History & Mission

IMEC 1984 - 2007

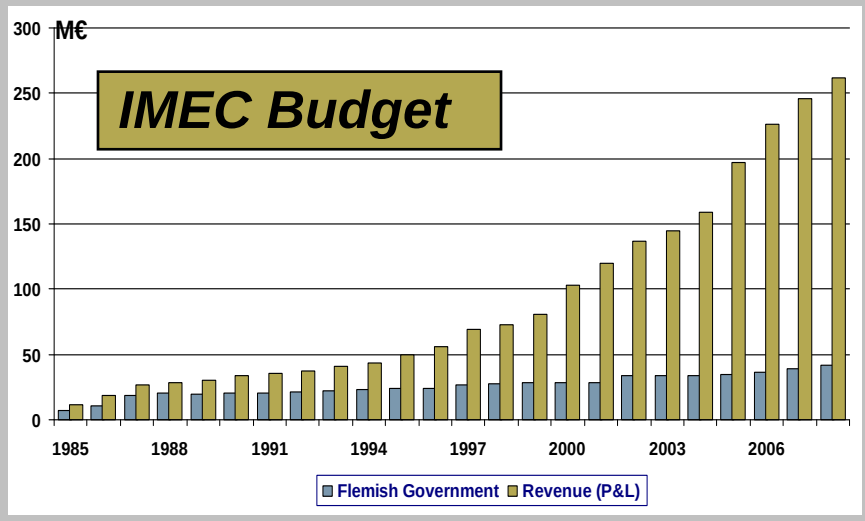
1984

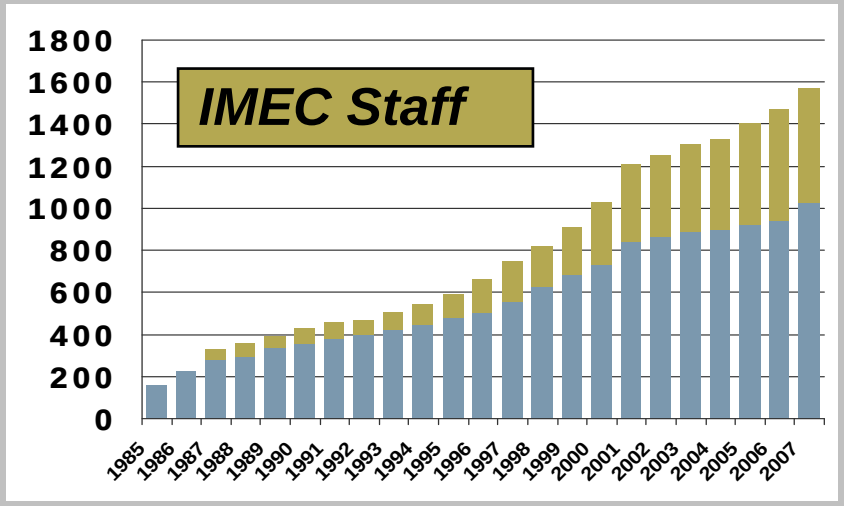
Established by state government of Flanders in Belgium

Non-profit organization

Initial investment: 62M€

Initial staff: ~70





2008

One of the largest independent R&D organizations in this field.

Annual budget 2008: 262M€

Staff (2008): > **1650** → >55 nationalities

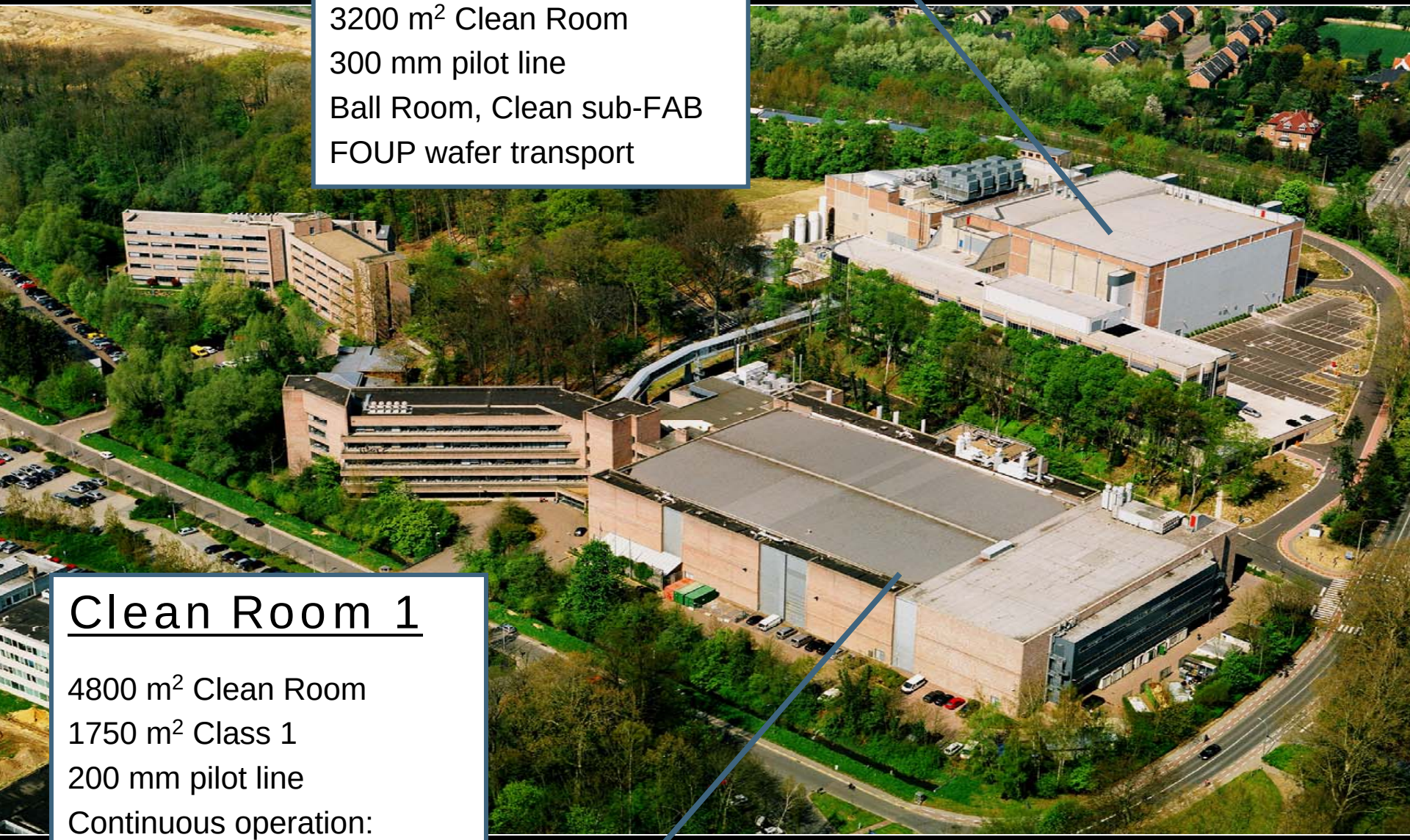
Collaboration with **>600 partners worldwide**

< 17% government/state funding

IMECAMPUS

Clean Room 2

3200 m^2 Clean Room
300 mm pilot line
Ball Room, Clean sub-FAB
FOUP wafer transport

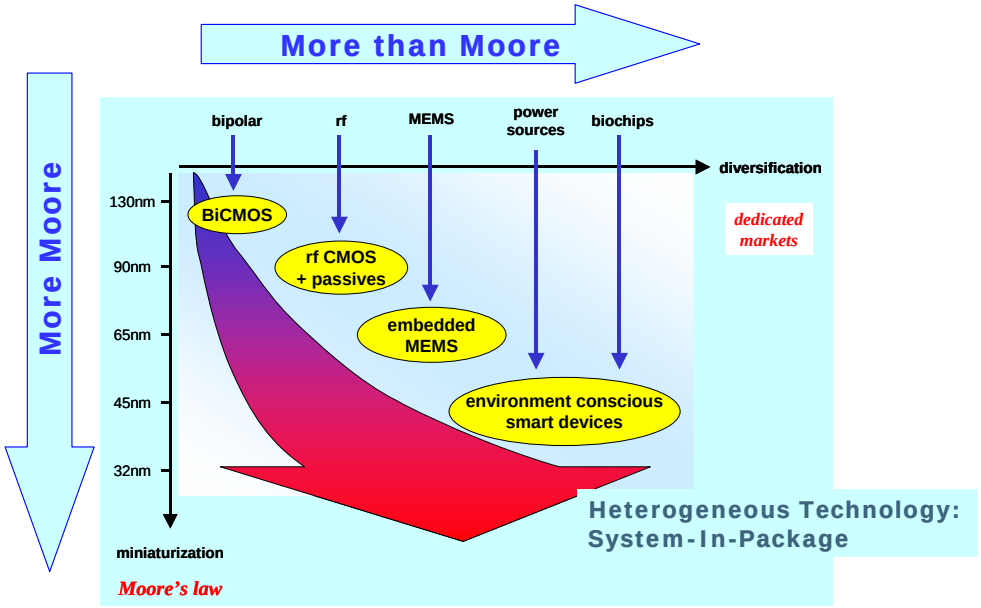


Clean Room 1

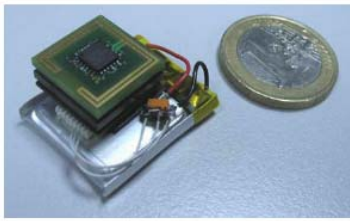
4800 m^2 Clean Room
1750 m^2 Class 1
200 mm pilot line
Continuous operation:
24hrs / 7 days

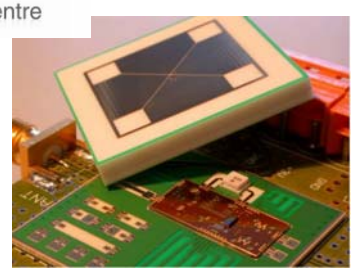
Total: **8000 m^2** Clean Room

Heterogeneous Systems:
'More Moore' and 'More than Moore' go hand in hand



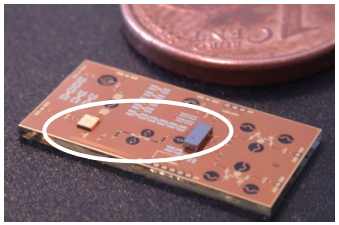

Holst Centre

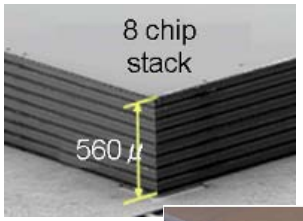


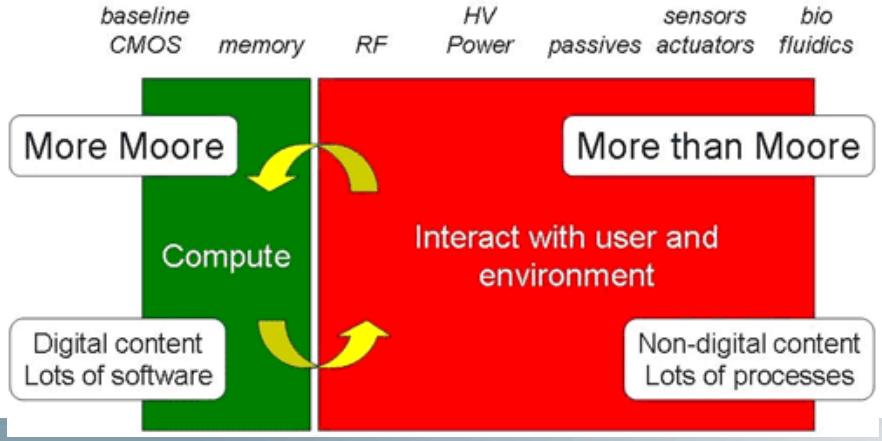


- **Wireless applications**
- **biomedical applications**
- **Automotive applications**
- **…**

