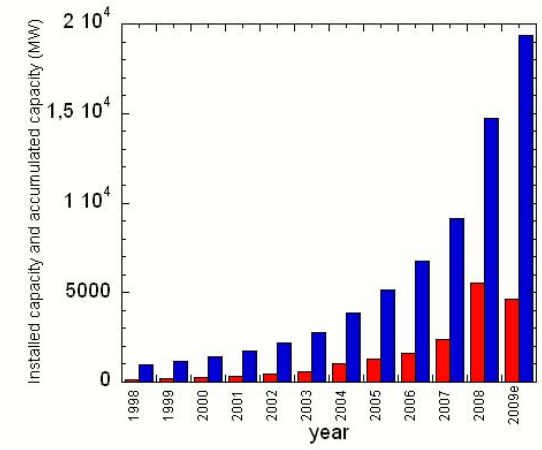
Solar business from research to enterprise

Marika Edoff

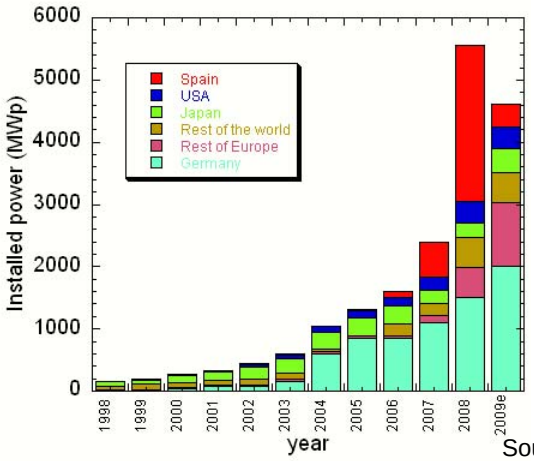
Market for solar cells



- Steady growth of the market for 10 years
- Set back in 2009

Source: EPIA Global market outlook
Scenario: moderate (for 2009 estimate)

Installed capacity/region



- Spanish government cap on subsidies
- Limitation to 500 MW/year installed
- New subsidies in Japan, japanese market expanding

Source: EPIA Global market outlook
Scenario: moderate (for 2009 estimate)

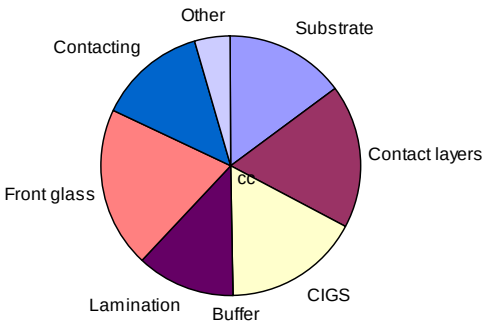
Products on the market today

- Crystalline silicon modules (80%)
- Thin film modules (20%)
  - CdTe (50 % of thin film market)
  - CIGS
  - Thin film silicon

What are the requirements on a successful large scale technology?

- High efficiency
- Low cost
  - 1,4 €/Wp and 12 % efficiency (total area) corresponds to 170 €/sqm (1700 SEK/sqm)
  - 1,4 €/Wp and 7 % efficiency (total area) corresponds to 100 €/sqm (1000 SEK/sqm)
- Excellent long term stability
  - >20 years in the field
- High energy yield
  - Many kWh/Wp*year
  - Performance at high temperature
  - Performance at low illumination

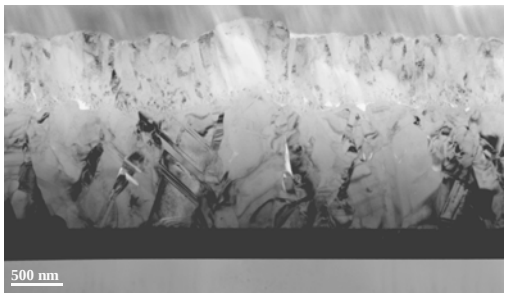
The cost structure: ex CIGS thin film modules



The front glass is the most expensive part of the module!

Why CIGS?

