

Photovoltaïque: potentiel et réalités



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Les énergies renouvelables



**Une opportunité ou une
destruction d'argent ?**

Le renouvelable est-il considéré sérieusement ?



L'énergie solaire est dangereuse !





Le solaire ça ne marche pas ...



Mais quand même....

Modules are sold according to W or Wp (=W peak)

Light intensity 1000 W/m²

Exemple: 1 m² of a 15% at 25° C →
module is rated at 150 Wp

Rule of thumb:

in CH or Germany 1 Wp → 1 kWh per year

Best places 1 Wp → 2-2.5 kWh per year

1 square meter in Neuchâtel will provide
50 to 200 kwh annually

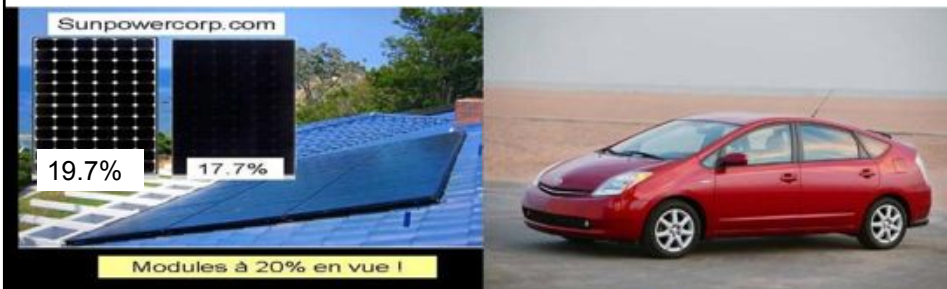


Energy density of PV

With 5% (20%) pannels in central Europe, per year

60 m² (15m²) → electricity needs of a small family (3000 kWh)

20 m² (5m²) → 10'000 km by efficient electrical car (4 L/100 km)



If storage is improved (batteries, fuel cells,...)
→ totally autonomous

Quelques faits

- **Temps de retour en énergie des systèmes PV**

0.75-3 ans (couches minces au Sud ou cristallin au nord)

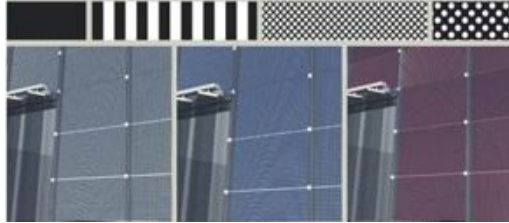
- **Potentiel technique**

50 x plus de rendement que la biomasse: surface suffisantes pour totalité du courant, voir de l'énergie

Micromorph modules



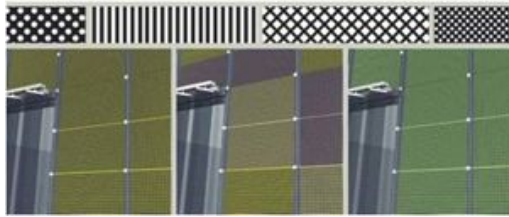
Thin films: all grades of transparencies



The "curtain walls" at Kameyama Plant No. 2 look like windows yet generate electricity while letting light shine through at the same time.



And colors....



Swiss made



Source: Schweizer-Metallbau

Building integration of photovoltaics



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Et pourquoi pas ailleurs...