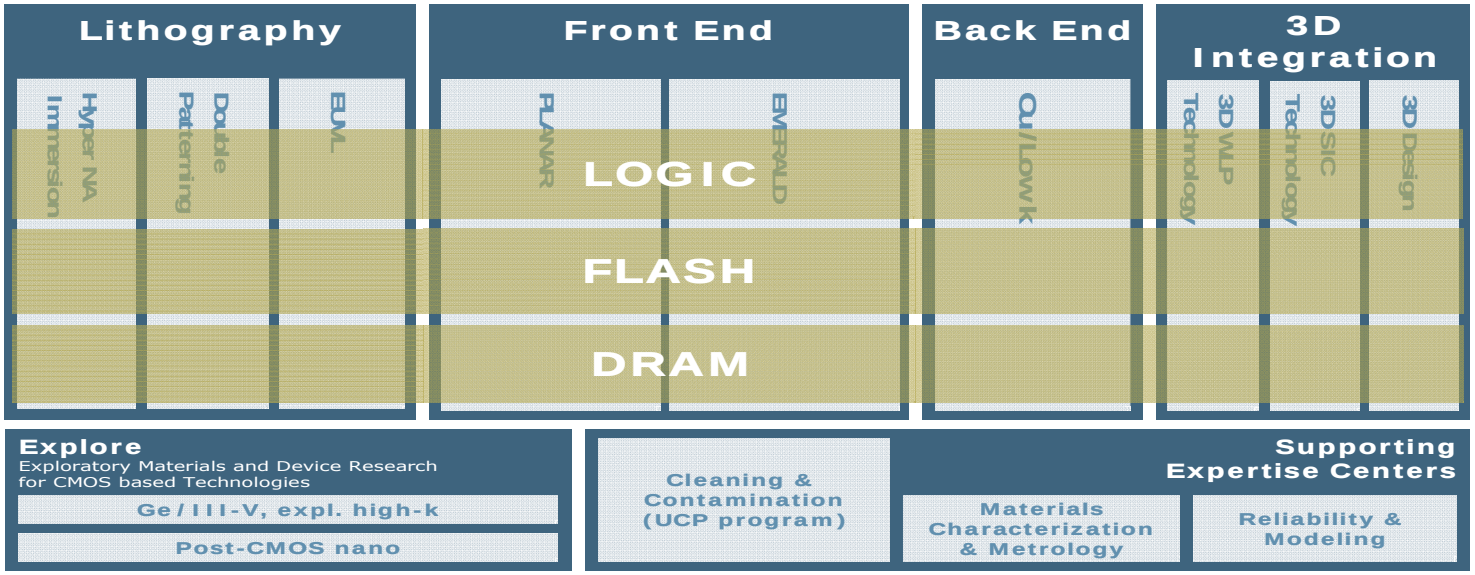
- **More Moore & More than Moore**
- **SoC – SiP; 2D – 3D; flexible electronics, …**







More "Moore"



Generic technology programs
For increasing complexity

"More than Moore"
Heterogeneous Integration

CMORE (i-SOC)

R&D platform for Multi Functional SoC (MEMS, Sensors, Actuators, …) based on 130 nm, 200 mm CMOS

Above CMOS SiGe MEMS platform

RF / Mixed Signal BiCMOS / RFCMOS

APIC (SIP)

Advanced Packaging
3D SIP, WLP
RF Integrated
Passive Technology
Flexible substrates

Si Nano Photonics

Organic Electronics

Nomadic Embedded Systems

Design for new technologies

Applic. Enabling components

Wireless Autonomous Transducer Systems

Application Enabling components

Application 1: Industrial Monitoring Systems

Application 2: Body Area Networks HUMAN++

Bio-Medical Electronics

Brain Computer Interface

Nano-Pore sequencing & magn. NP

Functional surfaces Bio-sensors

Implantable Devices

Photovoltaics (SOLAR⁺)

Si based PV

Organic PV

III-V-based PV

Thermal PV

Power Elec

GaN Poiwer switches

Application Driven

More "Moore"

Core CMOS Programs

Lithography (incl. DRAM eval.)
- Hyper NA Immersion
- EUVL

Front End (incl. DRAM eval.)
- PLANAR
- EMERALD
- GATE STACK

Back End (incl. DRAM eval.)
- Cu / Low k
- 3D-SiC

Flash Memory
- Floating Gate
- Charge trapping
- Flash Scaling

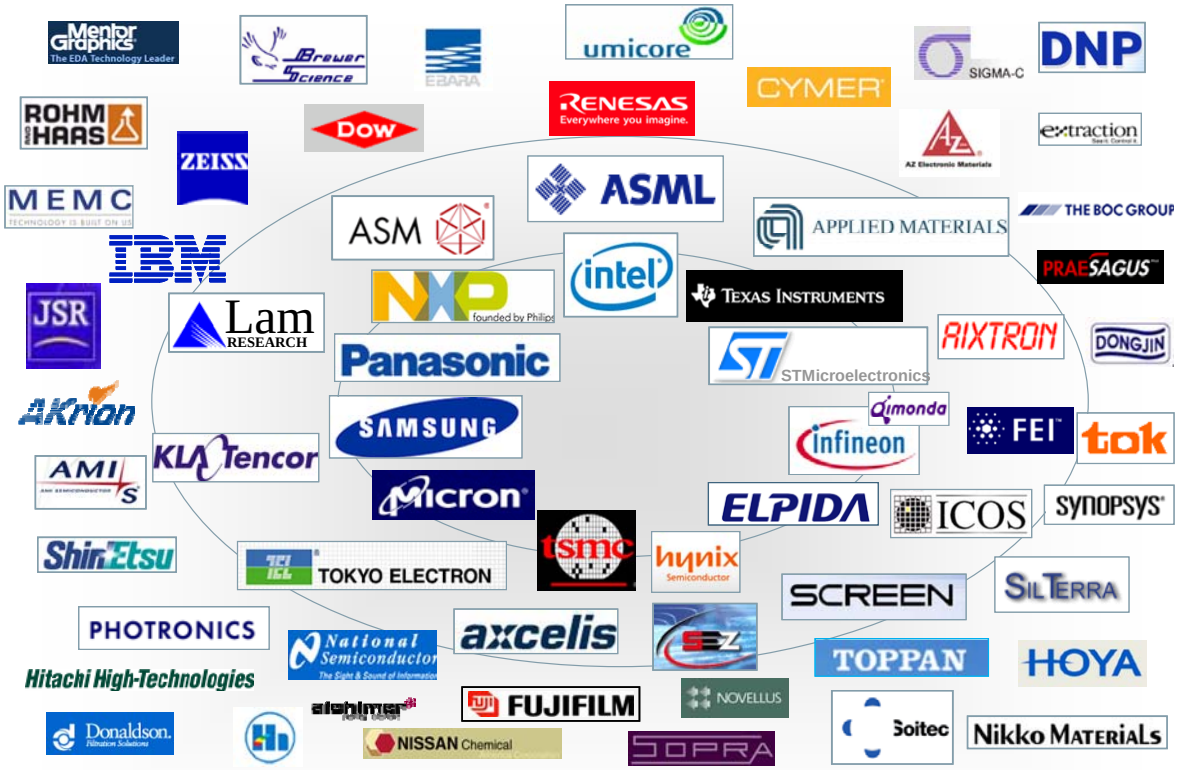
3D integration (under construction)
- 3D integration Technology
- Application evaluation
- 3D Design Technology
- Test Vehicle Development

Explore
Exploratory Materials and Device Research for CMOS based Technologies
- Ge / III-V, expl. high-k
- Post-CMOS nano

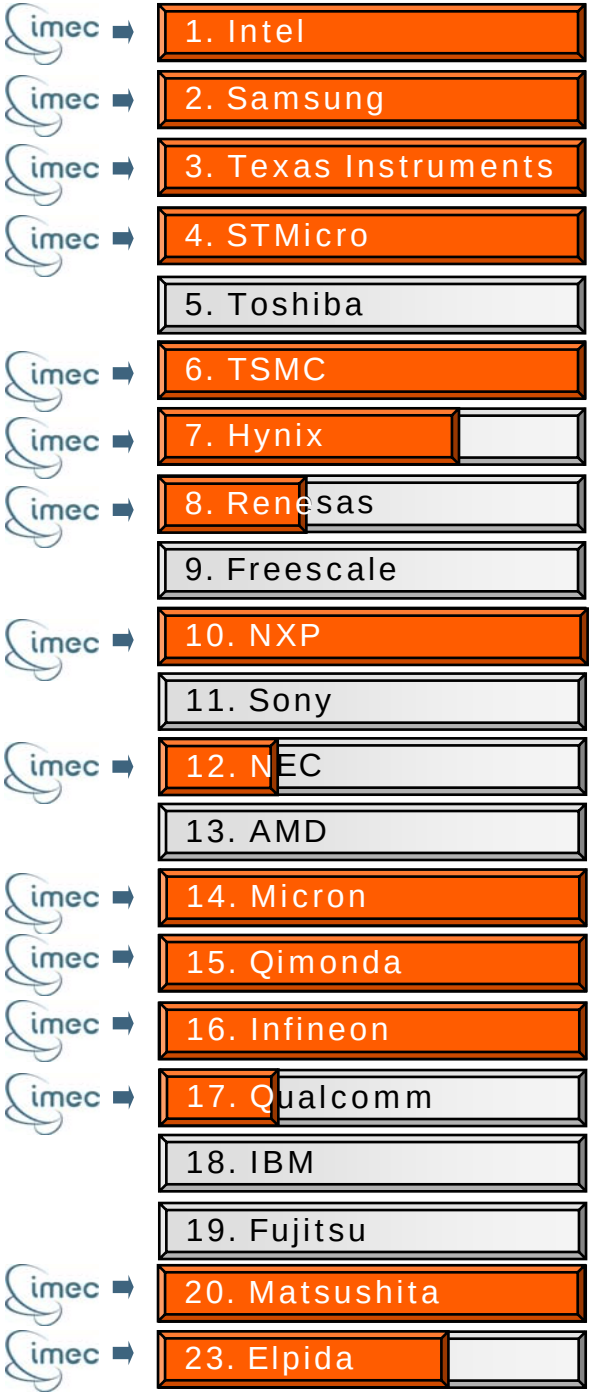
- Cleaning & Contamination (UCP program)

Supporting Expertise Centers
- Materials Characterization & Metrology
- Reliability & Modeling

Generic technology programs
For increasing complexity



2007 Ranking
IC manufacturers



(after IC Insights)

Top-5 DRAM suppliers:

- Samsung
- Hynix
- Qimonda
- Micron
- Elpida

Majority of top IC-manufacturers build on IMEC for providing research know-how as critical input to their process development activities

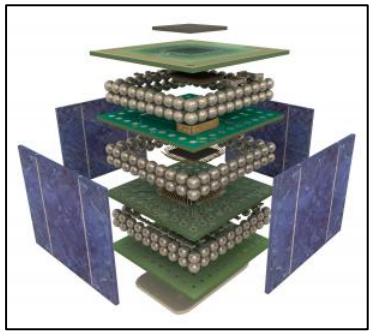

imec

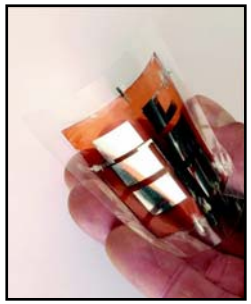
Introduction to IMEC's Solar Cell Research

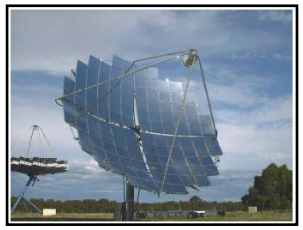
May 2009

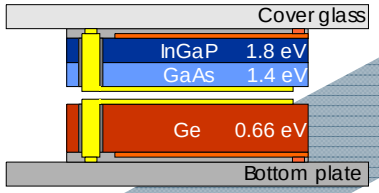
Jef Poortmans
Program Director

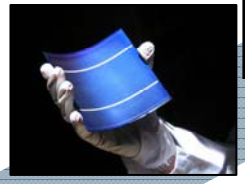
Strong history in solar cell research

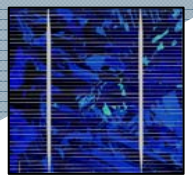












2002-2003: Technology transfer to Photovoltech

2001: Creation of Photovoltech

2000: Start of III-V solar cell activities

1998: Start of organic solar cell activities

1994: Start of thin-film crystalline Si solar cell activities

1993: Build-up of crystalline Si solar cell pilotline

1984: Crystalline Si solar cells

(a-Si:H solar cells, till 1988)

Macro-trends in PV/Si Solar Cells

Less "grams of Si / W_p"

- Reduced (→ "zero") wafering loss and active layer thickness
- Efficiency increase > 20 %

(and in very long term: recycled Si from end-of-life modules)

