From R&D to Thin Film Silicon PV at Oerlikon Solar

3rd Gen Photovoltaics: CleanTech Day
CSEM Basel / 19th August 2009

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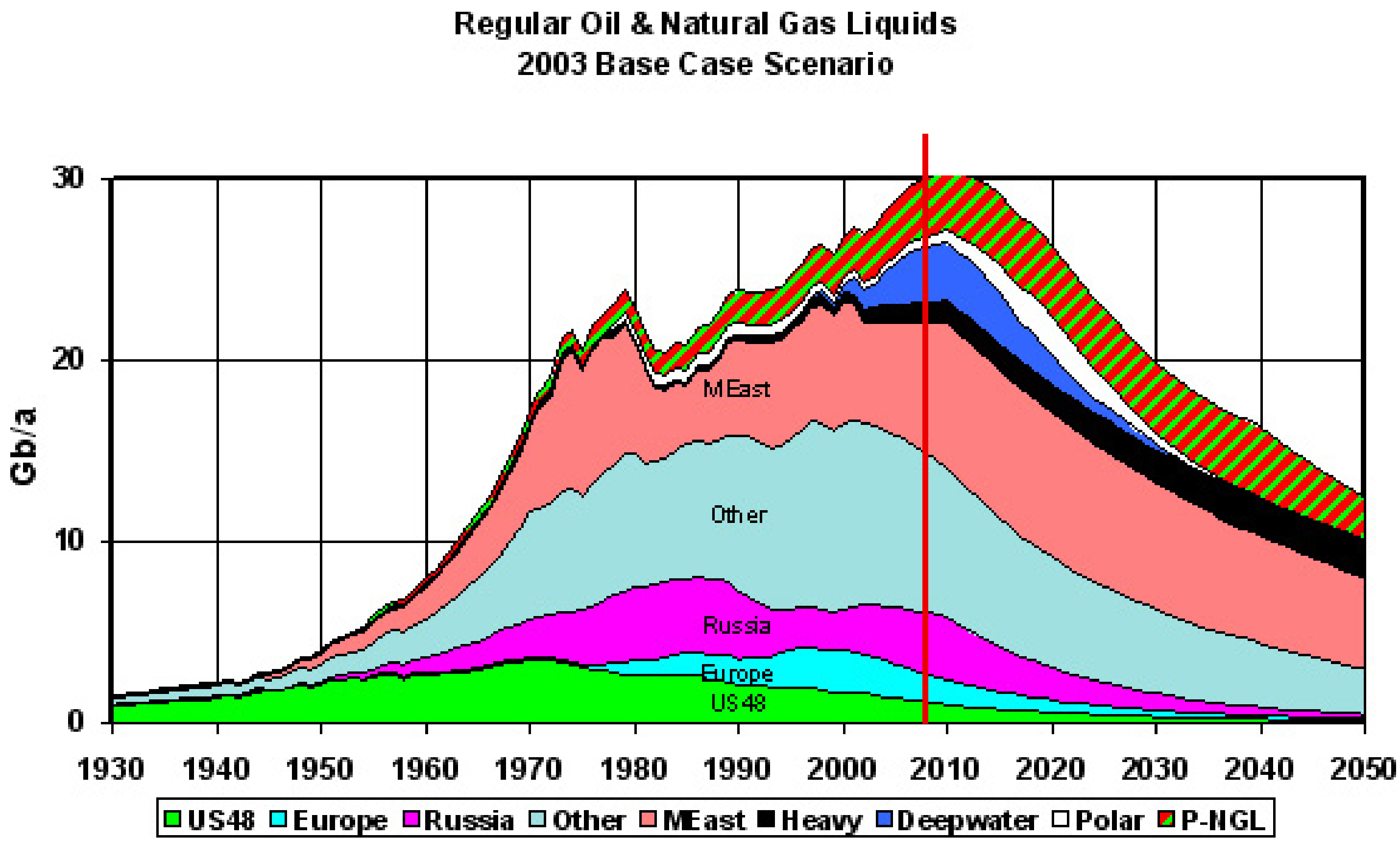
Oerlikon Solar-Lab SA
CH-2000 Neuchâtel

Agenda

1. Why Solar?
2. History IMT - Oerlikon Solar
3. Oerlikon Solar: R&D tasks and results
4. Proven Thin Film Manufacturing Solutions
5. Perspectives & Opportunities

The Need for Renewable Energies



The end of the oil era

Source: Uppsala Hydrocarbon Depletion Study Group

Renewable Energy Options

Sun	120,000.0 TW
Geothermal	12.0 TW
Wind	3.0 TW
Tide and ocean currents	2.0 TW
Hydroelectric	0.5 TW

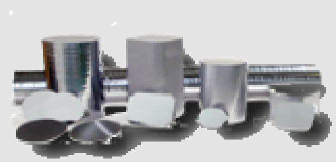
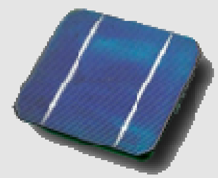
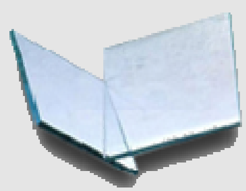
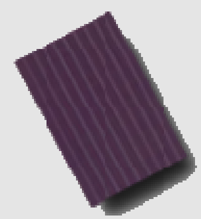
Solar has greatest potential to meet world's growing electricity needs compared to other renewable energy sources





Source: Engineering and Science No. 2 2007

Two cell technologies

Technology	Substrate	Cell	Issues
Crystalline Silicon			Cost Silicon Supply
Thin Films			Large Scale Efficiency

Option:Thin film silicon

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A little bit of history….to achieve to

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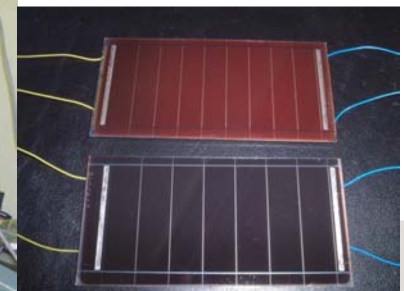
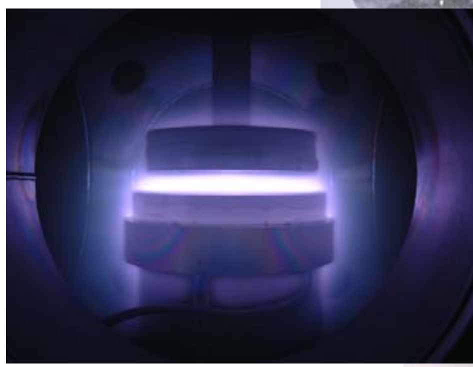
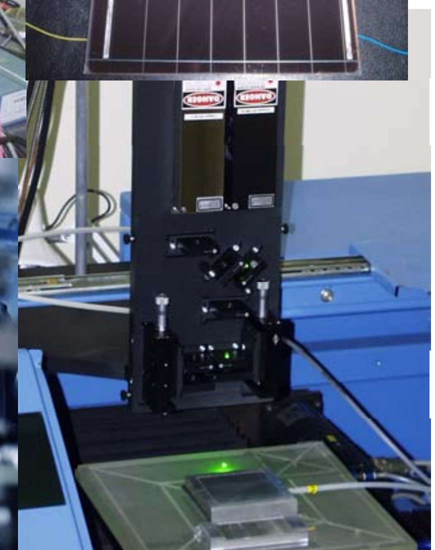
solar