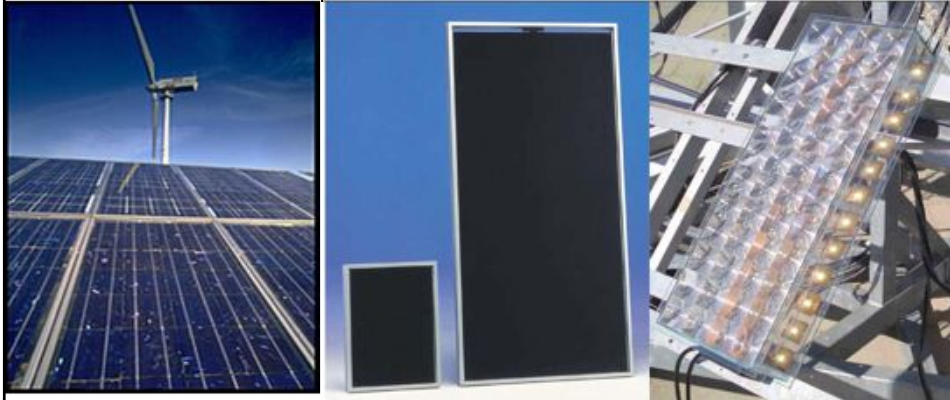


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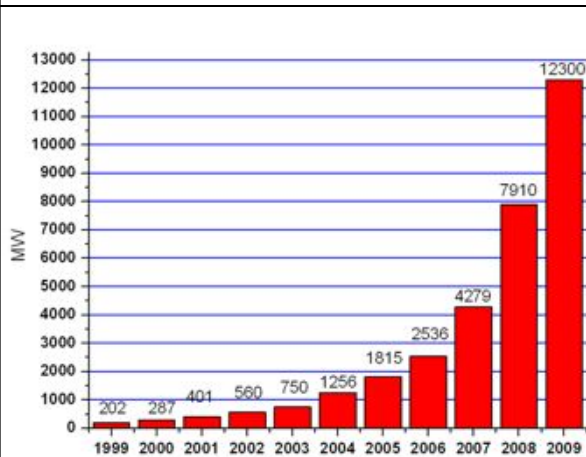
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Photovoltaics: current status



Cristalline Si		Thin film		Concentration	
Multi	Mono	CIGS	a-Si / μ c-Si	CdTe	III-V based
Efficiency	12-19.5%		6-12%		20-28%
Potential	20-25%		12-20%		30-50%

PV markets



Cell and thin film module manufacture

Source
Solar Buzz/Photon Magazine

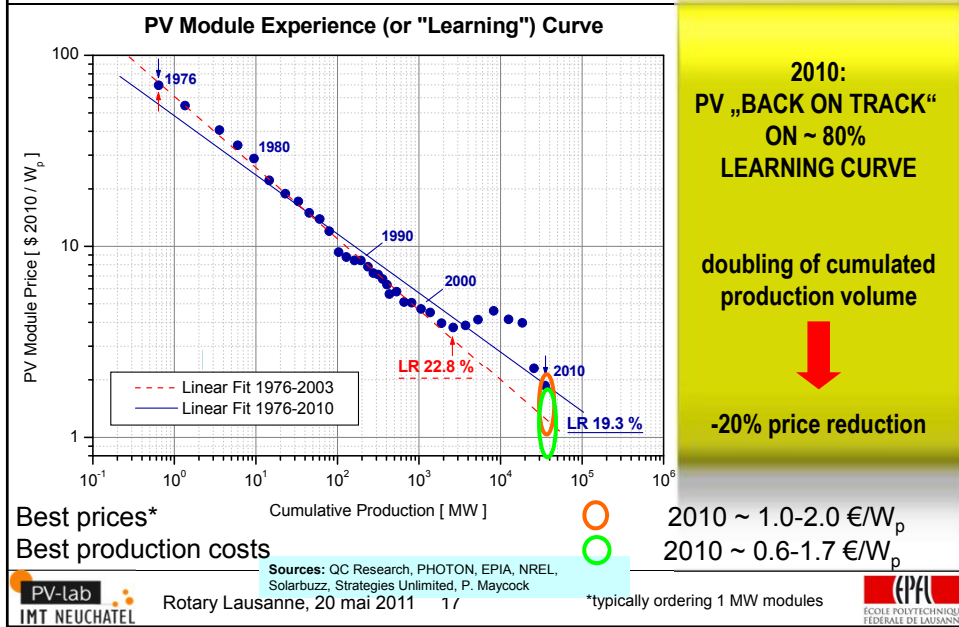
Note: there can be a delay
Between production of cells and
installation of modules !