- High absorption (can be thin)
  - Low distance to junction
  - Low material usage
  - High process speed
- Electrically inactive grain boundaries
  - Vertical boundaries have very small influence on efficiency

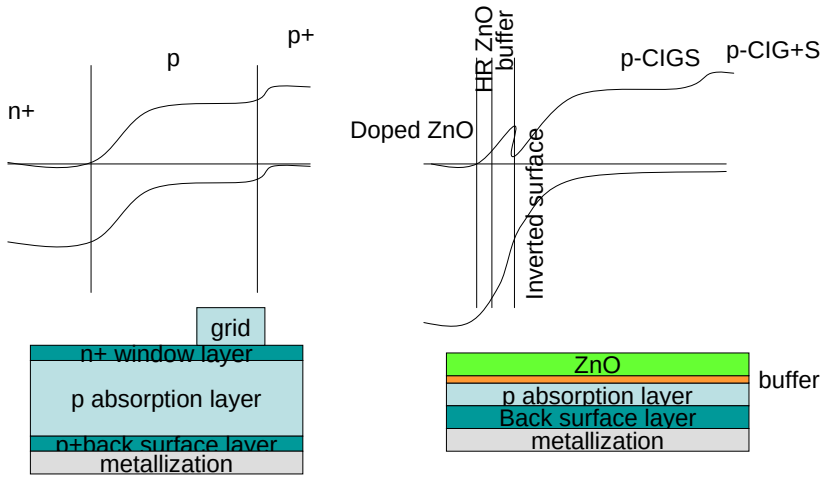


TEM: Timo Wätjen

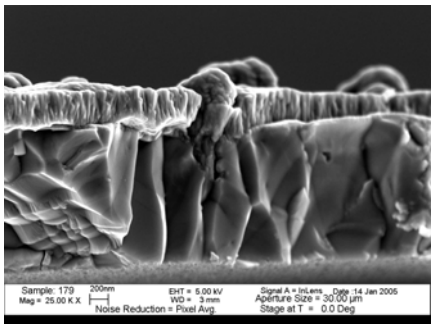
What is CIGS?

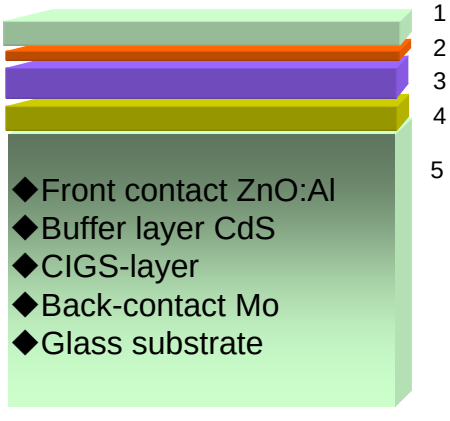
- Copper indium diselenide - $CuInSe_2$ - CIS
  - A chalcopyrite semiconductor
  - 1,0 eV bandgap
- Se is replaced with sulphur – $CuInS_2$
  - 1,5 eV bandgap
- In is replaced with gallium – $CuGaSe_2$
  - 1,7 eV bandgap
- Alloying between these compounds possible – CIGS
  - $CuIn_{1-x}Ga_xSe_2 : x < 0,5$
  - $Cu(InGa)(Se_{1-y}S_y)_2 : y < 0,5$

Comparison Si - CIGS



The structure and build up



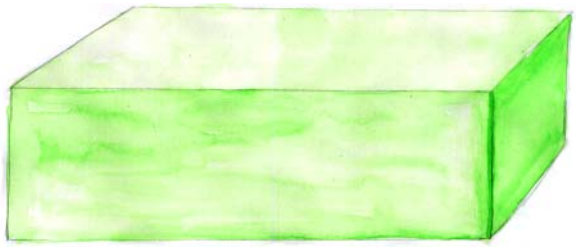


- Front contact ZnO:Al
- Buffer layer CdS
- CIGS-layer
- Back-contact Mo
- Glass substrate