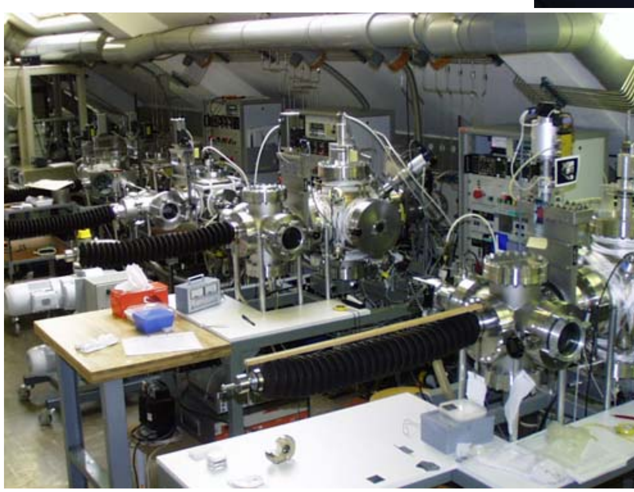
IMT in the early days.....

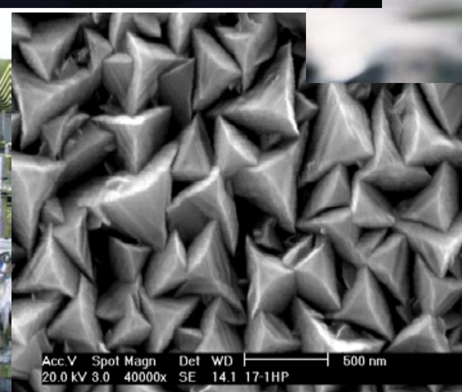
imt
institut de microtechnique
université de neuchâtel

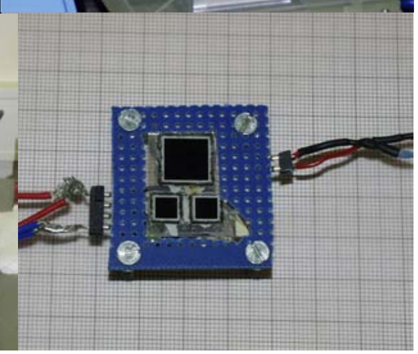










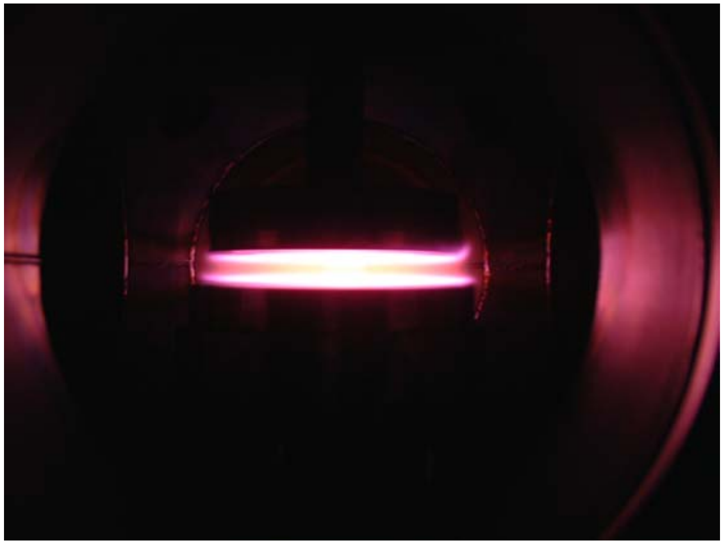


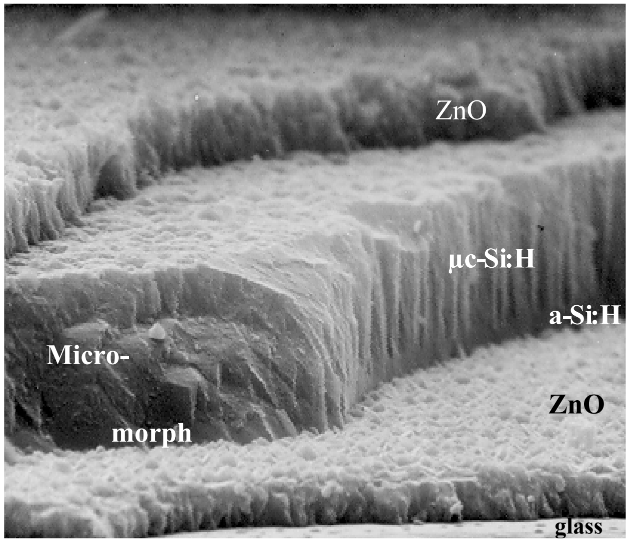
Courtesy of IMT-NE

Roots: Long-term research at IMT Neuchâtel

Very promising concepts (cost reduction & efficiency)

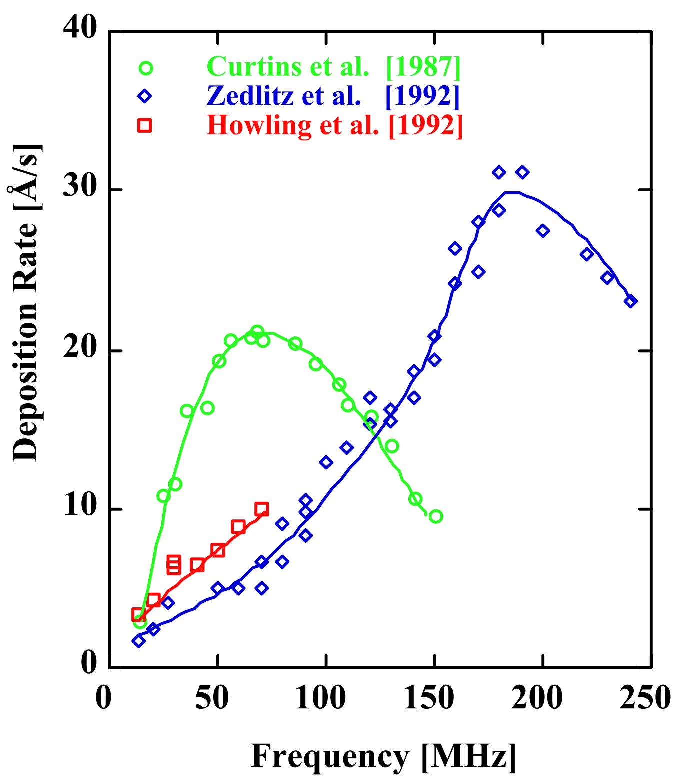
- 1987: Introduction of VHF-GD PECVD deposition
- 1994: Introduction of "Micromorph" concept
- LPCVD ZnO for advanced light-trapping