Strong market
growth >40%
thanks to policy
programs:
Germany, Spain
(07-08)
Japon, Italy, France,
US,...

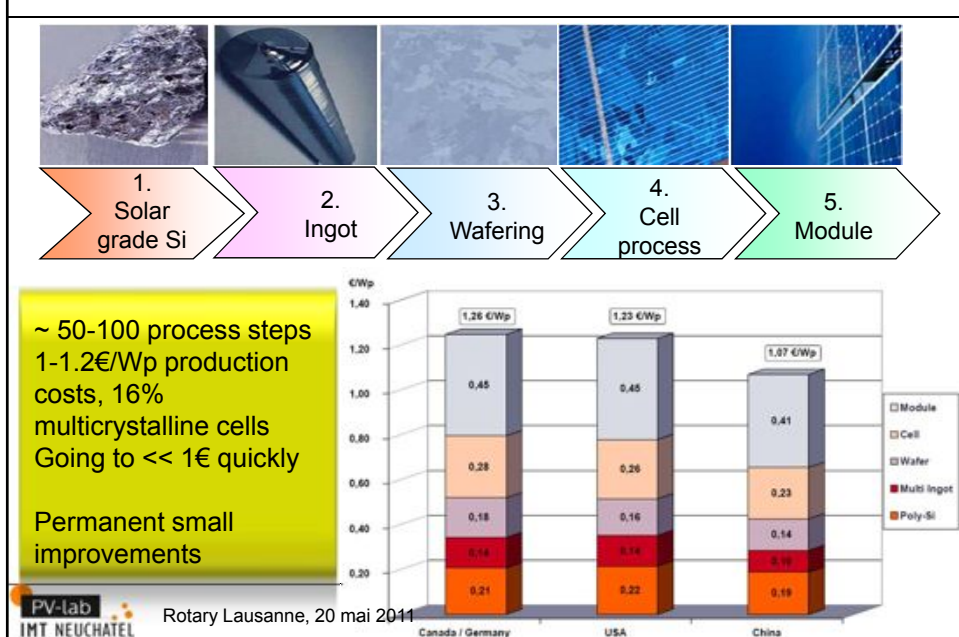
~12 GWp new
modules in 2009 !