Total thickness of all thin film layers together 3-4 µm

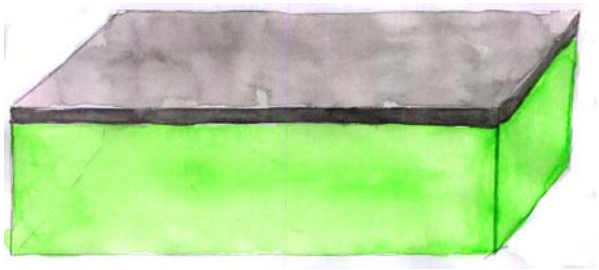
To make a solar cell module

- Ordinary soda lime glass as carrier



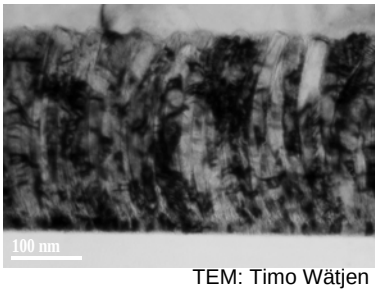
Back contact

- A thin layer of Mo is deposited on the glass



Back contact

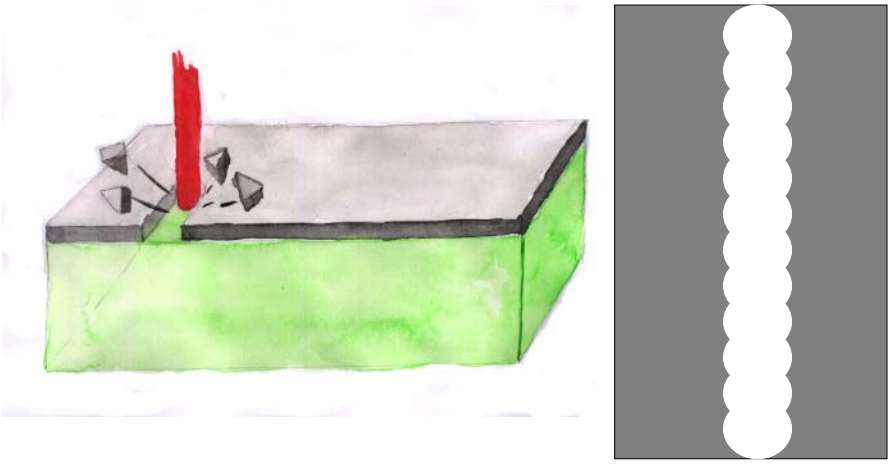
- Made by in-line dc magnetron sputtering
- Columnar grain structure
- Na transport in grain boundaries