Courtesy of IMT-NE

Deposition Rates vs. Plasma Excitation Frequency



Curtins et al., Elec. Lett 23 (1987) 228
Zedlitz et al., MRS Symp. Proc. 258 (1992) 147
Howling et a., J. Vac. Sci. Technol. A 10 (1992) 1080

U. Kroll et al., Sol. Ener. Mat. & Sol. Cells 48 (1997) 343.

Deposition rate increase has been reproduced and confirmed by other R&D groups

- **no electrical artefact**
- **hence, real plasma effect**
- **position of rate maximum due to electrical losses in system**

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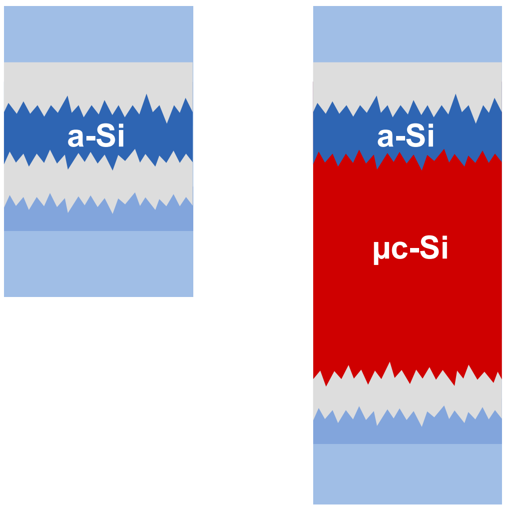
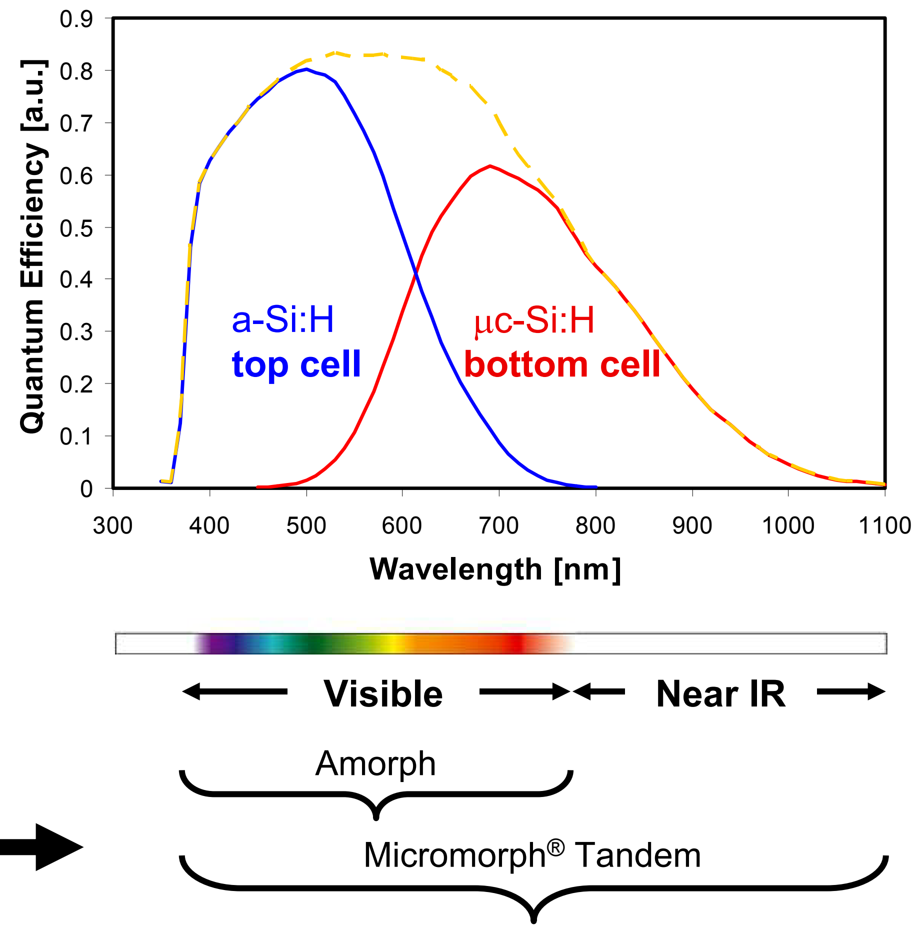
Micromorph® Process Technology