~ 20-25 GW in 2010
50% from China

PV module experience or learning curve

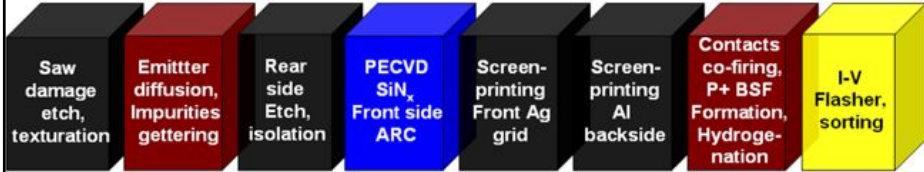


Crystalline Si standard chain: bulk of PV today

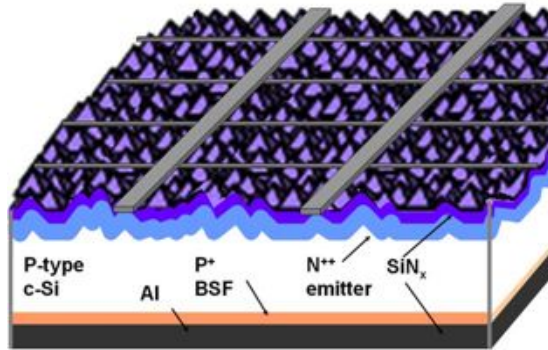


From wafers to solar cells

4.
Cell
process



Standard
« cheap » process



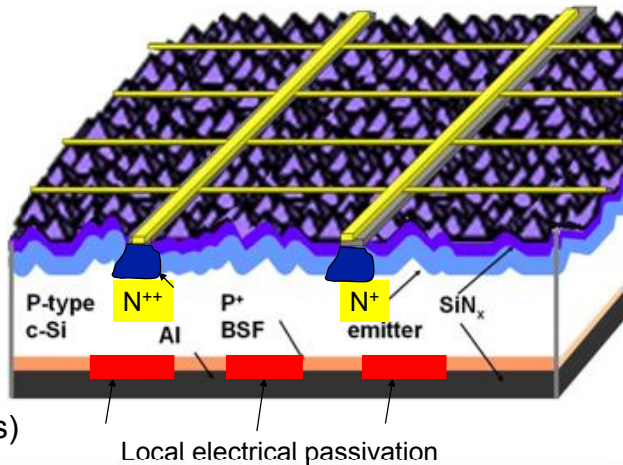
Target: cost effective efficiency increase

4.
Cell
process

selective emitters
From 16 to 16.5%

Backside passivation
From 16.5 to 17%

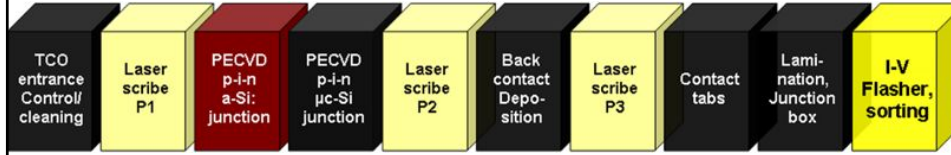
Plating
17. To 17.5%
(multicrystalline cells)



Soon 19% for monocrystalline (17% module)... In pilot phase at companies

Thin film: directly from glass to module

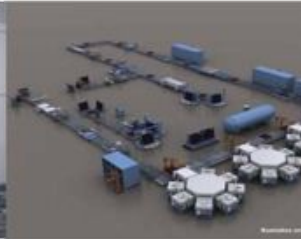
Exemple: thin film silicon « micromorph » process



Fewer (but more challenging) process steps than full c-Si chain



Oerlikon line view



AMAT Sunfab sketch



ULVAC system

Thin film: leader in production costs



First solar (USA)

Thin film CdTe modules

- > 20 years work
- Ramped up to ~ 2GW in 2011
- Continuous improvements:

→ production costs < 0.75 \$/ W_p

1 m² (100W_p) ~ 75 \$
→ 100 to 250 kWh yearly
depending on location



Balance of system costs have to follow a similar reduction

A note on cost/price of solar electricity

Installed systems (large):

Today's best → 1.7-2 €/Wp
(Swiss; 2.7 €/Wp...)

Tomorrow's best → 1 €/Wp ?
(module 0.5 €/Wp, BOS 0.5 €/Wp)

In sunny areas

1€/Wp → 50 kWh in 25 years

➔ 2 €cts/kwh at 0% interest rates

➔ ~ 5 €cts/kwh at 5% interest rates



**Large supply of
clean and low cost
electricity possible !**

Fazit PV

- First time in history:

Micro and macroelectronics contribute directly to energy !

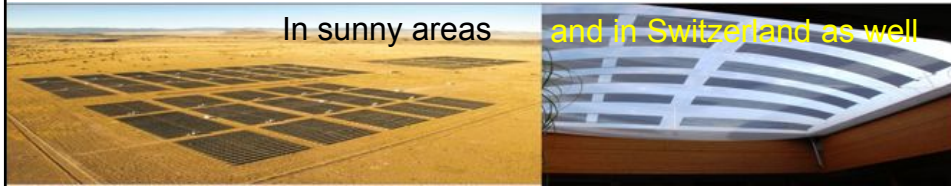


→ results guaranteed:
cost of PV components will not
be an obstacle



For example PV panels will (some are now) cheaper than building
elements
(60€/m² to buy now !)

Potential of PV.....



5-10% PV electricity is a must by 2020-2025 ("easy integration")..
(asset: combination with hydro-pump storage) .
15-20% by 2030 but will start to require serious adaptation

If storage/smart grids/and complementarity with other sources
are developed, PV has the technical potential to become
a major energy source of the 21st century

Example of potential developments

- Storage: from local to global, even with batteries ?