TEM: Timo Wätjen

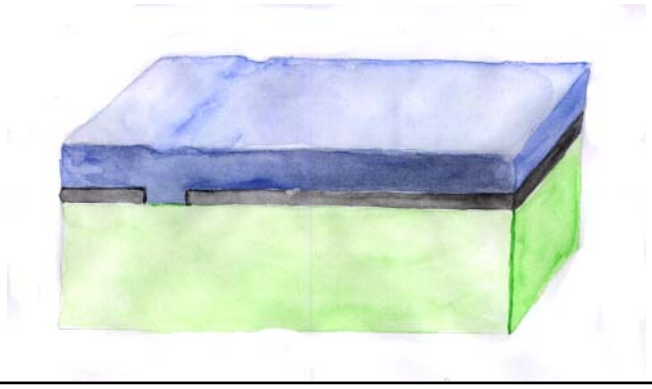
First patterning step

- Thin lines are scribed with a laser beam

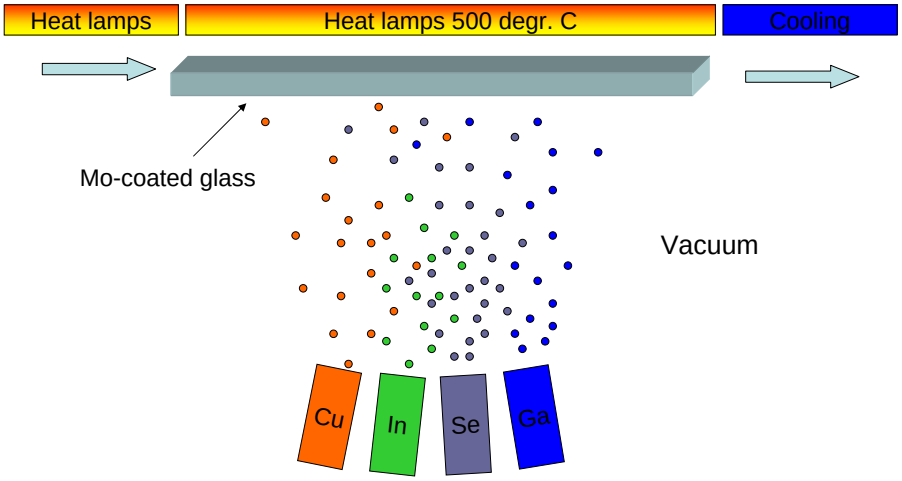


The absorbing semiconductor

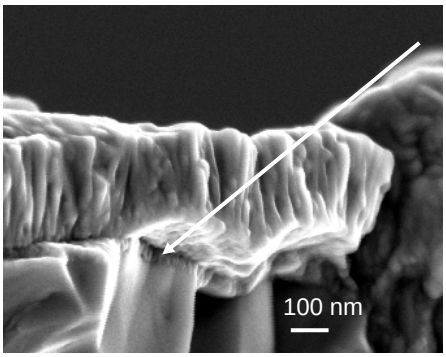
- A thin film of CIGS is deposited on top of the scribed Mo layer



Co-evaporation of CIGS

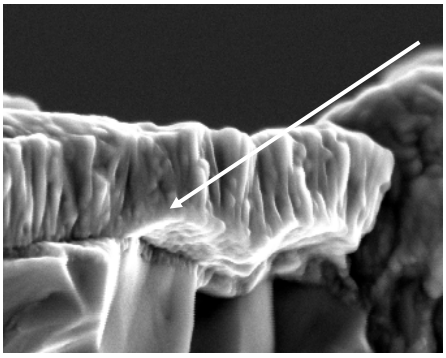


Deposition of buffer layer (CdS)



- Wet chemical process
  - Excellent coverage
  - Good passivation
  - 50 nm thickness