Amorph
Single
Junction

Micromorph®
Tandem
Junction



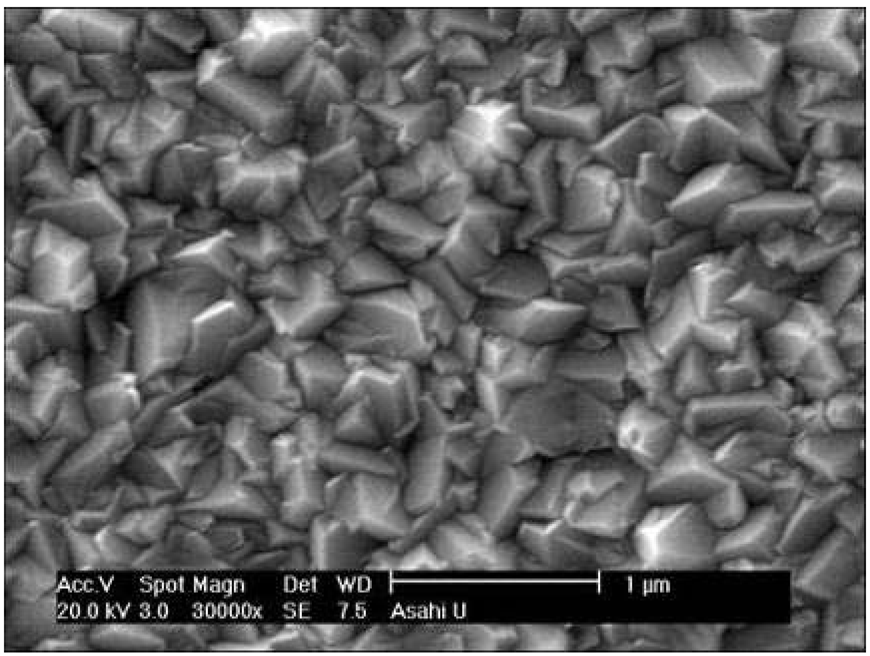
More Energy Absorbed

Kroll / 3rd Gen Photovoltaics: CleanTech Day; 19th August 2009

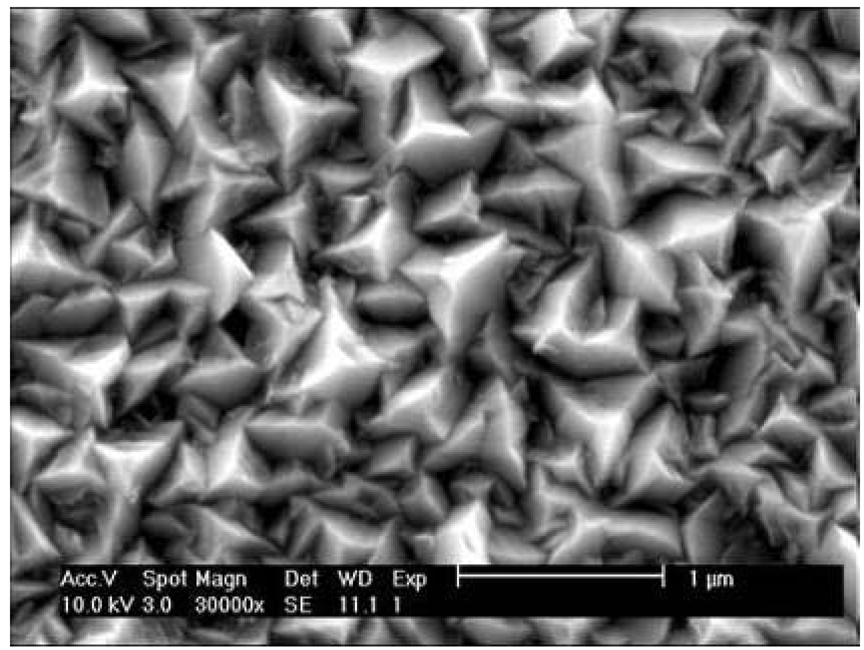
Light-trapping – fundamental for thin film Si solar cells:

Key issue TCO: **approach by LPCVD ZnO**

Asahi U



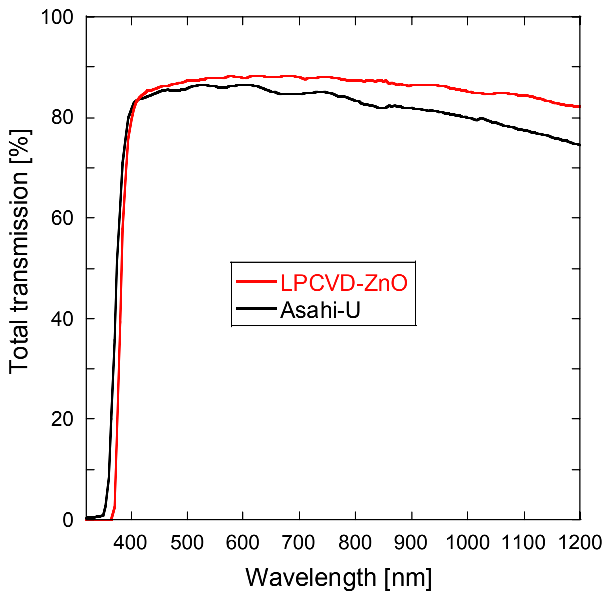
LPCVD ZnO

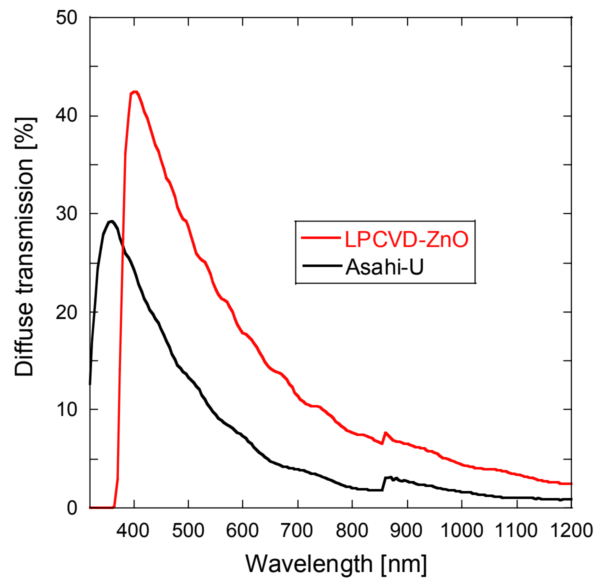


Optical properties:

Enhanced total & diffuse Transmission (Haze)

→ Better quantum efficiency (for a-Si) on ZnO compared to Asahi SnO_2



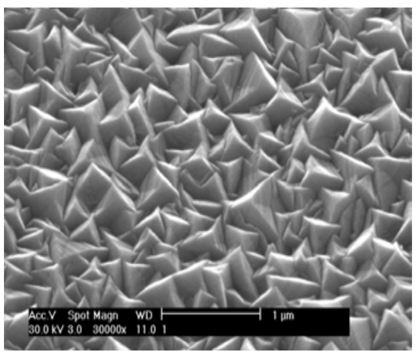


Highest stabilized efficiency for a-Si:H p-i-n on LPCVD ZnO (confirmed)

IMT Neuchâtel 2003:

η **= 9.47 %** stabilized (with ARC)

single-junction a-Si:H p-i-n with "modified" LPCVD ZnO process



(J. Meier et al., WCPEC-3, Osaka 2003)

Our Motivation !

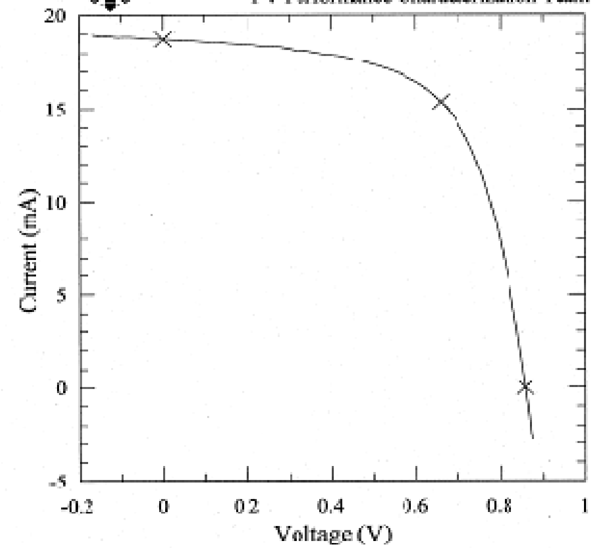
University of Neuchatel (Switzerland)

a-Si Cell

Device ID: C170103
Apr 21, 2003 15:12
Reporting Spectrum: AM1.5 Global

Device Temperature: 25.0 ± 1.0 °C
Device Area: 1.070 cm^2
Irradiance: 1000.0 W/m^2

NREL X25 IV System
PV Performance Characterization Team



V_{oc} = 0.8585 V
I_{sc} = 18.739 mA
J_{sc} = 17.519 mA/cm^2
Fill Factor = 62.96 %

I_{max} = 15.365 mA
V_{max} = 0.6592 V
P_{max} = 10.128 mW
Efficiency = 9.47 %

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In 2003:

Bottle-necks: up-scaling to 1 m^2

- availability of production system
- high investment cost and high risk

Thin film silicon PV technology developed at IMT

search for industrialisation partner

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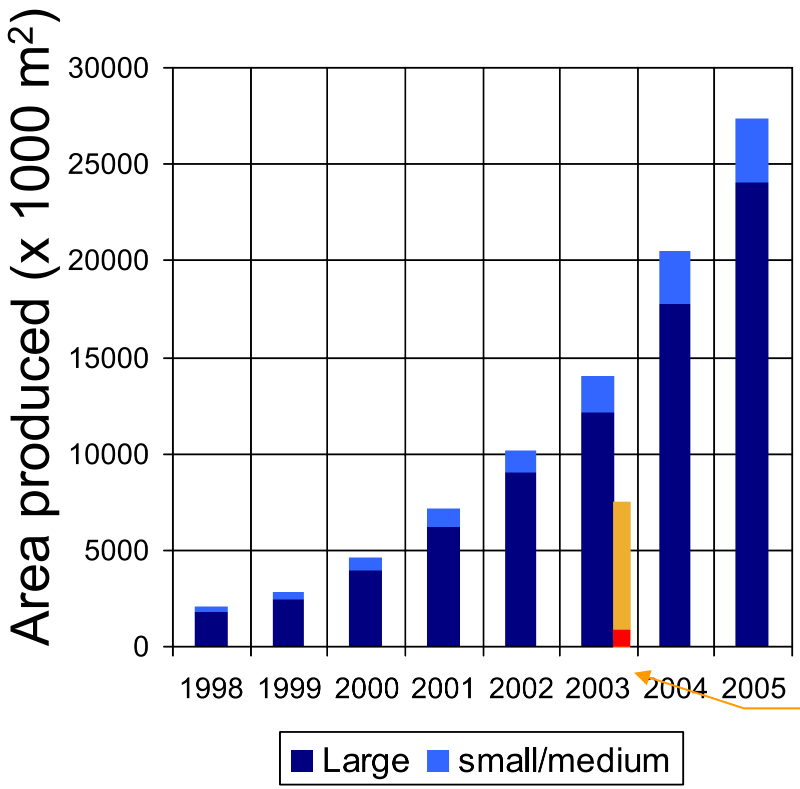
Find Synergies for large-area deposition

In 2003: AM-LCDs: Strong growth



Source :Nikkei Microdevices FPD 2002 yearbook
and Display search 2003 feb

Solar cells:
c-Si: ~7 km^2
Thin film:~0.6km^2

From 22 bn$ to 48 bn$ in 2005
Monitor and TV will be the main driver

Mio Units	2000	2005
Mobile	380	460
Laptops	24	47
Monitors	6	90
TVs	0.2	7

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2003

Oerlikon founds own R&D lab and enters thin film silicon PV

Why Neuchâtel?
Close to IMT and CRPP/EPFL (strategic partners)

Goal: Process Transfer from Lab to Production

Oerlikon Solar-Lab, Puits-Godet 12a, Neuchâtel:

- complete R&D Lab (clean/grey room)
  - LPCVD system for ZnO deposition
  - PECVD system for silicon deposition
  - Laser scribing system
  - Cell characterisation
  - cleaning, glass cutting, gas delivery systems etc.

Today Oerlikon Solar-Lab SA have 21 employees working in a Lab of about 550 sqm surface

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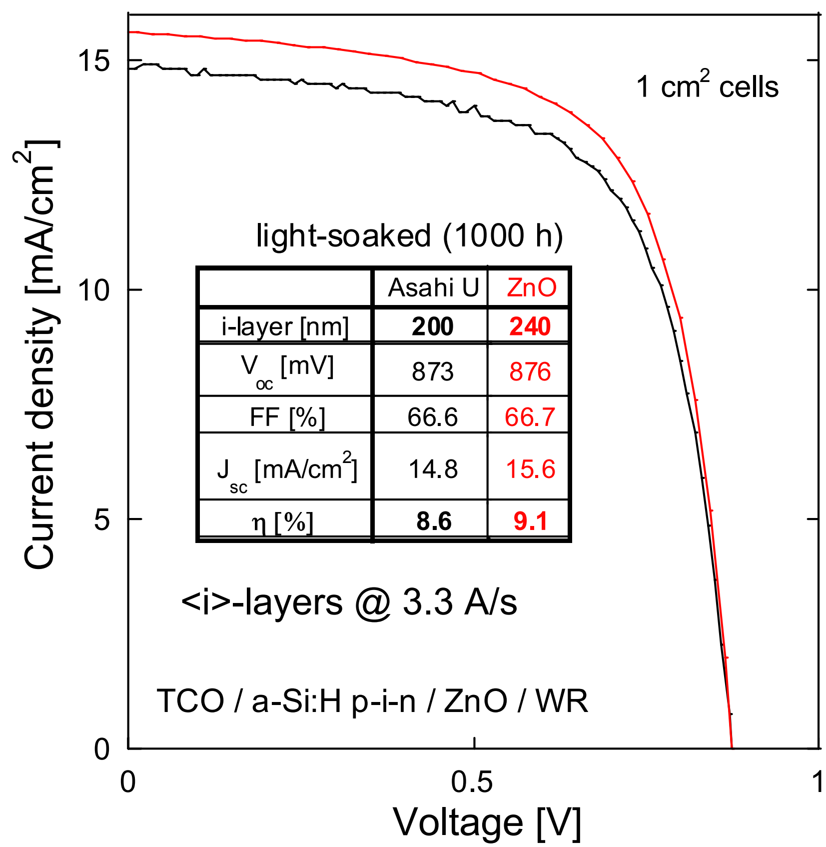
Optimization of devices & deposition processes

a-Si:H p-i-n test cells

9.1 % stabilized
a-Si:H p-i-n on ZnO

Update at 24th EU PVSEC
Hamburg, September 2009 !



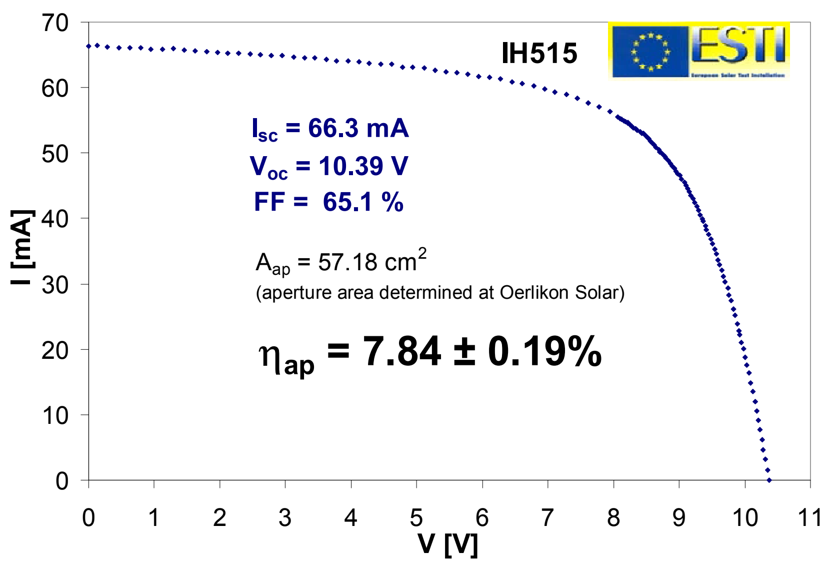
	Asahi U	ZnO
i-layer [nm]	**200**	**240**
V_{oc} [mV]	873	876
FF [%]	66.6	66.7
J_{sc} [mA/cm^2]	14.8	15.6
η [%]	**8.6**	**9.1**