Reduction of mfg cost

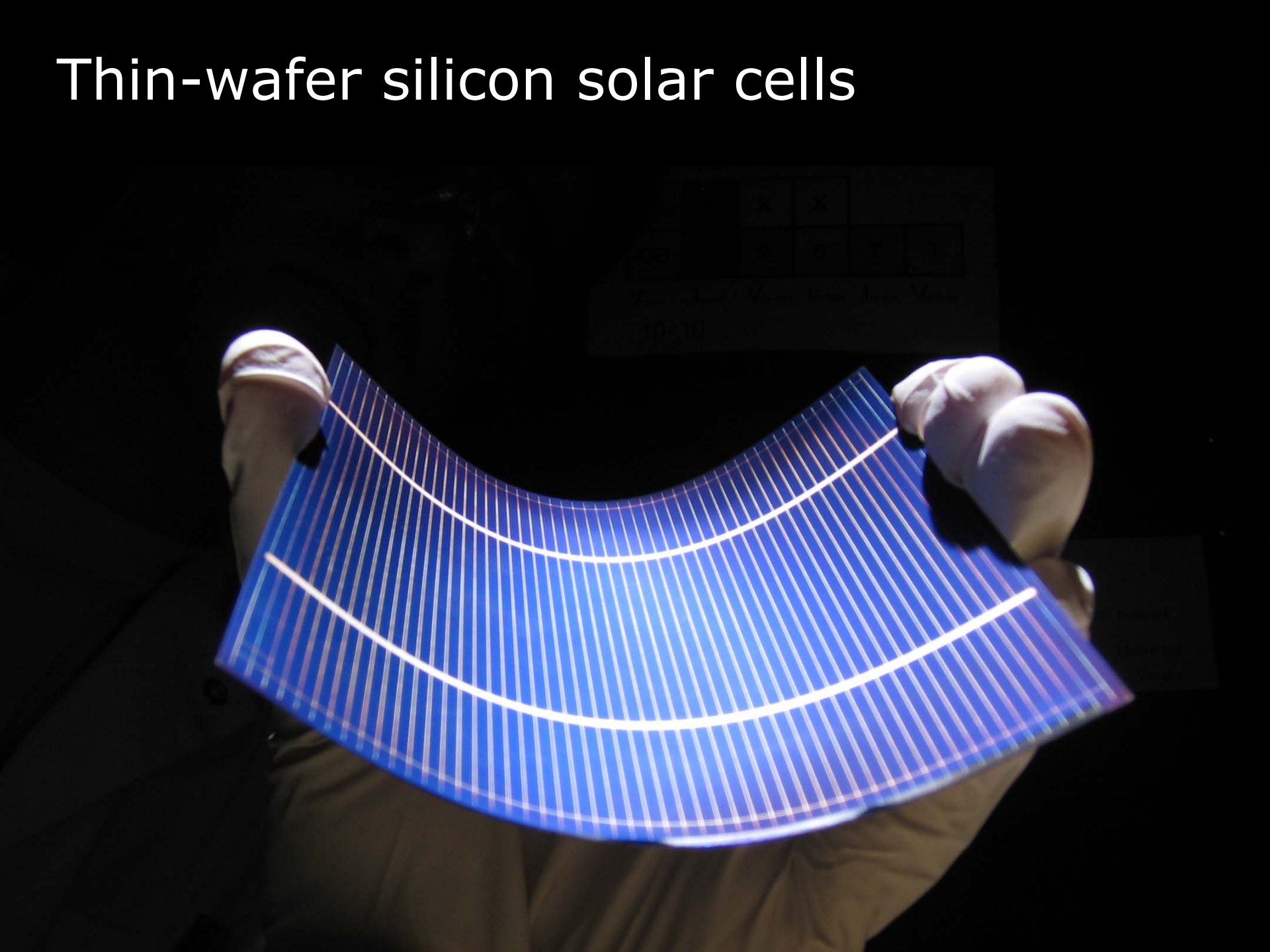
- Equipment scaling and increase of areal throughput
- Fab scaling MW/yr → GW/yr
- Reduction (phase out) expensive materials (Ag, Al-paste)
- Standardisation & vertical integration
- Integration cell/module manufacturing

Speeding up the PV learning curve

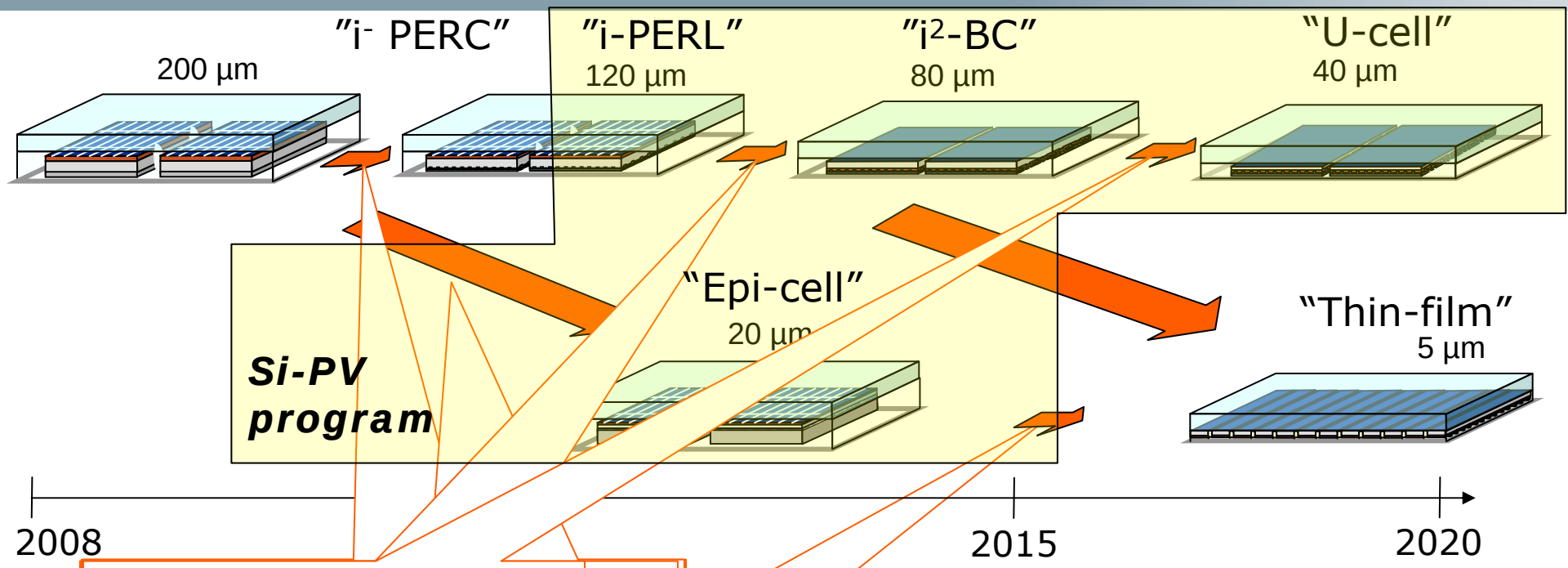
- Increased price competition from new technologies
- Accelerated reduction of feed-in-tariffs
- PV dedicated equipment

Critical: Industry-wide acceptance of a roadmap

Thin-wafer silicon solar cells



The future of c-Si PV technology by IMEC



Rear-surface processing

Interdigitated back-contact

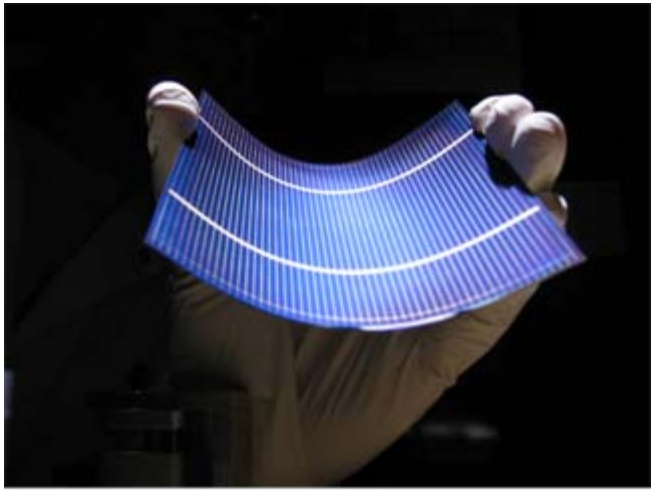
Layer-transfer process

Cost effective epitaxial deposition

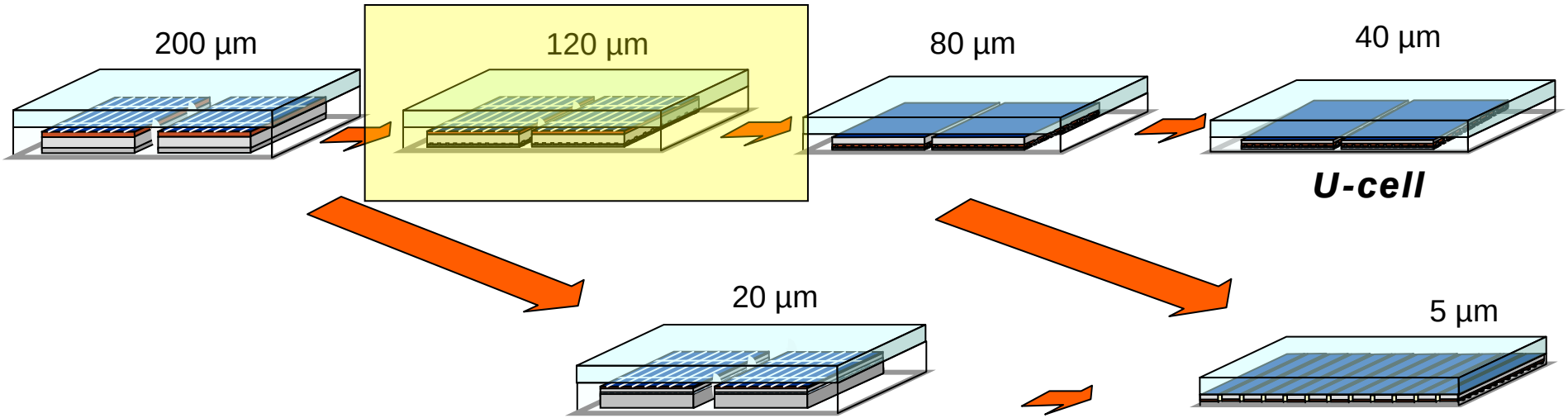
Si seed layer on glass

- Sustained decrease in active layer thickness
- Roadmap is accelerating
  - Past: "one major process transition only for each new process generation"
  - Today: accelerated evolution