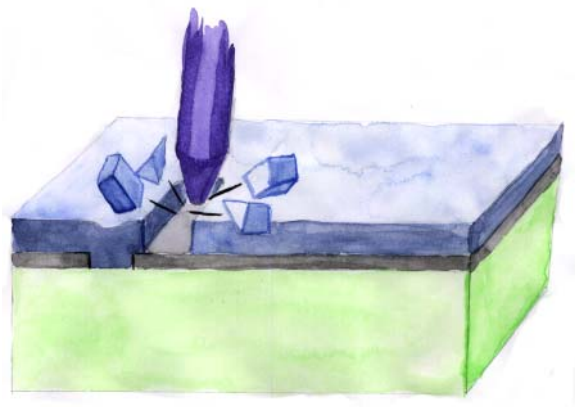
Deposition of non-doped ZnO

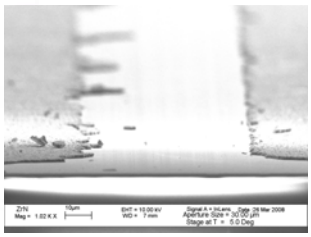


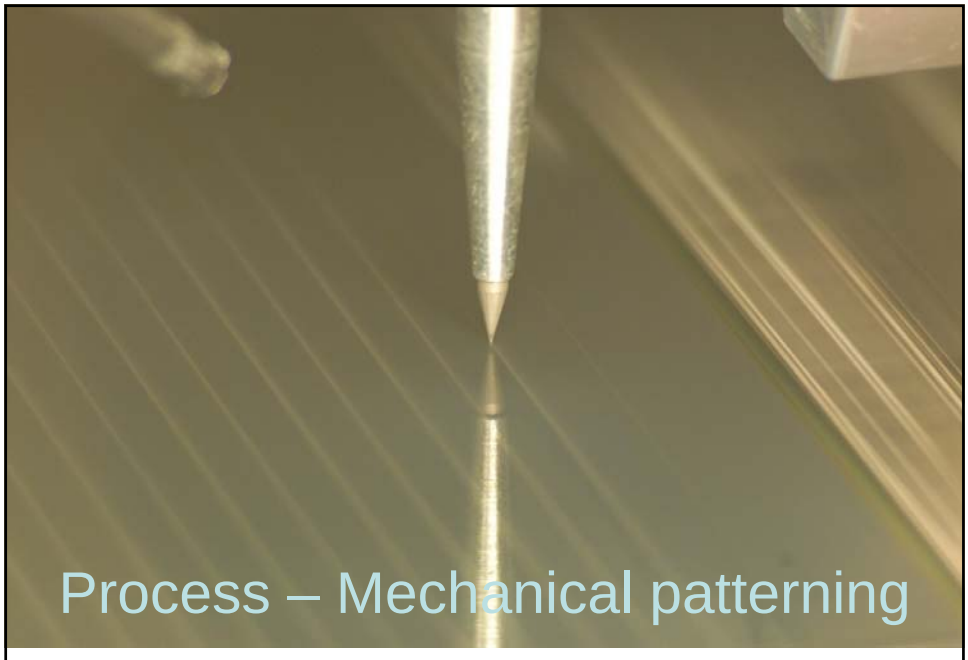
- Rf sputtering

Second patterning step

- A hard metal tip makes contact vias through the CIGS layer down to the Mo

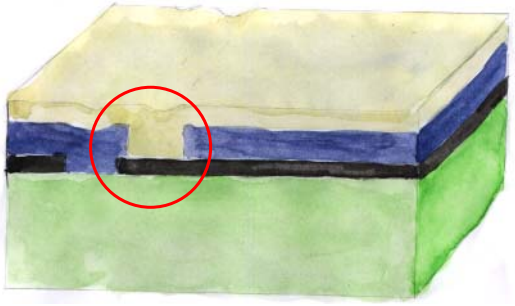






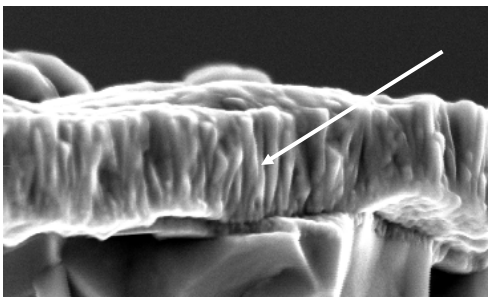
Front contact

- An transparent conducting oxide is deposited, e.g. ZnO doped with Al



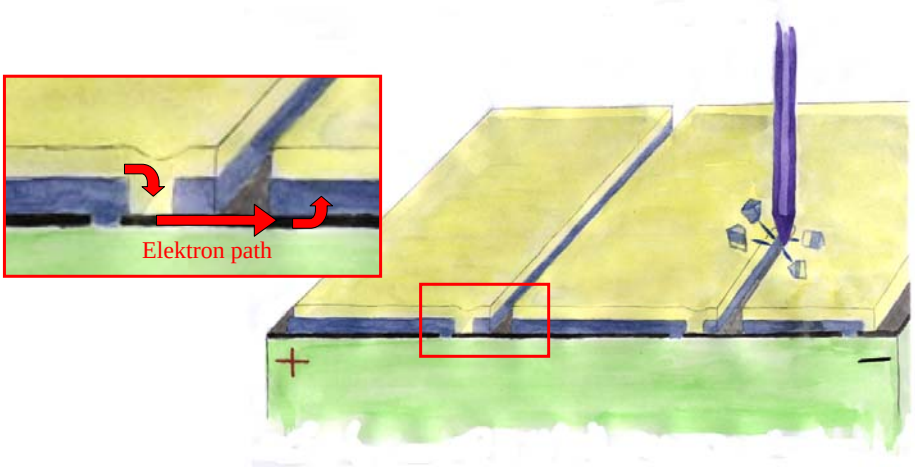