S. Benagli et al., 23rd EUPVSEC Valencia (2008)

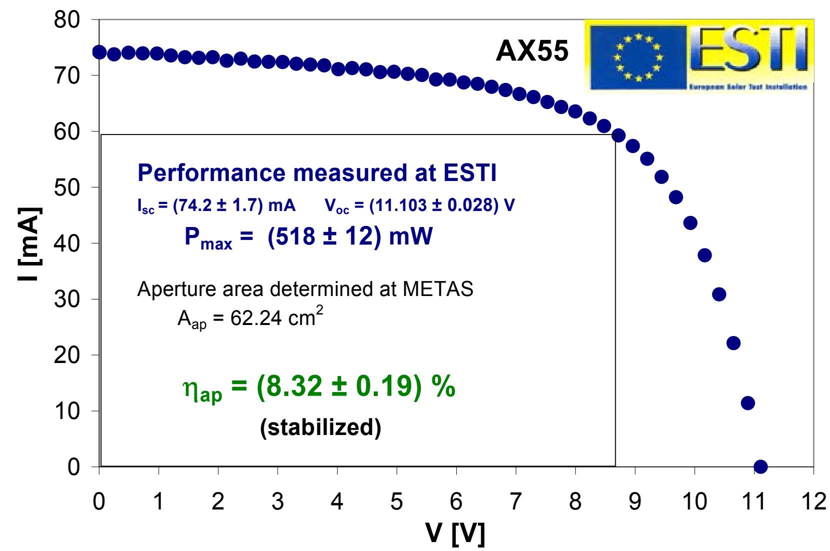
Up-scaling to 10x10 cm^2 mini-modules in KAI-M

Characterisation by ESTI of JRC in Ispra

Asahi



LPCVD ZnO



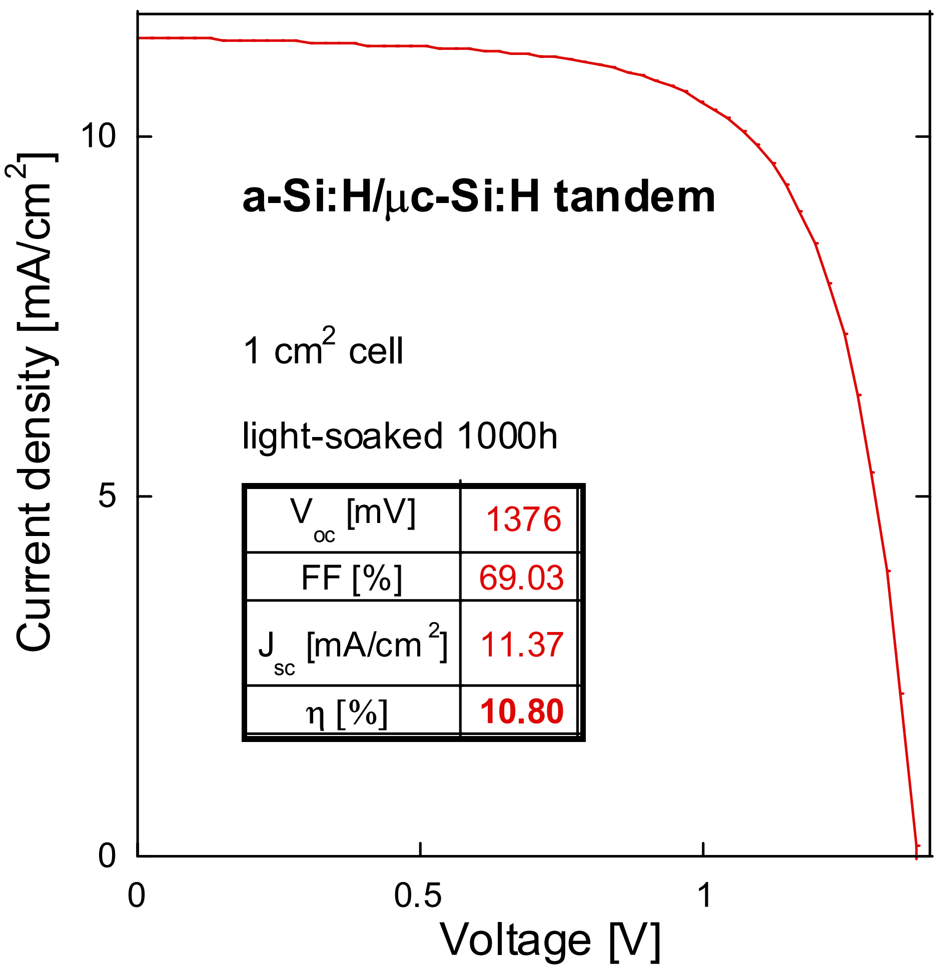
0.5 % abs. enhanced stabilized efficiency compared to Asahi SnO_2
~1 % abs. compared to commercial TCO

Best lab Micromorph tandem cell (light-soaked)