Si-PV activities
i-PERC: Passivated Emitter and Rear Cells Eye-catcher 2008

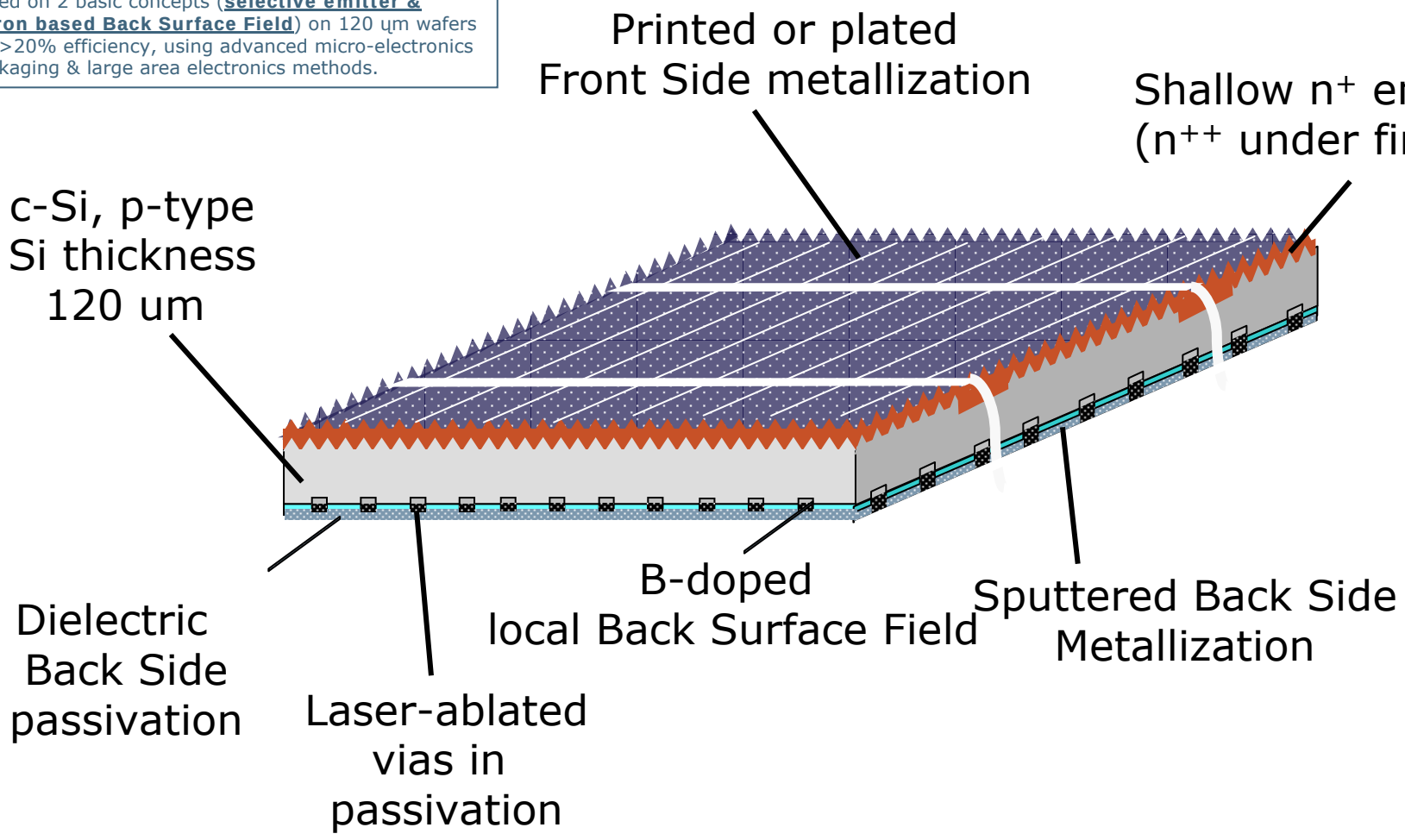


Material	Thickness [μm]	Efficiency [%]
Mono	130	17.6
Multi	120	16.8
EFG	170	16.6



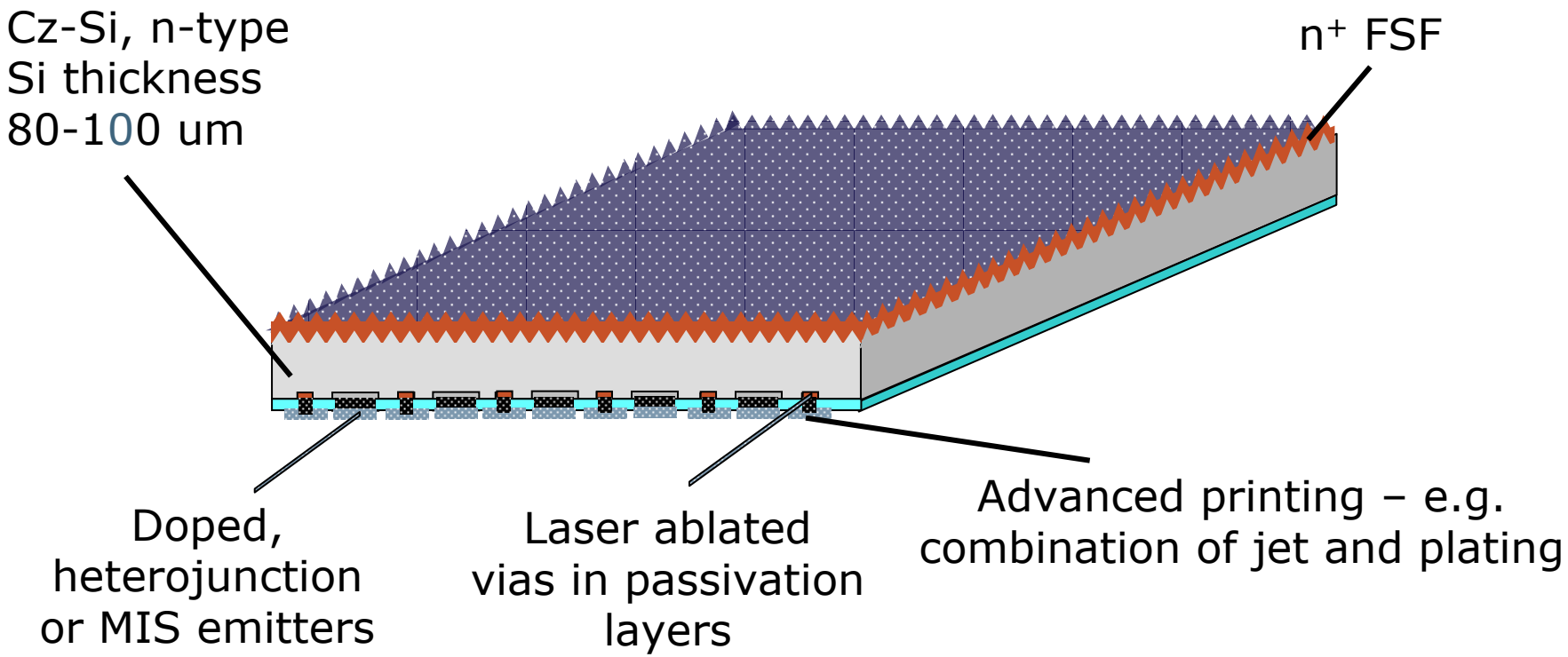
"i-PERL" concept *passivated emitter and rear local back surface field*

i-PERL based on p-type Si (industry standard) based on 2 basic concepts (**selective emitter & Boron based Back Surface Field**) on 120 µm wafers for >20% efficiency, using advanced micro-electronics packaging & large area electronics methods.

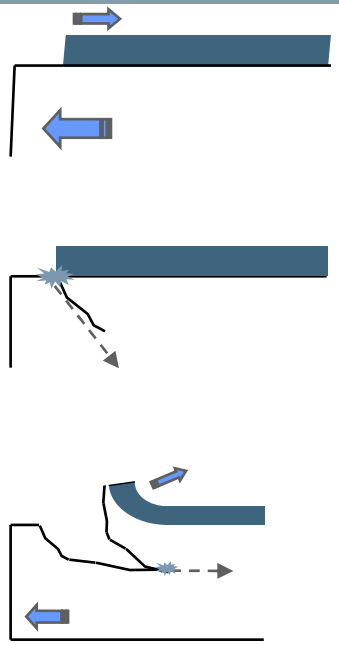


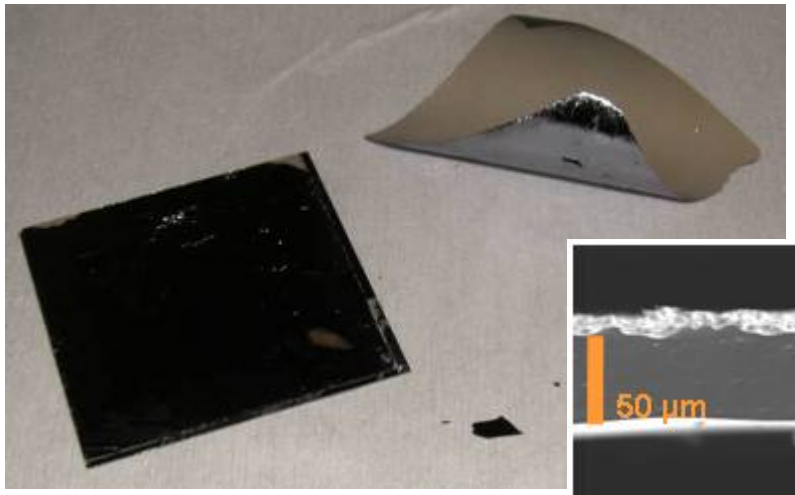
"i²-BC" Inter-digitated Back Side Contacts

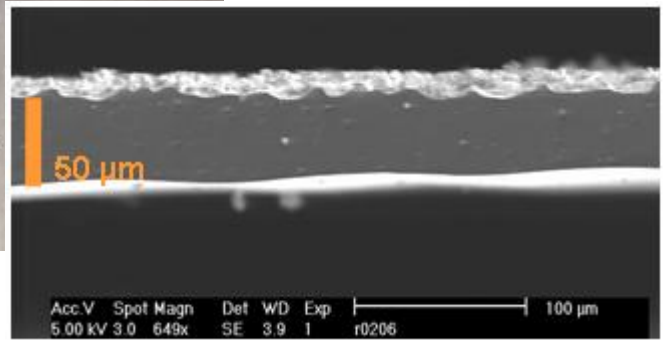
Efficiency gain (no shadowing loss)
Front-surface passivation becomes easier (no metal);
Simplified module processing (with thinner wafers);
More homogeneous look to module (esthetics)

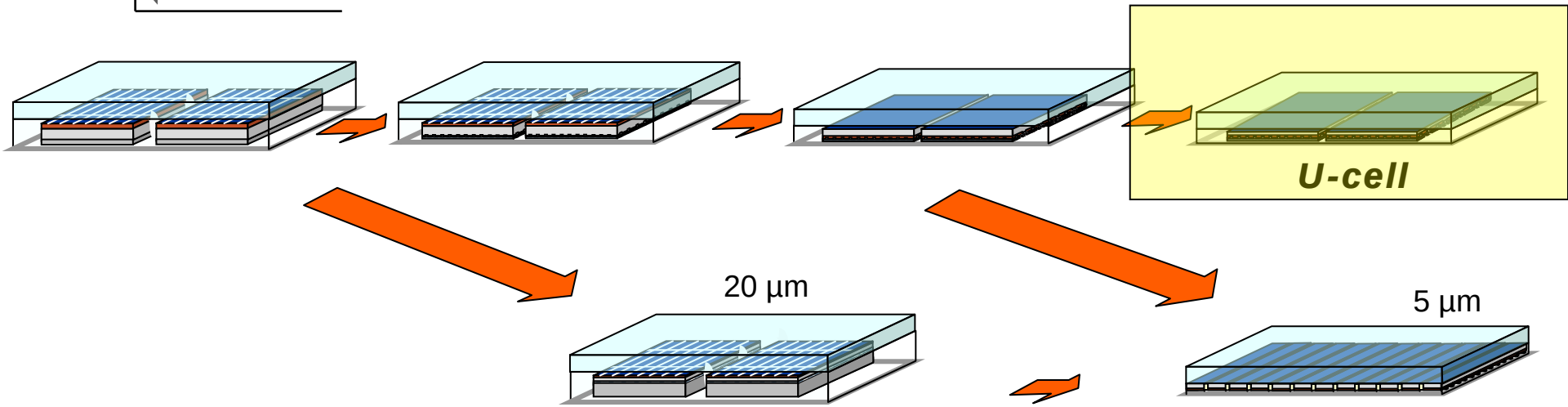


Si-PV activities: Si-foils
The Slim Cut: Eye-catcher 2008



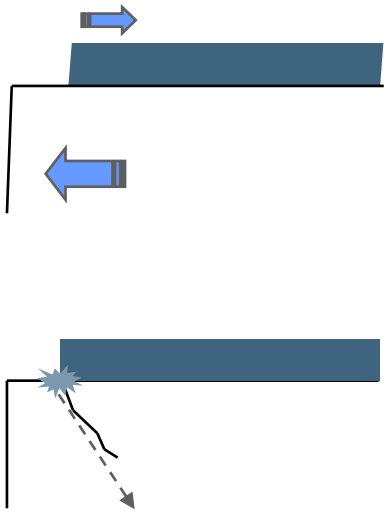




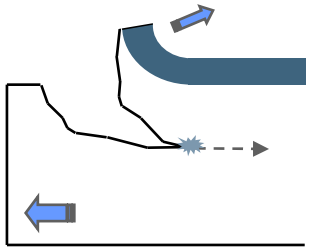


Si-foils: SLIM cut/spalling

- Thermal coefficient of expansion
  - Metal bonded at high temperature on silicon
  - Upon cooling down, high stress
  - Crack initiation at the interface (where the stress is the highest)
  - Goes deep in the bulk (if interface strong enough)