From houses



to GW electrochemical stations



In October 2010, Mexican President Felipe Calderon announced that Rubenius (United Arab Emirates) will install 1GW of sodium sulfur (NaS) batteries at a facility it is developing in Mexicali, Mexico. The USD \$4 billion project will sit on 1.4 square kilometers that Rubenius has purchased near the U.S.-Mexico border....

Strength of Switzerland for PV

- A strong expertise in machines, processes, automation
- A good network of academic and research institutions
- Visionary people and projects

→ good starting technological position

In 2010 over 2 billions CHF PV products export !

- CH attractive for qualified personal
- « seed money » for industry-research collaboration (CTI)

→ Potential for CH to become a « PV Technology Hub »



Photovoltaics and thin film electronics laboratory

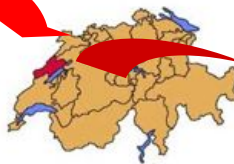


Switzerland

IMT Neuchâtel

Founded by Prof. A. Shah 1984

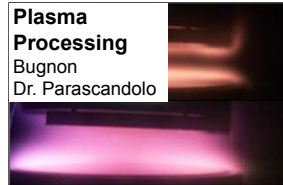
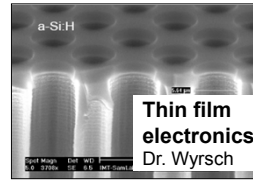
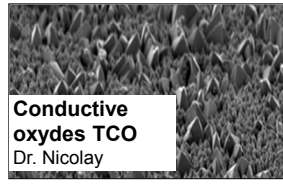
Neuchâtel



EPFL

until 31.12.2008, part of University of Neuchâtel

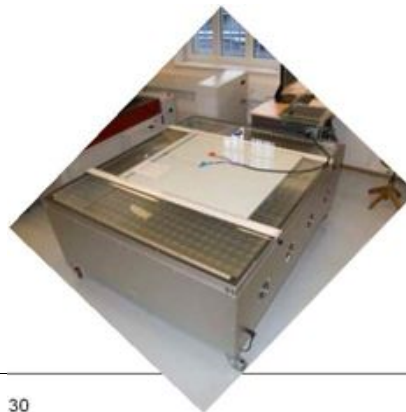
PV-Lab in Neuchâtel : close to 60 people



Equipment « module technology »



- Full equipment for module fabrication flexible, thin film on glass, crystalline
- Extensive testing facilities for reliability and performance



Module technology, product design

Goal:

- Contribute to scientific understanding of packaging (reliability, failures)
- Bring in better – lower cost solution
- Design novel product solutions for build environment taking into account esthaetics, costs, reliability....



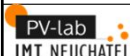
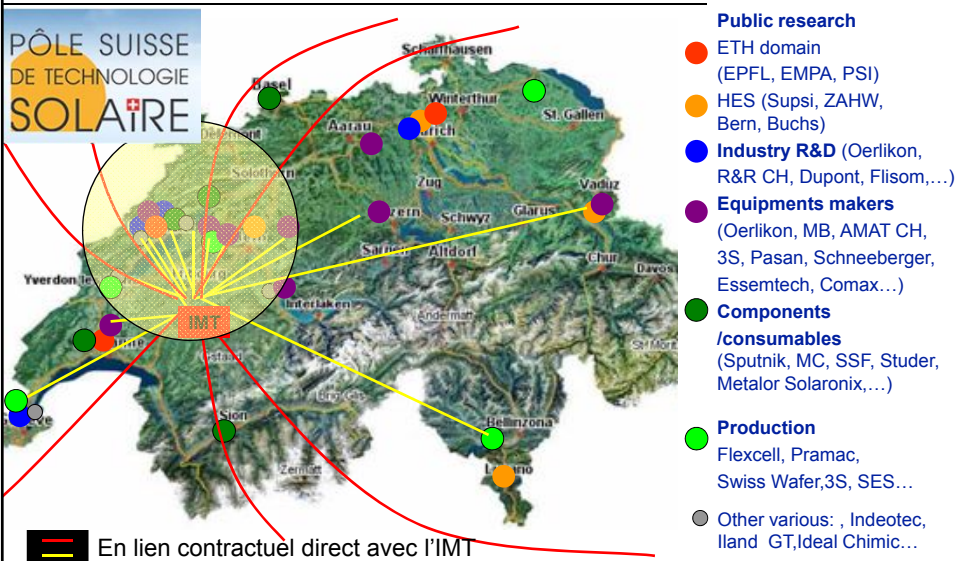
PV-Lab coordinate the Archinsolar project (with EPFL LESO-LTC, EMPA, ETHZ)
(Funding Swiss-electric research, SFOE, SIG)



