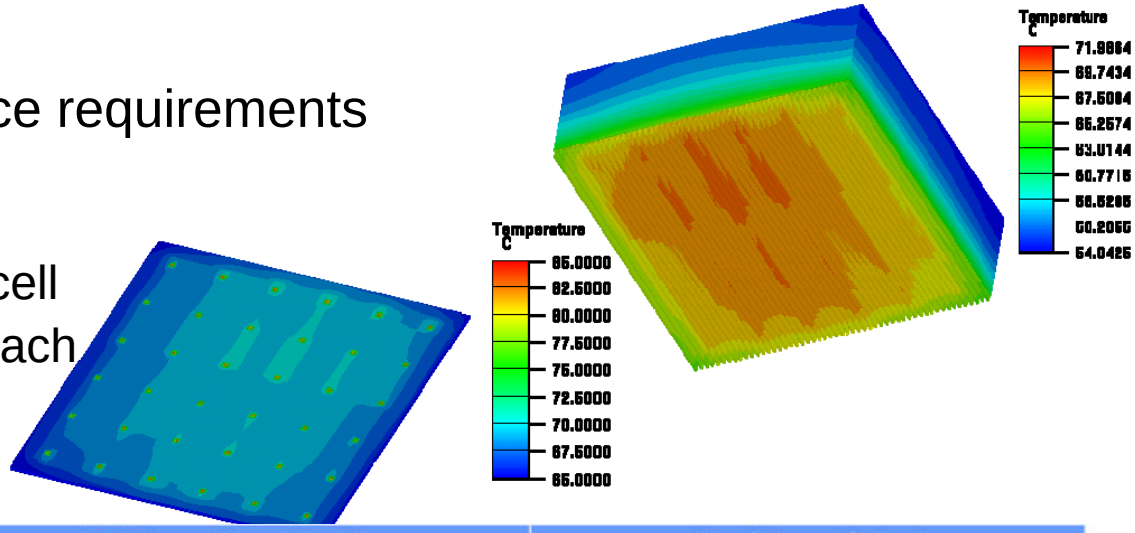
CPV Module

Design Challenges

- Thermal (up to 100W/cm^2 @1000 Sun)
  - High power density
  - Passive cooling
- Low cost
- Tough dimensional tolerance requirements

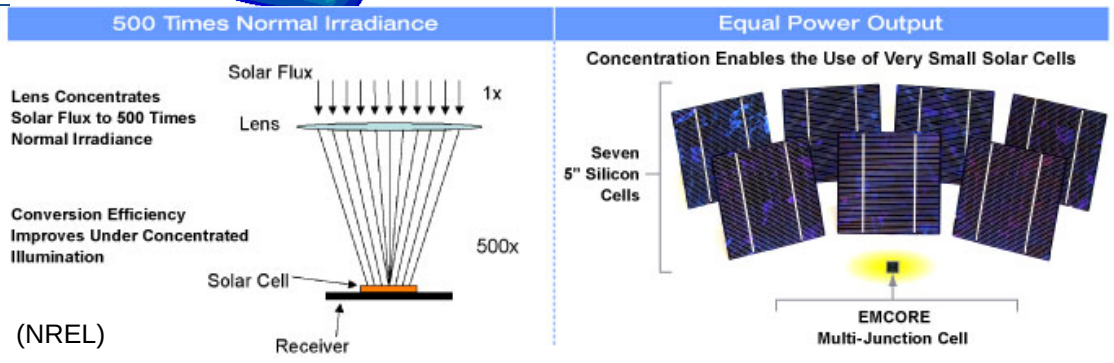
Process Challenges

- Die attach
- Interconnection



Reliability Challenges

- Thermal stresses on the solar cell
- Thermal stresses on the die attach
- Humidity and UV



IPC Solar PV Module Standards

Description: industry workmanship and performance standards for Crystalline Photovoltaic Cells and Modules

Drivers/Objectives

- Workmanship Acceptability Standards
- Module Performance Test methods
- Qualification Requirements, Repair Standards