SnO_2 Asahi glass substrate

Best cell

10.8 % stable efficiency

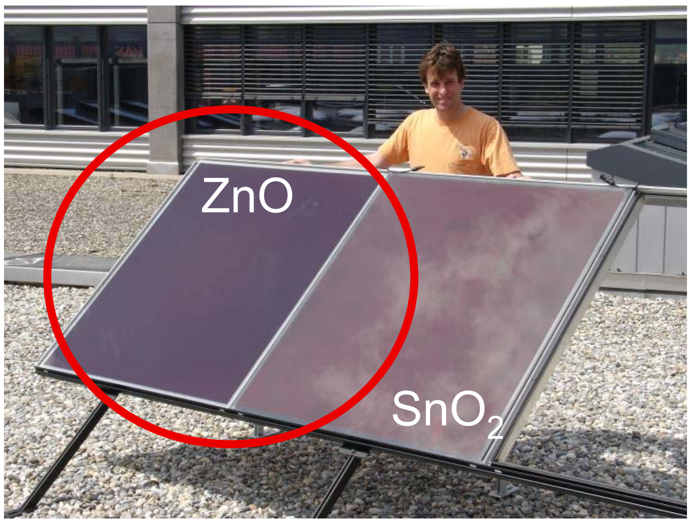


V_{oc} [mV]	1376
FF [%]	69.03
J_{sc} [mA/cm^2]	11.37
η [%]	**10.80**

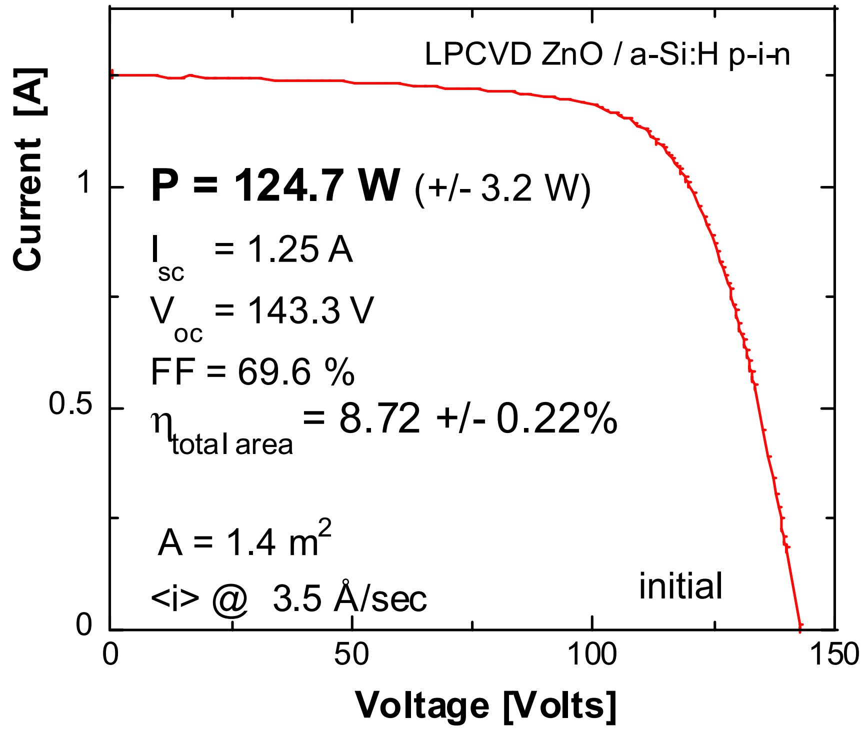
Scaling up in R&D Pilot line / Trübbach

a-Si:H p-i-n single-junction R&D module on ZnO: **124.7 W** (ini.)

Confirmed by ESTI of JRC Ispra



Industrial size 1.1x1.3 m^2 module on front LPCVD ZnO



>100 W stabilized expected

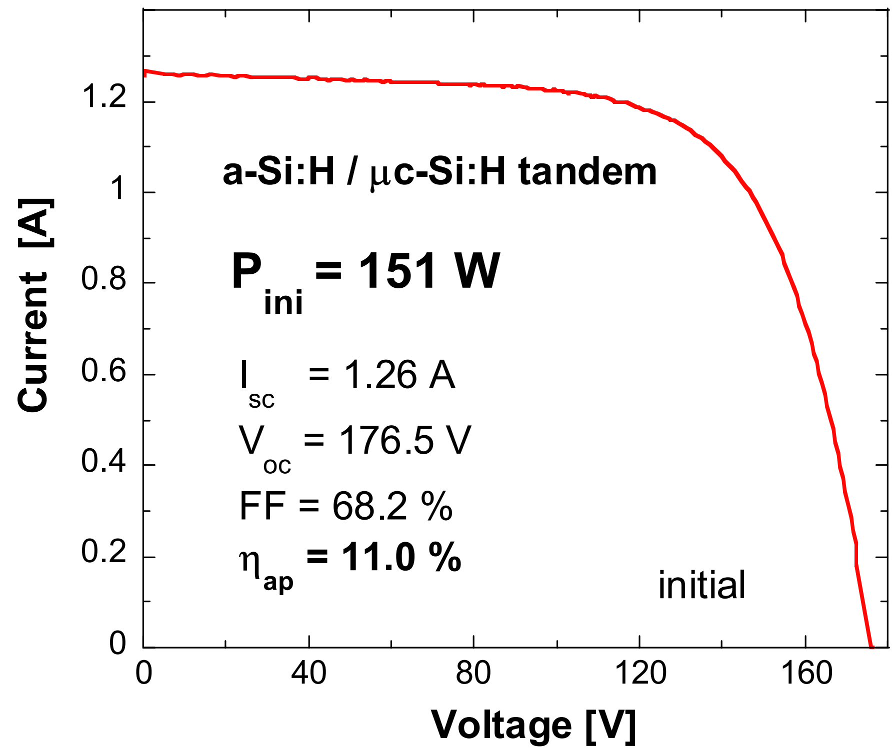
→ Still room for further improvements!

Micromorph Module 1.4 m^2

R&D Pilot line in Trübbach:

151 W initial 1.4 m^2 module !

Industrial size 1.1x1.3 m^2 module
on in-house front LPCVD ZnO



→ Still room for further improvements!

CTI Projects of Oerlikon Solar from start until now

- **CRPP/EPFL: CTI 9675.2 running**

  A new low ion energy bombardment PECVD reactor for the deposition of thin film silicon for solar cell applications

- **IMT CTI 8968.3 running**

  Development of a novel surface treatment of LP-CVD ZnO layers used as Transparent Conductive Oxide for thin film silicon solar cells.

- **CRPP/EPFL: CTI 6947.1 EBS-IW finished**

  A new large area very high frequency reactor for the high rate deposition of microcrystalline silicon for thin film solar cell applications

- **IMT: Eureka 7253.2 EPRP-IW finished**

  Stability of advanced LP-CVD ZnO within encapsulated thin film silicon solar cells

- **IMT: CTI 6928.1 IWS-IW finished**

  High rate deposition of microcrystalline silicon layers and cells

- **NTB (Neues Technikum Buchs): KTI Nr. 7112.2 EPRP-IW finished**

  Development of QE measuring system

Oerlikon Solar
Segment Overview

Solar key member of the group with global footprint

800 employees worldwide
- 280 global support
- 300 scientists and engineers

20 locations in 11 countries

Over CHF 23m R&D investment in 2007

Over 350 living patents

Over 900 000 modules produced by customers of Oerlikon Solar

Oerlikon Solar

Equipment manufacturer for cost-effective production solutions for thin film silicon solar modules

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Oerlikon provides end-to-end (E2E) production solutions…

Oerlikon Solar | Partner | Metrology

Front-End

Clean → TCO FC → Laser → Clean → PECVD → Laser → TCO BC → Laser → Voc

Line Automation

Back-End

Contacted Tested Device

- Contact
- White Reflector
- Edge Isolation
- Flasher

Encapsulation-Lamination

- Cross Contact
- Lami-nation
- Junction Box
- Flasher

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Oerlikon Solar Manufacturing Systems