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PV seen from IMT ...



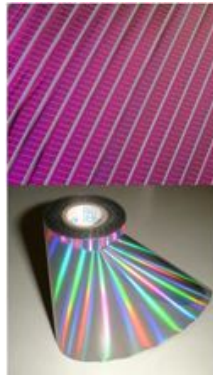
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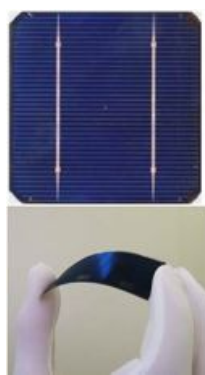
PV-Lab: exemple of valorisation, Neuchâtel



Micromorph cells on glass



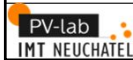
Cells on plastic foils



High efficiency devices



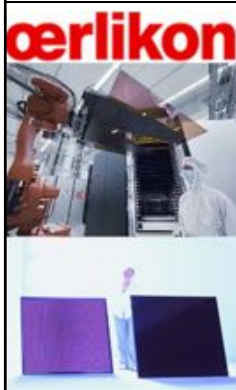
Building of own R&D tools



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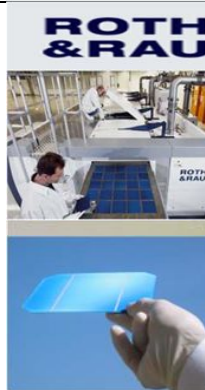
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Production lines for micromorph modules on glass



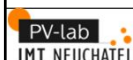
Manufacturing of flexible PV foils



Production tools for high eff. Crystalline -Si cells



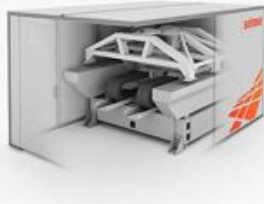
Start-up company for R&D tools



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Some examples of partnership with industry



With Solneva AG
Innovative laser scribing systems



With Essem solar AG
Screen-printing systems



With Pasan
Illumination systems

Some examples of partnership with industry



With 3S Moduletec
Lamination processes



With Bosch DE
Solar cell process

With Dupont CH
Novel
encapsulation
materials



And more with IBM, Solvay, Metalor, Tetrasun, Gadir, Photosolar...


Valencia EU-PVSC 2010
New world record
micromorph at 11.9%
(Paper Oerlikon-PVLab)



Oerlikon Solar announced
0.5 €/Wp possible at 10%

www.oerlikon.com/thinfab



oerlikon  www.oerlikon.com/ecomaXL/index.php?site=SOLAR_EN_press_kit

INTRODUCING THE NEW THINFAB

Oerlikon Solar proudly announces the new ThinFab which reduces the manufacturing cost of the thin film module to a record breaking € 0.50/Wp, with 10 percent stabilized efficiency and 143 Wp module performance. Record that we introduce our new world record breaking cell efficiency of stabilized 11.9 percent on Micromorph[®] technology confirmed by NREL.