Deposition of doped ZnO

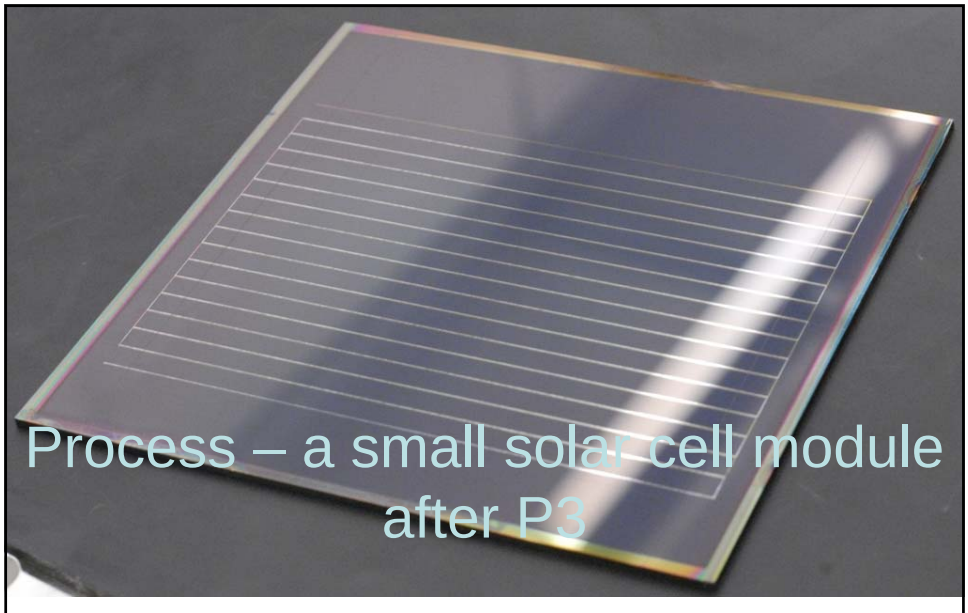
- Pulsed DC magnetron sputtering



Third patterning step

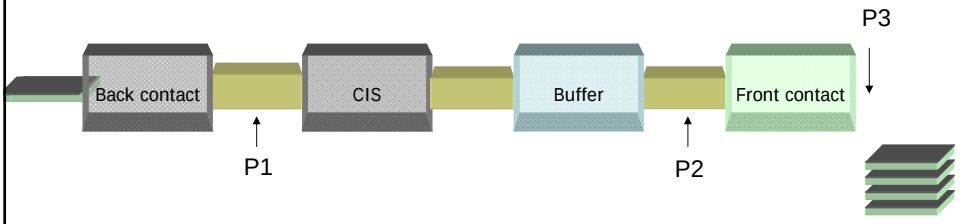
- A hard metal tip is used to define the solar cells from each other





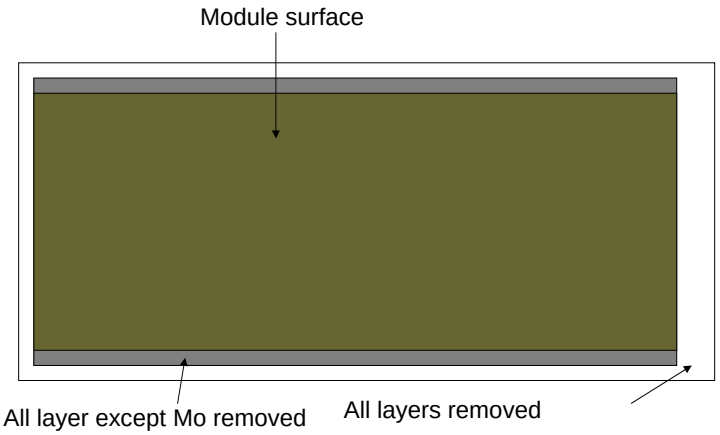
Automized production of solar cell modules

- Module direct
  - 4 Production steps
  - 3 Patterning steps

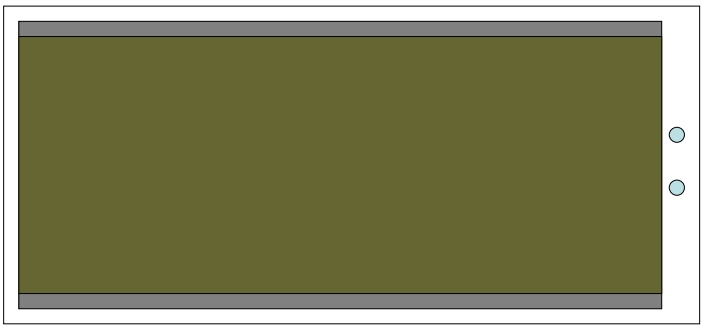


But this is not all!