TCO 1200

Transparent conductive oxide deposition

KAI 1200

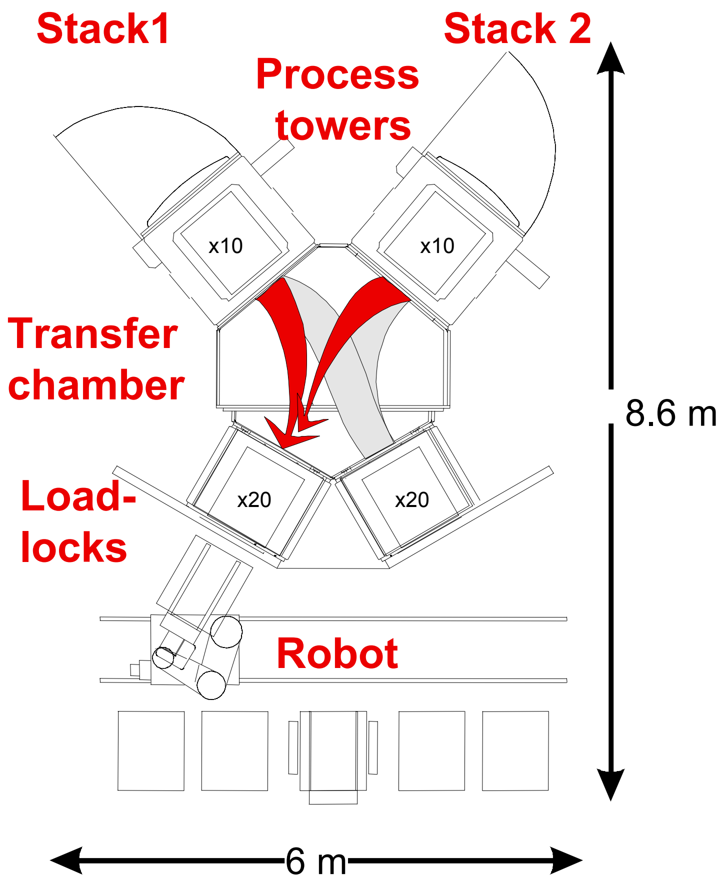
Photovoltaic layer deposition

LSS 1200

Laser scribing

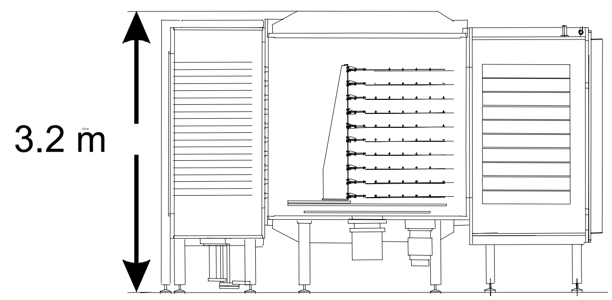
Clean → **TCO** → **Laser** → **PECVD** → **Laser** → **TCO** → **Laser** → **Assembly**

KAI System Concept - Parallel Processing of 20 reactors



KAI 20-1200

- Excitation frequency 40.68 MHz
  to significantly enhance deposition rate



2 process towers with 10 reactors in each stack
2 load-locks
1 transfer chamber
External robot for glass loading from cassette

Highest productivity on small footprint: 20 MW_p / y for a-Si:H

KAI 1200 - Proven Product for PV Layers

KAI 1200 with Plasma Box® reactor

- 40.68 MHz for higher rate & quality
- a-Si:H & μc-Si:H p-i-n layers
- Single-chamber process
- Auto-clean after every run

Result

- High film quality
- High throughput
- High system flexibility & utilization
- Small footprint

Clean → TCO → Laser → **PECVD** a-Si/μc-Si → Laser → TCO → Laser → Assembly

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Front and back view photo of KAI 20-1200

TCO 1200 - Higher Efficiency and Lower COO

Proprietary LPCVD technology

- High conductivity
- Transparent conductor deposition and texturing in a single step

Integral to Micromorph process

- High transmission in visible and near IR light spectrums

Clean ▶ TCO ▶ Laser ▶ PECVD a-Si/μc-Si ▶ Laser ▶ TCO ▶ Laser ▶ Assembly

Project update

Customer	Technology	Type	Contract Signed	Move-In On-Time	SOP On-Time	MW
Bosch/Ersol	Amorphous	Equipment	✓	✓	✓	40
Schüco	Amorphous	Equipment	✓	✓	✓	R&D
Schott	Amorphous	Equipment	✓	✓	✓	40
CSG	Amorphous	Equipment	✓	✓	✓	20
Sun Well	Amorphous	End-to-End	✓	✓	✓	50
Inventux	Micromorph®	Equipment	✓	✓	✓	30
HelioSphera	Micromorph®	End-to-End	✓	✓		30
Tianwei	Amorphous	End-to-End	✓	✓		46
Auria Solar	Micromorph®	End-to-End	✓	✓		60
Pramac	Micromorph®	End-to-End	✓	✓		30
Sun Well (2)	Micromorph®	End-to-End	✓			60
Sun Well (3)	Micromorph®	End-to-End	✓			120
Gadir	Amorphous	End-to-End	✓			40
Chint	Micromorph®	Equipment	✓			40

Total more than 600 MW

1st Micromorph line in Berlin

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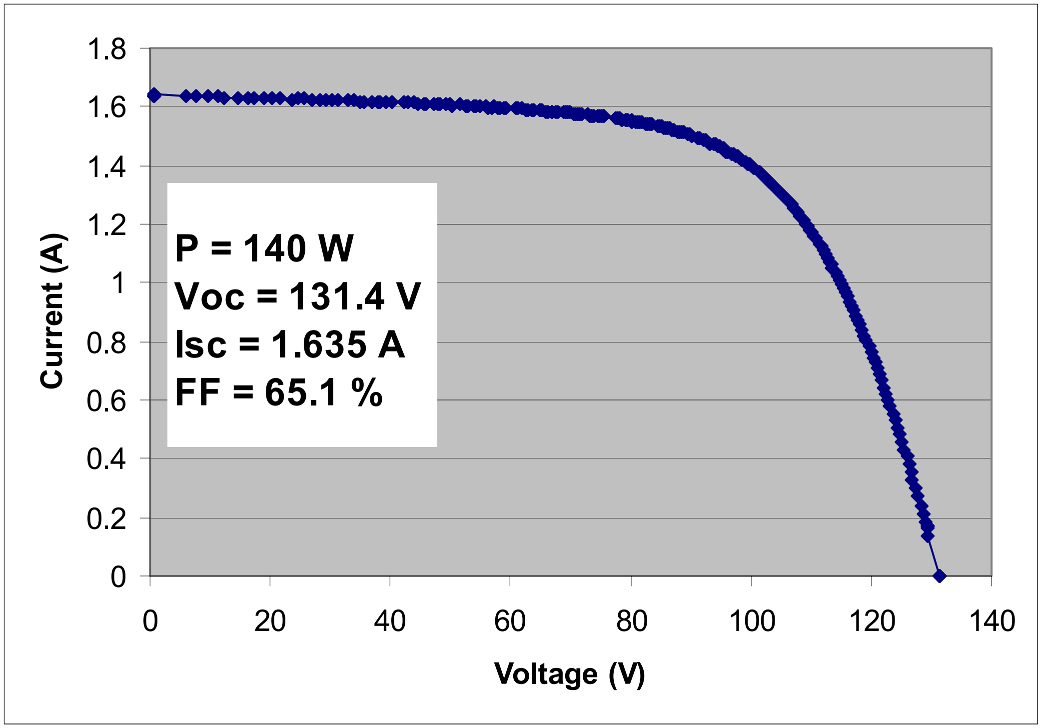
inventux® SOLAR TECHNOLOGIES

Mass production line at Inventux – best Micromorph modules

140 W initial module power (April'09)



Operational silicon thin film fields

3.4 MWp a-Si installation (Zahna, Germany)
- 39,000 thin film modules & 747 trackers
- Start of operation: 19 February 2009
- System integrator: AC Energy GmbH & Co. KG

1.3 MWp a-Si installation (Zahna, Germany)

Perspectives & Opportunities

Nice example from basic research to mass production

Success recipe:
- Partners with commitments
- Long-term support for basic research (OFEN, CTI)
- Well-trained experts & specialists

Oerlikon Solar:
- Proven solutions for high volume solar module production with more then 900'000 produced panels
- Oerlikon Solar is well-placed for the challenges of the coming PV century

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Thank you for your attention.