**FEATURES & BENEFITS
NEXT GENERATION PV CELL**

- 10% higher productivity throughout entire length of Micromorph[®] to significant reduction of system TCO
- Best in class in facility consumption (up to 30% less gas and electricity usage)
- Integrated Micromorph[®] process for research, technology transfer (with absolute first) using 20 W/m² technology
- Optimized temperature cycles during deposition (see heat & cooling steps)
- Consistent thin processing enabled by the advanced process in the Plasma Clean[®] and the new gate valve between the process chambers

**FEATURES & BENEFITS
NEXT GENERATION TCO**

- 20% higher throughput and 60% lower cost of ownership compared to the previous generation
- Best in class transmittance and light trapping enables a high efficiency thin absorber layer
- In-house front contact TCO enables cost efficient business plan execution
- Standard maintenance cycles allow higher system availability

**FEATURES & BENEFITS
NEXT GENERATION CELL**

- Faster process through 10% less time reduction
- Reduced surface recombination leading to increased silicon area in higher module power
- Improved process stability leading to even higher reproducibility


**FEATURES & BENEFITS
NEW LOW COSTING MODULE**

- Up to a 0.50 Euro/watt saving on electrical BOM per module
- Operating voltage (Vmp) in the region of optimal silicon
- Advanced Perovskite/Si cell appearance across the entire module
- Low-temperature tolerant and uniform up to 20°C power maximum power point (MPP)
- Best in class TCO conversion resistance even in existing transformer less inverters, leading to up to 3% higher energy yield

Lowest Module Production Costs of € 0.50/Wp
Module Efficiency of 10% Stabilized at 143 Wp

THINFAB FEATURING

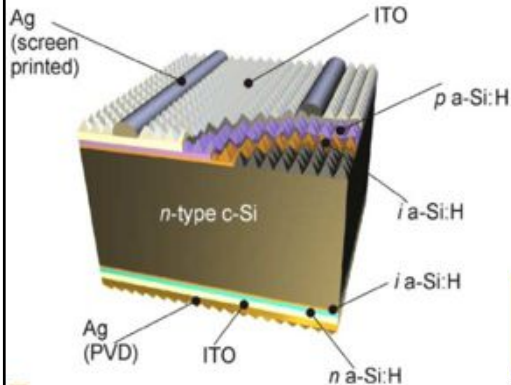
- Lowest Module Production Costs of € 0.50/Wp with Module Efficiency of 10% Stabilized at 143 Wp
- ...and a New Champion Cell with 11.9% Stabilized Efficiency
- Lowest Energy Payback Time compared to c-Si
- Output capacity of 130 MW, approx. 800'000 Modules/year
- Non-toxic and Environmentally friendly Micromorph[®] Technology
- Unlimited Resources for Thin Film Silicon

 Low cost solar electricity with Swiss technology

ThinFab module energy yield: 11.9% @ 143 Wp

Heterojunction crystalline solar cells

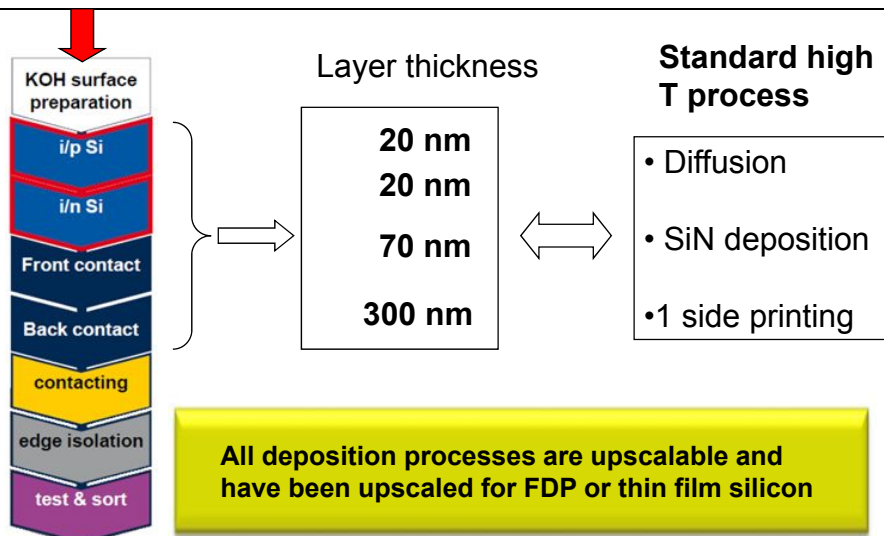
Since 2005 a new activity developed at IMT Neuchâtel



- Excellent passivation with a-Si layer!
- Low temperature processing!
 - compatible with thin wafers
 - low wafer breakage
- Simple structure and simple process !