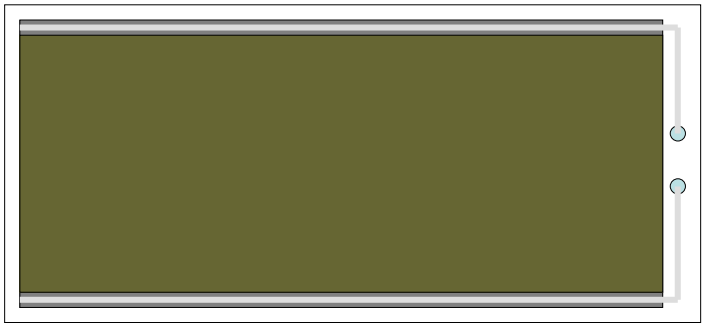
Preparing for contacts



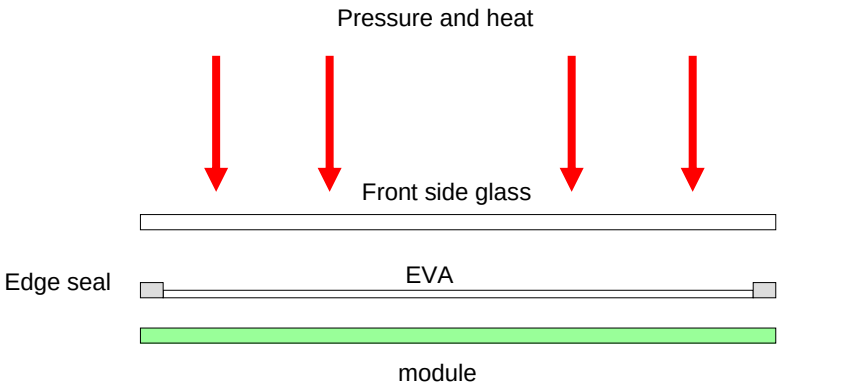
Drilling of holes



Attach tab wires



Lamination

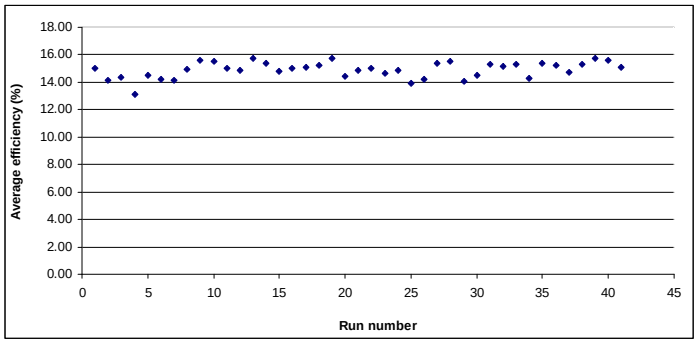


After lamination the junction box is mounted and the module frame

Production yield

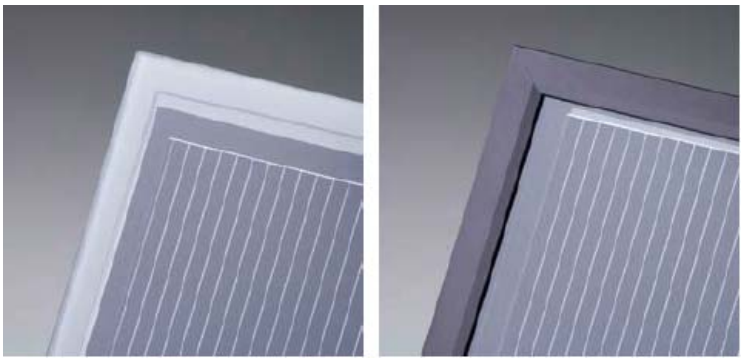
- Many process steps:
  - High yield in each step necessary
  - Large process window for each process
  - Excellent process control

Ex: Process statistics (for lab process)