Focus

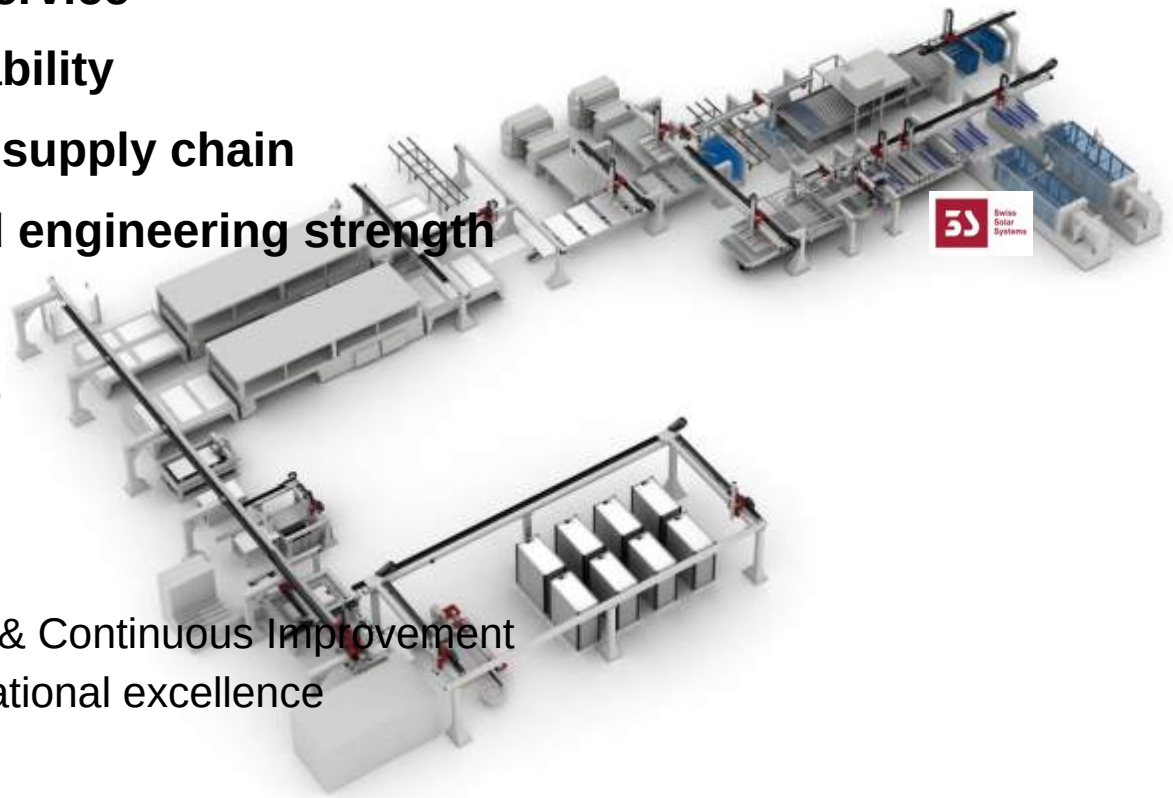
- Workmanship Acceptability Standards
- Design Guidelines for Tabbing and Stringing
- Acceptability Guidelines for Solar Panel Lamination
- Specification for Materials Used in Tabbing and Stringing
- Acceptability Criteria for Tabbing and Stringing
- In-Process Test Methods for Solar Panels
- Visual Acceptance Criteria for Solar Panels – Final Assembly
- Guidelines for Final Test with an Emphasis on Flash Test
- Module Performance Test methods, Qualification Requirements, Repair Standards

Solar Module Assembly: Key Considerations

- Technology
  - Semiconductor material; Device structure
    - GaAs, GaInP, …
    - Crystalline Si (poly / mono)
    - Thin film: Amorphous Si; CIGS; CdTe; Organic; …
- Cell / module design
  - DFM
- Quality & reliability
  - Performance over 10/20/30 yrs under UV and weather exposure
  - UL / CE certification: Product qualification vs. Line qualification
- Process capability & quality
- Cost effective equipment configurations
  - Individual equipment vs. turnkey
  - Line configuration and balancing
  - Automation vs. Manual
  - CapEx
- Industry standardization
  - Qualification; Workmanship Acceptability; Module Performance Test; Rework
- Cost reduction

EMS Role in Solar Module Assembly

- **Design, Build, Ship and Service**
- **Global footprint and scalability**
- **Materials purchasing and supply chain**
- **Technology solutions and engineering strength**
- **Quality and reliability**
- **Manufacturing Excellence**
  - NPI to Volume
  - Equipment and materials
  - Certification
  - Process optimization / control & Continuous Improvement
  - Lean manufacturing and operational excellence
- **Industry Collaboration**
  - IPC PV Module Assembly Workmanship Standards



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Innovate. Enable. Partner.

Thank you