With an ultra-simple process
Similar to thin film coating

Simplicity of the process



Heterojunction solar cell results at IMT- EPFL



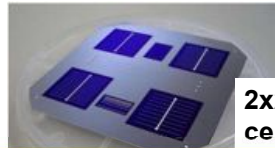
KAI-M, large-area industrial reactor,
40x50 cm² VHF (40.68 MHz)

21 %



OCTOPUS cluster from Indeotec SA
R&D reactor, 13x13 cm² (13 – 100 MHz)

20.4%



**2x2 cm²
cells**

Master > 20% cell with fully industry compatible process

Collaboration EPFL / R&R

EPFL/IMT
(EPFL, Neuchâtel
Switzerland)

RRS
(Subsidiary of
R&R in Neuchâtel)

R&R
(Roth & Rau AG,
Germany)

Basic Research
Group for HJT

Cooperation with
EPFL/IMT in place
since 2008



Transfer to industrial
R&D equipment

R&R research team in
Neuchâtel, starting
operation in Q2/2009

Equipments at IMT
facilities



Transfer to mass
production

Equipment
development team

Pilot Line at mass
production scale in
„Technikum“



EPFL / RRS virtual labtour



WET: Processing as-cut wafers

Specially designed PECVD tool:
R&R Patented S-cube reactor for
uniform a-Si:H layers deposition



EPFL / RRS virtual labtour



**Specially designed PVD R&R
tool:**
inline TCO deposition

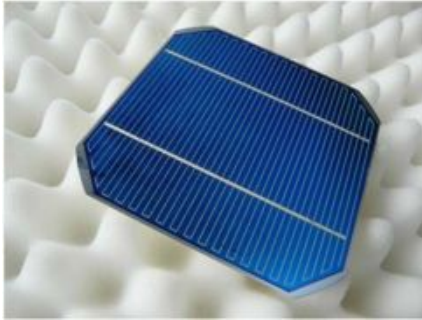
**Screen printer
(EssemSolar)**
Front grid metallization





R&R best cell results

Cz-Si 149 cm²
Eff: 19.4%
V_{oc}: 730 mV
J_{sc}: 34.8 mA/cm²
FF: 76.5 %



Full process upscaling

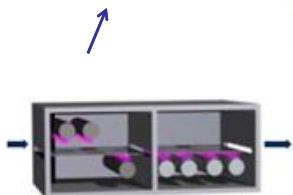
Still room for Jsc improvement for $\eta > 20\%$!

→ low cost 20% technology !



Large area tools at Hohenstein-Ernstthal-Germany

PVD Pilot Production Tool
Full HJT cell ITO / Metal
loop qualification done!



- Excellent target utilization with rotary magnetrons
- Low material cost

Large area tools at Hohenstein-Ernstthal, Germany

**ROTH
&RAU**

PECVD large
area tool



1st good results of in/ip passivated FZ
polished wafer in large area pilot tool !

Opportunities for a high end production line in CH ?

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Conclusion


- Tremendous (sometimes ignored) improvements in the last years
- 10-20% solar electricity in the next two decades possible
- A global and a local opportunity for Switzerland (jobs, export and energy) ...



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Merci pour votre attention !

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- CTI, EU FP6 and FP7, AxpoNaturstromfonds, FNS, Swiss Electric Research, SIG,...

Thanks also to

- **PV-Lab members**
- Oerlikon Solar, Roth and Rau CH, Flexcell, 3S Moduletec, Pasan, Indeotec, Solneva, Metalor, Dupont, Bosch, Gadir, Air Liquid ...