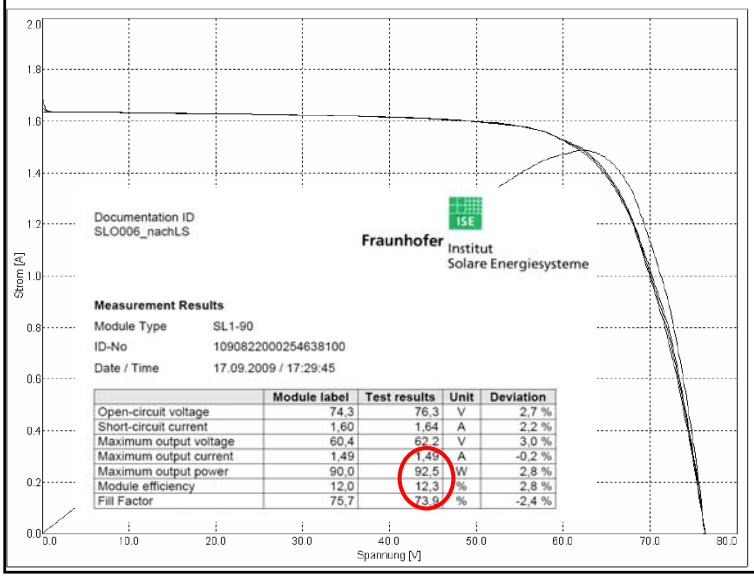
The product

With or without the frame



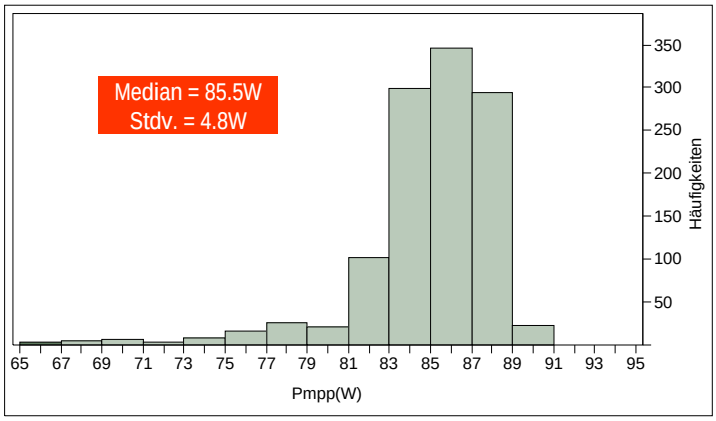
Certified according to IEC 61 646

Best module results



- Total area
  – 0,75 m^2
  – 12,3 % efficiency
- Aperture area
  – 0,684 m^2
  – 13,5 % efficiency
- World record for
- product size
- **Aperture area**
- **0,3459 m^2**
- **13,5 % efficiency**
- (***Green et al, Progr. Photovolt: Res. Appl. 2009; 17, 320***)

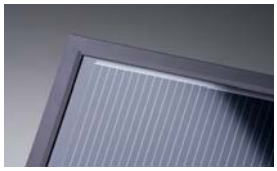
Statistics from production



A CIGS solar cell system (Ultuna)

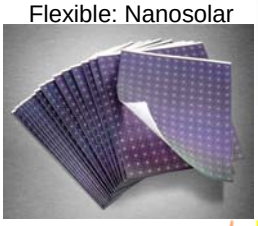
The idea

- There are many ideas out there….
- CIGS ideas:



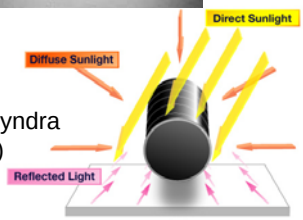
Conventional: Solibro
(on the market)

Flexible: Nanosolar



Final product
(not yet on the
open market)

Cylindrical: Solyndra
(on the market)



The Solibro story

2000

4 researchers
with ideas

16 MSEK

2003

Energy Agency
15 MSEK
+ support to research

Solibro AB

•Research since 1982

•Three years from
founding of company to
starting the activity

The Solibro story

Solibro AB
Stage 1, scale up of CIGS process proven

2005

- First investors
  - They knew results were good
  - They had the money
  - They had industrial competence
  - Not interested
    - ”not in our core business”

negotiations (foreign investors)

23 November 2006

Solibro AB
Uppsala

Q-Cells AG
Thalheim

32,5 % teknik

60 M€ **67,5 %**

Solibro GmbH
Thalheim

18 M€ support

Solibro Research AB
Uppsala

The Solibro story

Ground breaking for first Factory (25-30MW)
August 2007

First module produced
April 2008

First shipment to customer
August 2008

Success factors

- Long experience
- Good collaboration with other labs through a number of European research contracts
- Research program (Ångström Solar Center) dedicated to bring research to industry
- Applicability already in research
- A good choice of material system (luck)

Acknowledgements

- The Swedish Energy Agency
- Research team in Thin Film Solar Cell group, Solid State Electronics, Uppsala University
- Solibro GmbH and Solibro Research AB teams