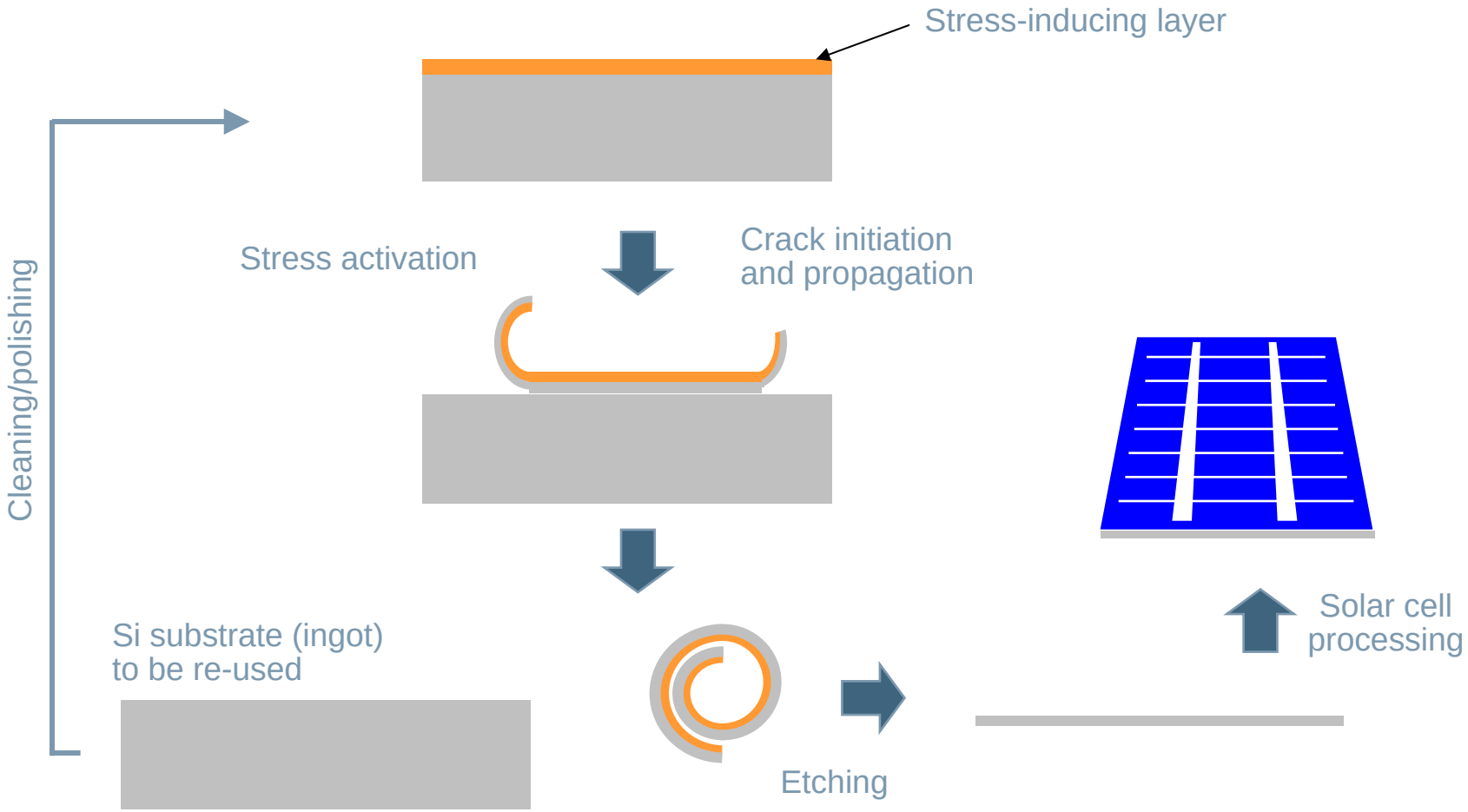


- Substrate "spalling"
  - Crack trajectory remains parallel to surface
  - Known as substrate "spalling effect" (usually an unwanted behavior)



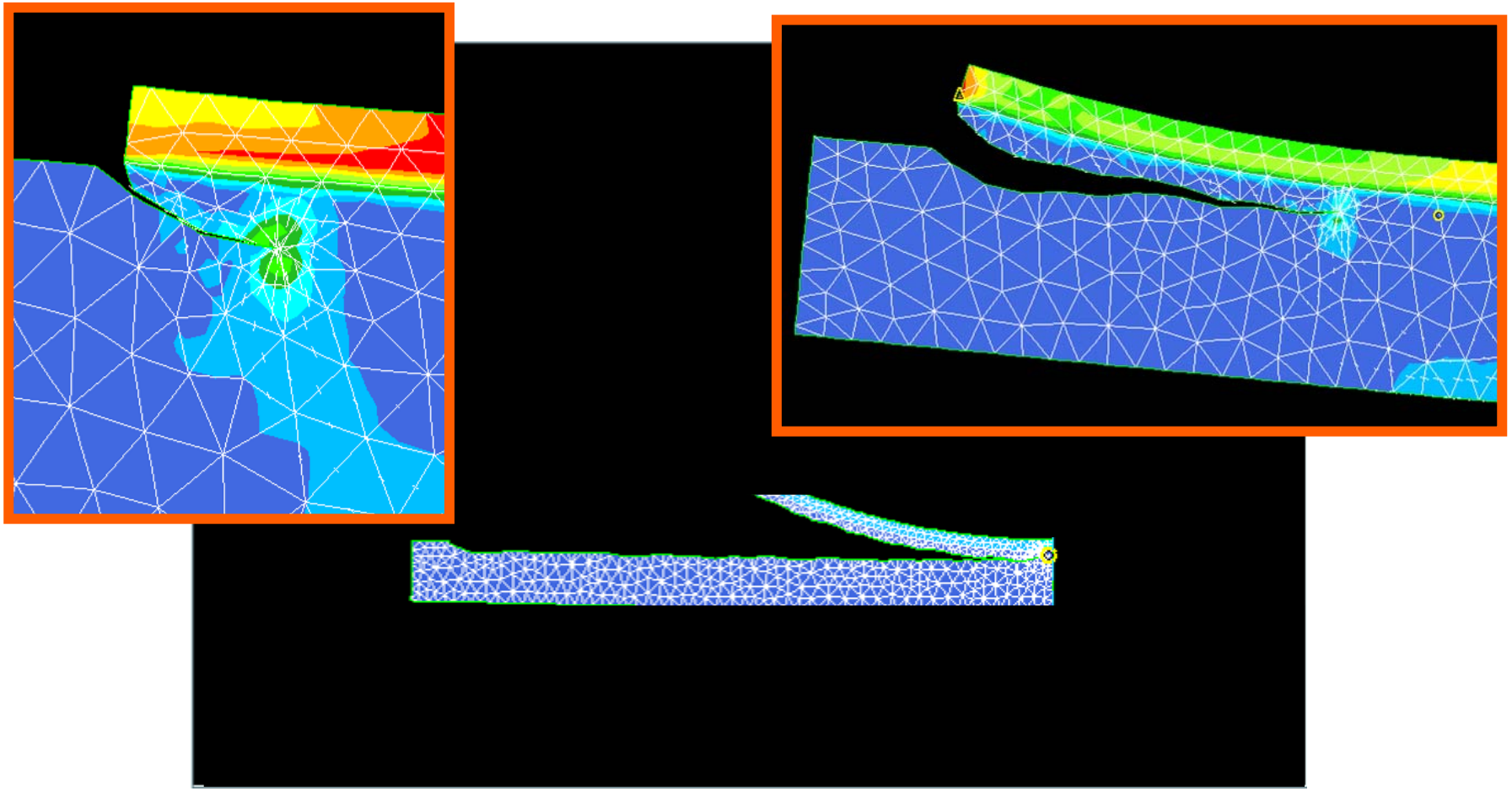
Si-foils: SLIM cut

- Implantation-free stress-induced lift-off

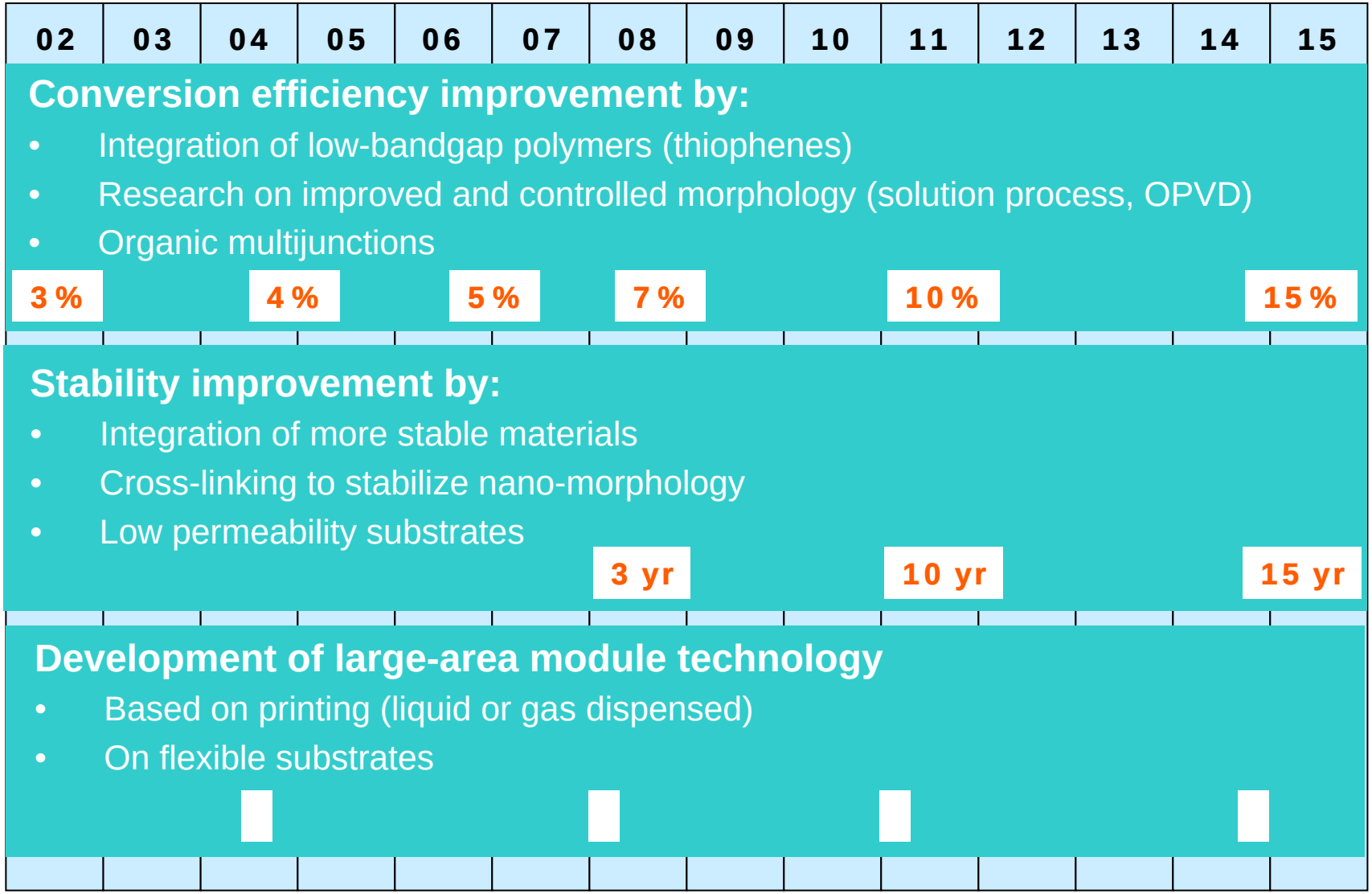


Si-foils: SLIM cut / Calculated crack propagation

- Purely mechanical modeling



OPV-Roadmap


02
03
04
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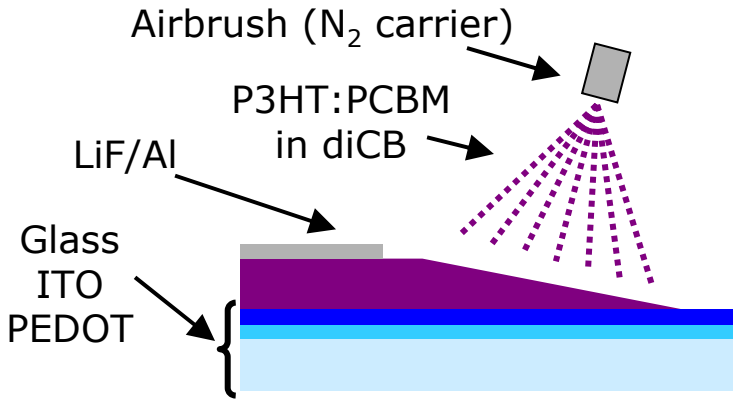
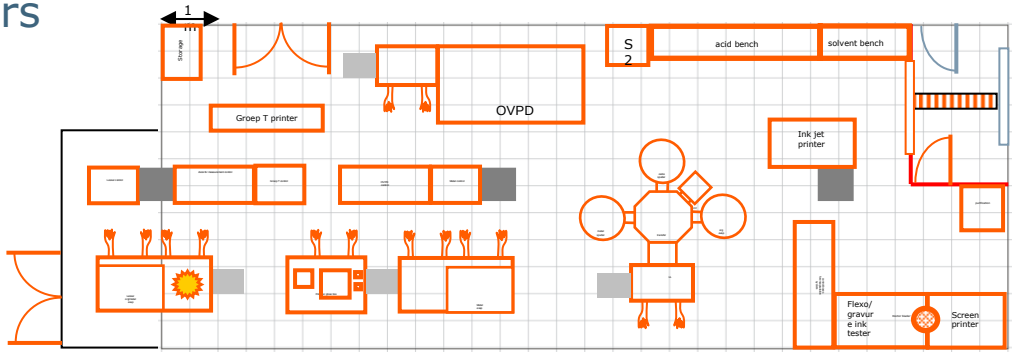
Conversion efficiency improvement by:
• Integration of low-bandgap polymers (thiophenes)
• Research on improved and controlled morphology (solution process, OPVD)
• Organic multijunctions
3 %
4 %
5 %
7 %
10 %
15 %
Stability improvement by:
• Integration of more stable materials
• Cross-linking to stabilize nano-morphology
• Low permeability substrates
3 yr
10 yr
15 yr
Development of large-area module technology
• Based on printing (liquid or gas dispensed)
• On flexible substrates

IMEC-OPV: activities and eye-catchers 2008

- Materials synthesis
  - Low-Eg polymers
  - Polymers improved stability
- Cell concepts
  - Multijunctions
  - Inclusion of nanoparticles
  - Novel cell concepts
- Technology development
  - Solution processing of polymers
    - Screenprinting
    - Inkjet
    - Spray coating
  - Small molecules



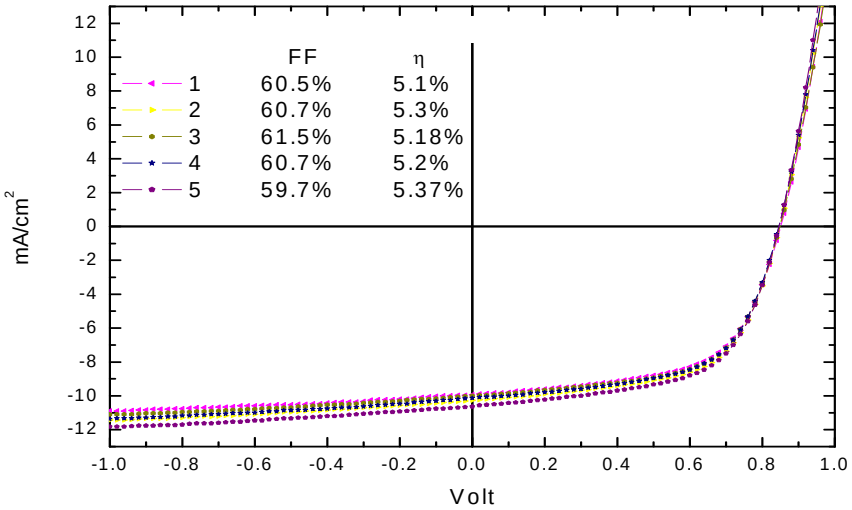


Ceiling height:
In lab = 2.75 m
In addition = 3.6 m

= flexible tube solvent exhaust

OPV@IMEC

- Controlled processing of new materials has resulted in further improvement of efficiency:
  - 5.4 %
- To allow for:
  - Better synergy of OPV activities
  - Increased throughput
  - Increased efficiencies



all OPV activities are concentrated in one lab:

the O-line

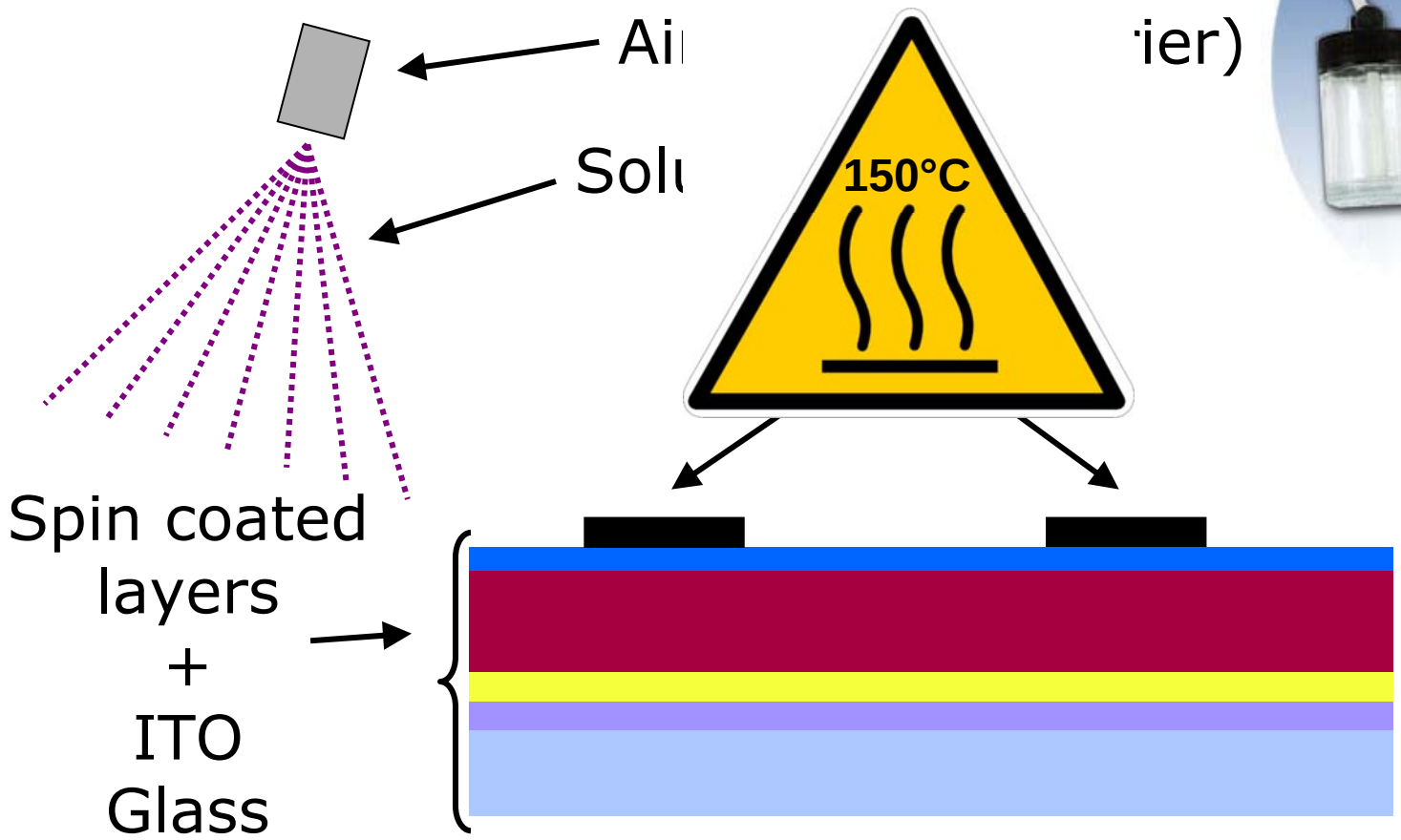
- enhanced processing of small molecule devices (evaporation) as well as polymer based solar cells (spraycoating)

Tom Aernouts

Spray coated top-contact for Organic Solar Cells

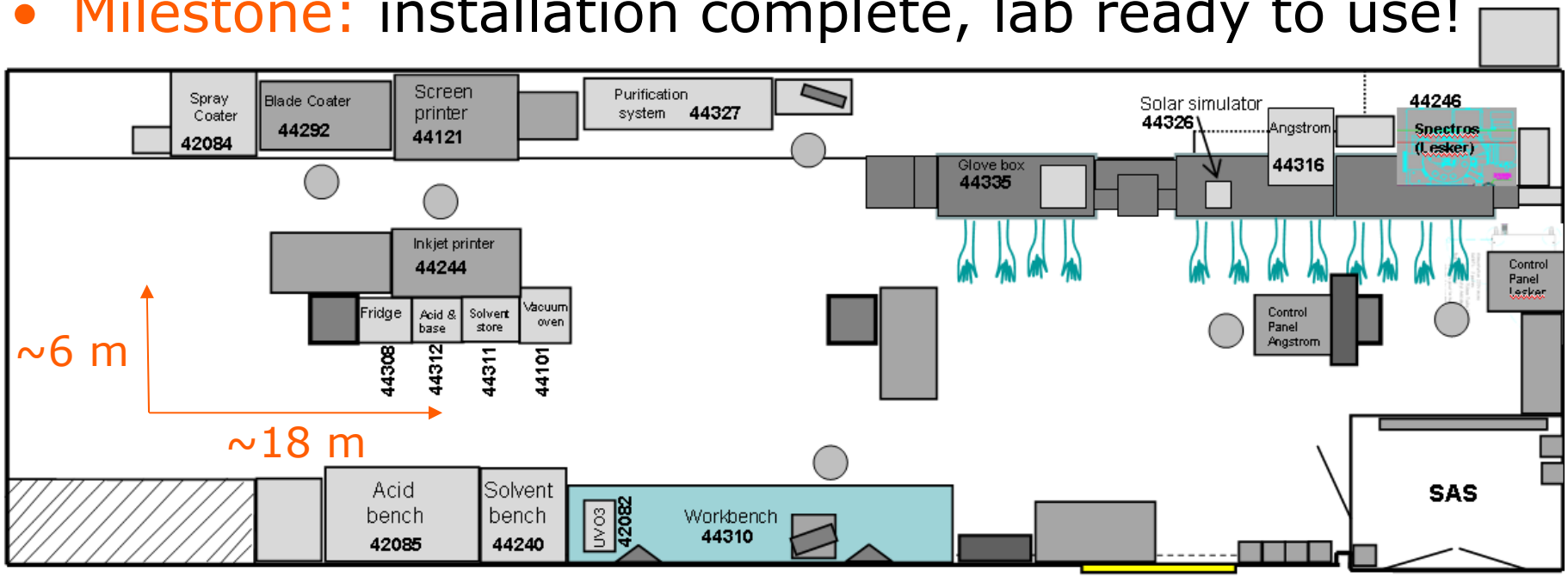
- Solution processed top-contact [1,2]

[1] Girotto, C. *et al.* MRS Fall 2008 Meeting G15.2
[2] Girotto, C. *et al.* Organic Electronics 10 (2009) 735-740

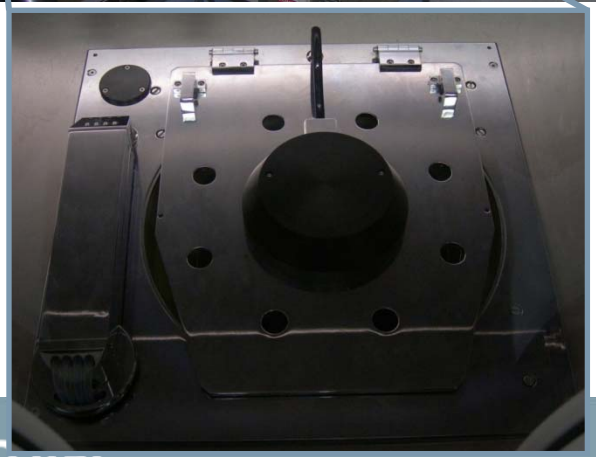


Our newest lab: the O-line!

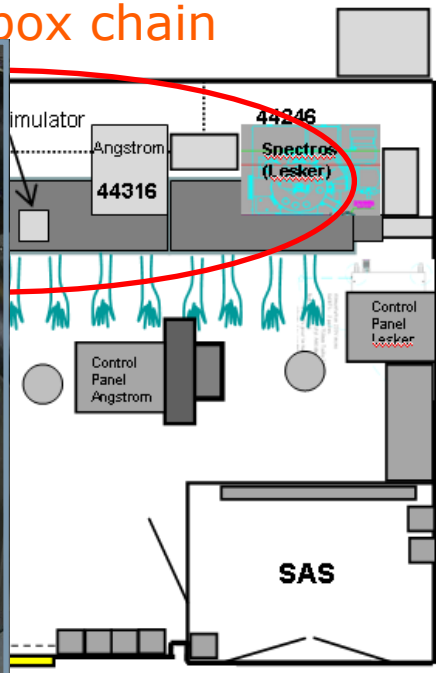
- Purpose: concentrate all OPV activities into one lab
  - Allows for:
    - Better synergy of OPV activities
    - Increased throughput
    - Increased efficiencies
- Milestone: installation complete, lab ready to use!



O-line status May 2009



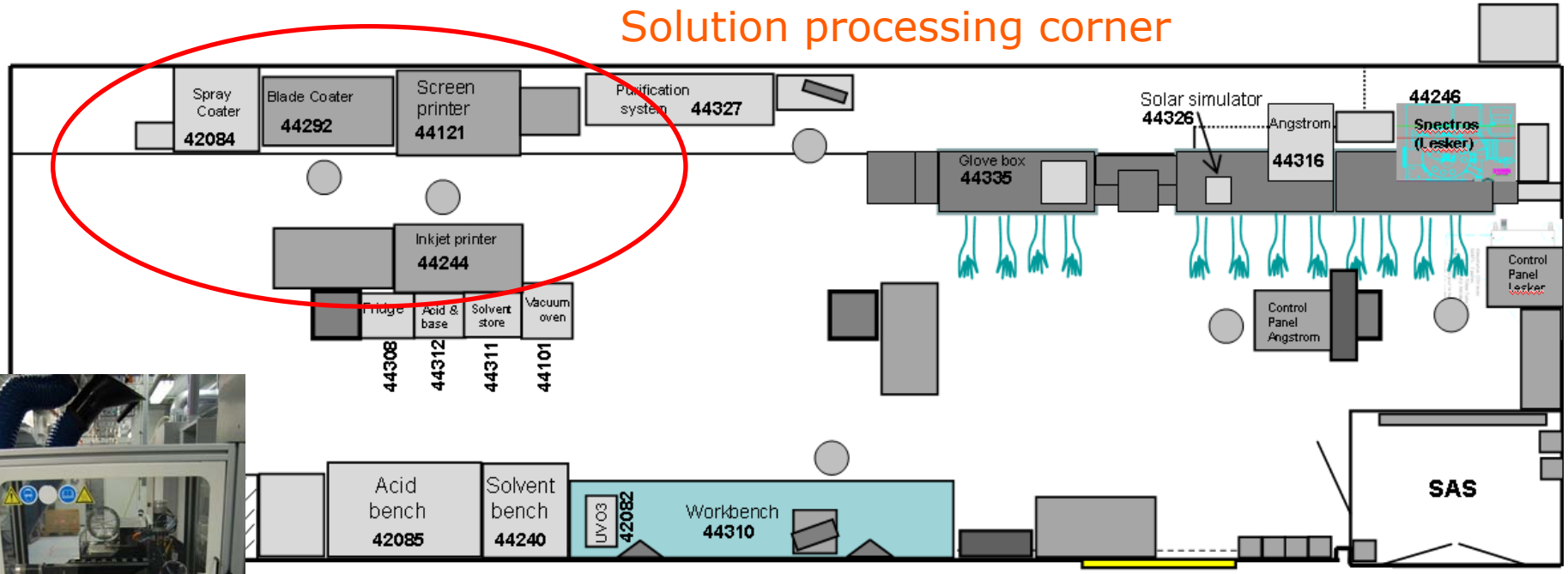
N_2 glovebox chain

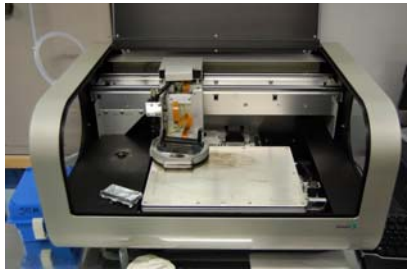


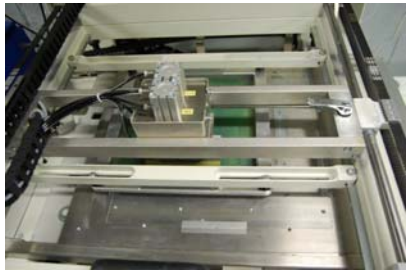
- Integrated solar simulator
- 6 " spin coater
- Angstrom HV metal evaporator (6 sources)
- Lesker Spectros HV metal and organic evaporator (12 sources)

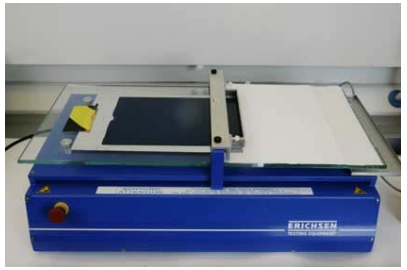
O-line status May 2009

Solution processing corner



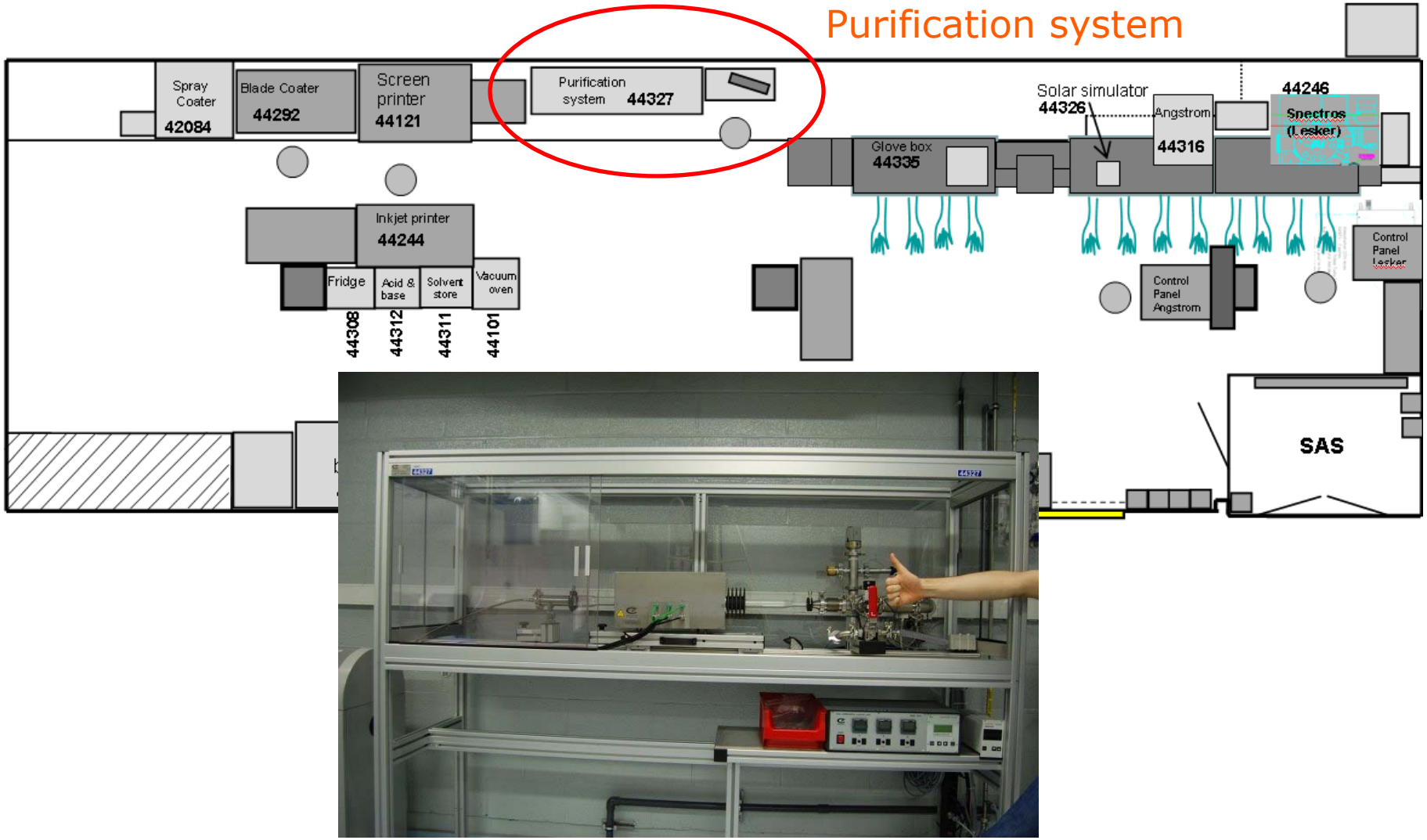




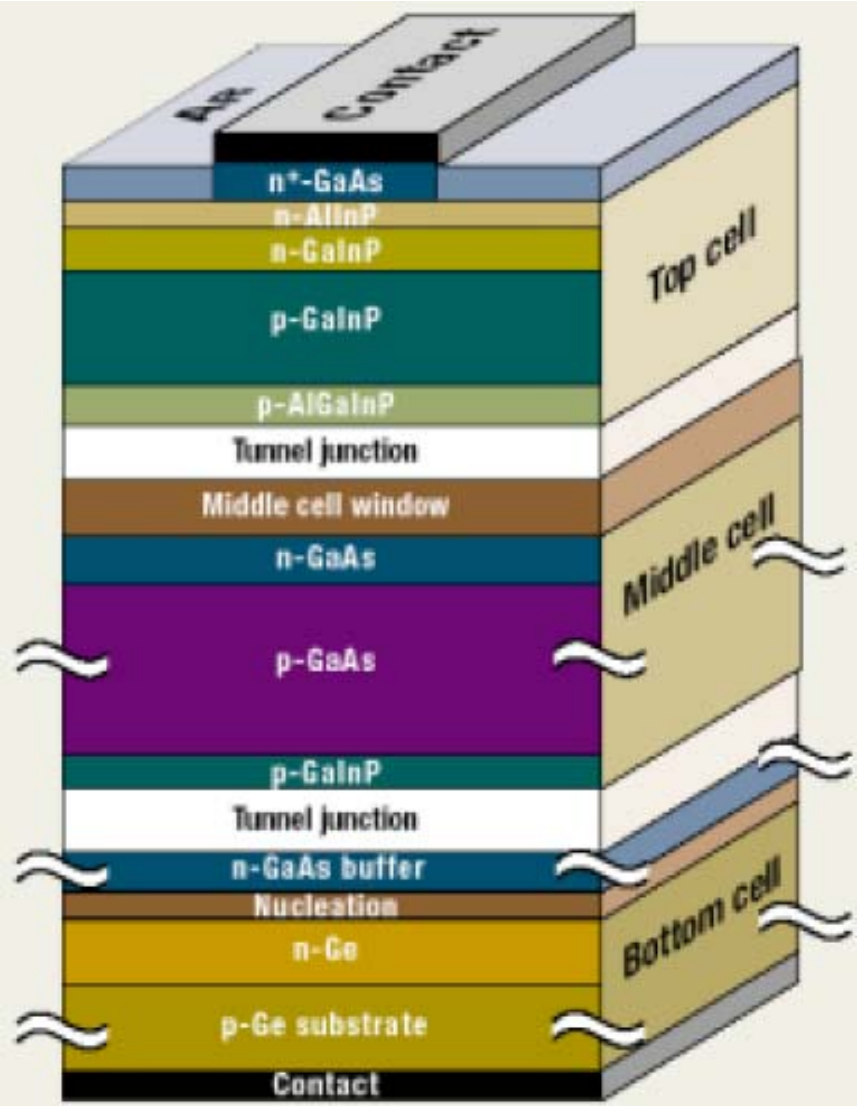


Spray coater | Inkjet printer | Screen printer | Blade coater

O-line status May 2009



Multi-junction solar cells: State-of-the-art



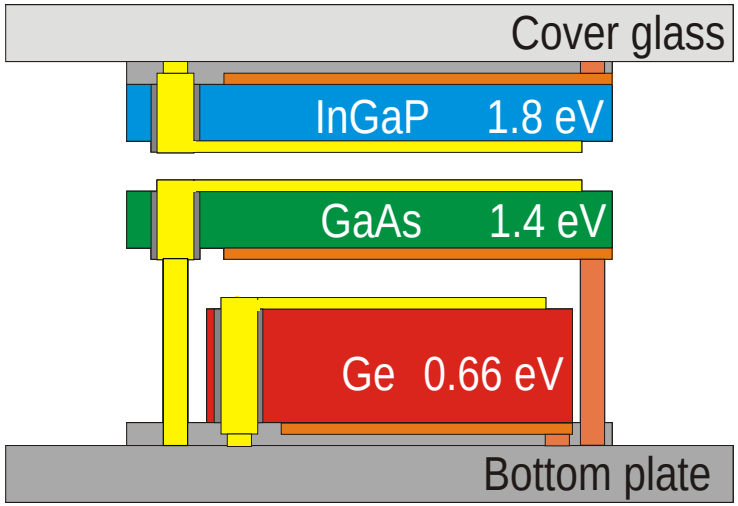
Record conversion efficiencies obtained (32% under 1 sun, 40.7% under concentration) - NREL

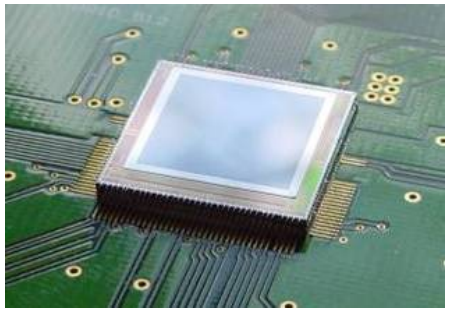
Key technologies:

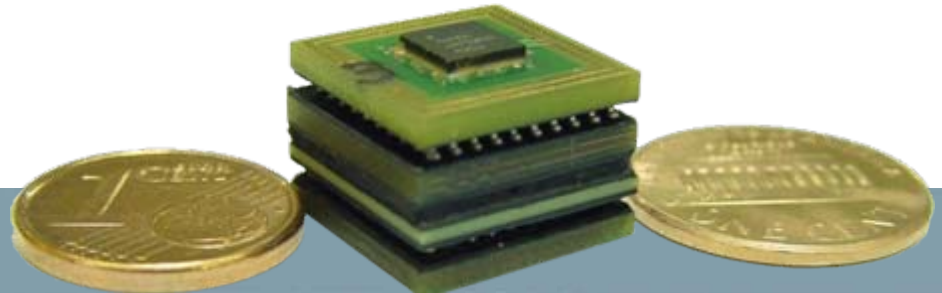
- **current matching** of top and middle cell
- **wide-gap tunnel junction**
- **exact lattice matching** (1% Indium added in GaAs cell)
- InGaP disordering
- **Ge junction formation**

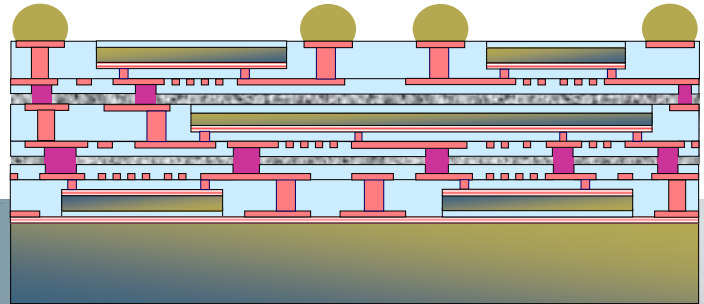
IMEC Approach for concentrator cells: mechanically stacked cells

- 6 terminal device (2 contacts/cell) => current matching not required
- Nominal efficiency: + 1.5…2 %
- System level efficiency improved (no losses by spectral variations)
- Modular: optimized and alternative cells can easily be incorporated
- No tunnel junctions needed
- Micro-system integration and reliability know-how at IMEC
- The Ge bottom cell is susceptible for application as stand-alone cell in TPV-applications



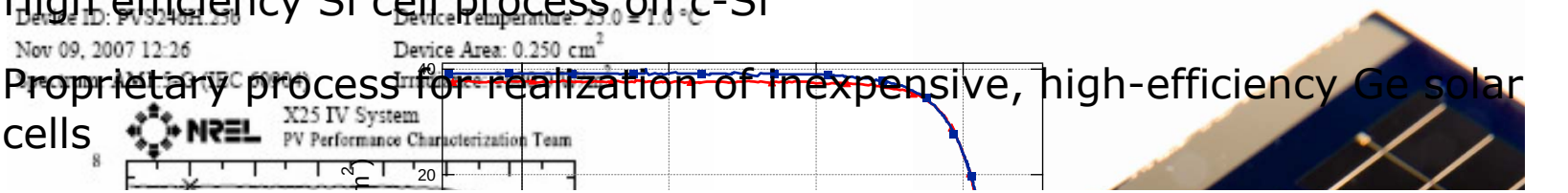


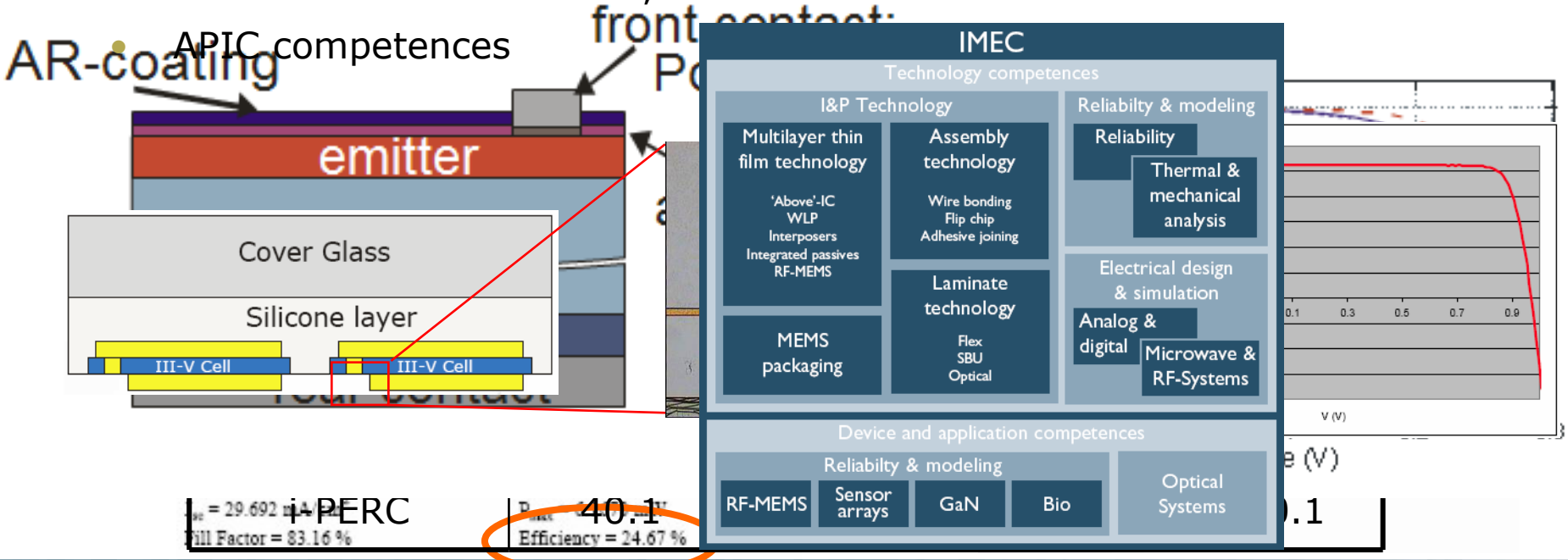




IMEC Approach: relevant expertise

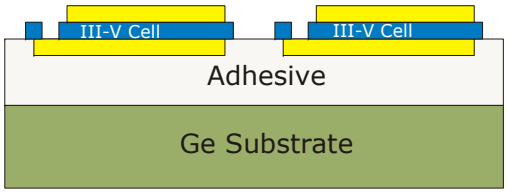
- MOCVD growth and processing of (world-class) InGaP and GaAs solar cells.
- High efficiency Si cell process on c-Si
- Proprietary process for realization of inexpensive, high-efficiency Ge solar cells
- First demonstrator of thin, one-side contacted GaAs cell
- APIC competences

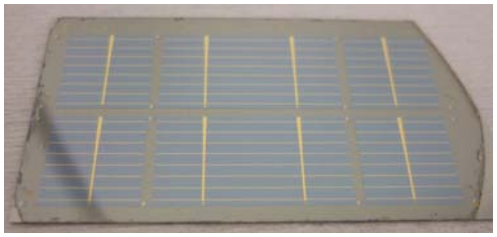


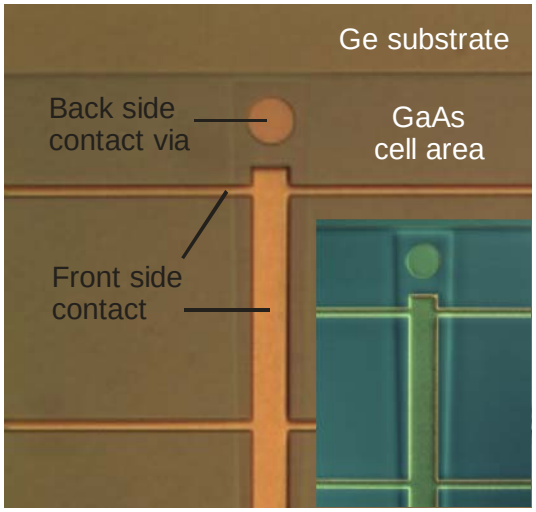


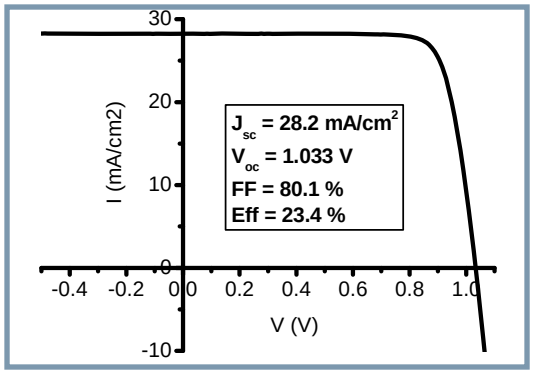
IMEC III-V Cell technology update

Recent result: Improved thinned-down, one-side contacted, IR-transparent GaAs solar cell transferred to separate Ge substrate









	Jsc (mA/cm²)	Voc (V)	FF (%)	Eff (%)
Best Cell	**28.2**	**1.033**	**80.1**	**23.4**
Average	**28.0 ± 0.6**	**1.014 ± 0.008**	**78 ± 2**	**22.2 ± 0.8**

Performance close to standard GaAs solar cell
Record efficiency for IR-transparent GaAs cell
New demonstration towards validity of IMEC technology

Summary

- Large ambitions on European level to make PV a major player on electricity generation in 2020:
  - 12% of electricity supply
  - > 400 GW installed in Europe
- Si-PV Affiliation Program **“Creating a Revolution through Accelerated Evolution of Si-based PV”**
  - is based on a aggressive roadmap towards thinner cells and higher efficiencies
  - First partner signed in
- “Beyond and besides Si PV” activities
  - Organic PV
    - Broad range of approaches in OPV with excellent results for both polymer and small molecules
    - O-line is starting operation
  - High-efficiency PV stacks
    - Significant step forward for stack based on combination of thin Ge and thin-film III-V solar cells
- IMEC’s PV-strategy is based on comprehensive approach covering three complementary **sustainable** PV-technologies (= compatible with **multi-tens of GW production**)

Vlaams Fotovoltaisch Initiatief

- Public support (Flemish government) for large-scale investment in PV R&D-equipment
- Public part of the investment ≈ 10 M€
- Covers:
  - Full PV value chain (materials → grid integration)
  - Three R&D-partners involved
    - University Hasselt (material synthesis, material characterisation)
    - IMEC (cell & module development & analysis)
    - University Leuven (PV-systems & grid integration)

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Years of Making
Technology Fly