OVERVIEW ENERGY ACTIVITIES

Embracing a better life

CONTACT

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As a **world-leading R&D** hub, we aspire the impossible and aim for **disruptive innovation**. We maximize societal impact by creating **smart sustainable solutions** that enhance **quality of life**.

At imec, we shape the future.

WORLD-CLASS INFRASTRUCTURE

> 12,000 M²

CLEANROOM

CAPACITY

MORE THAN

5,000 SKILLED PEOPLE

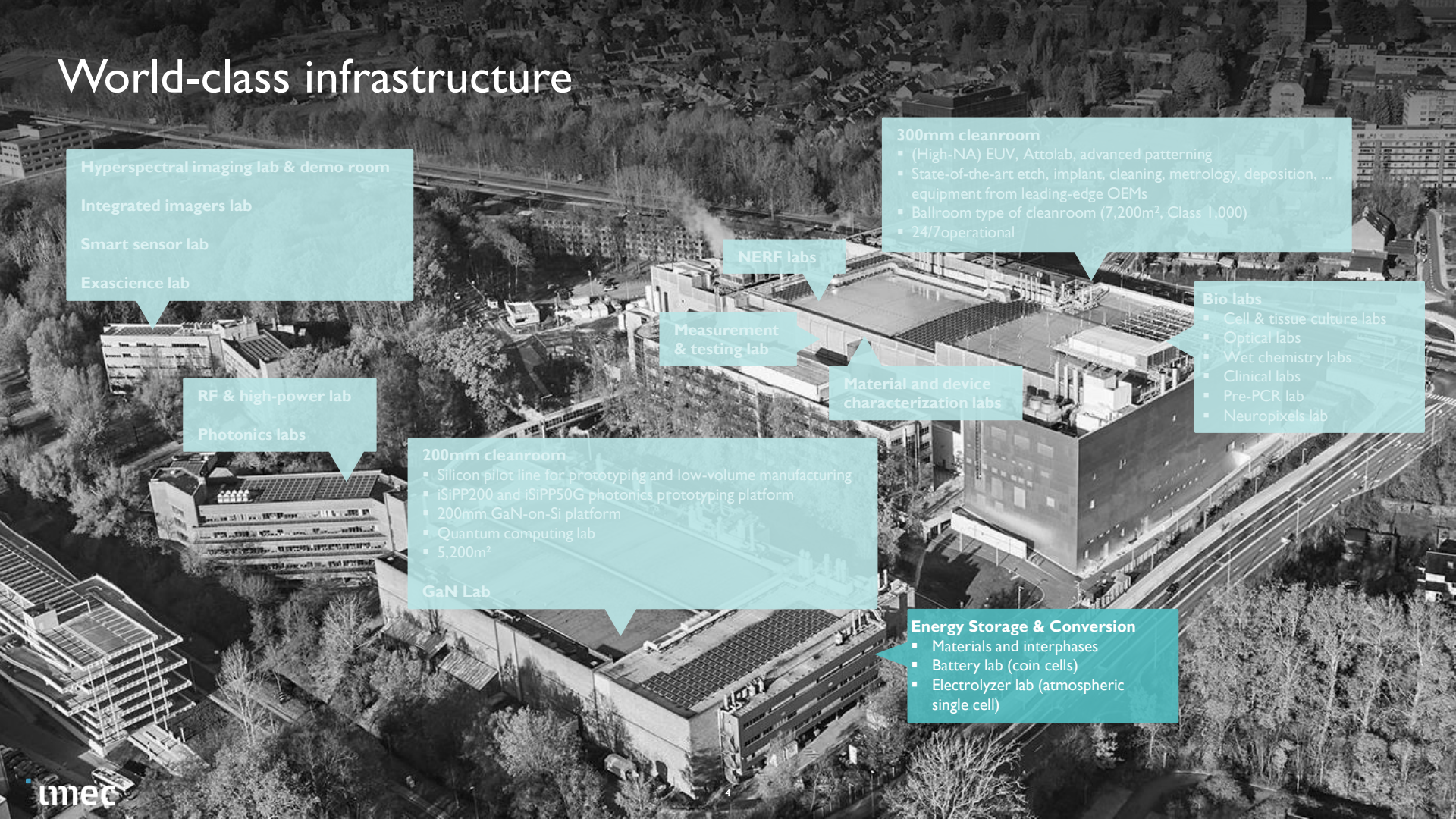
FROM OVER 95 NATIONALITIES

A

TRUSTED PARTNER

FOR COMPANIES, STARTUPS & ACADEMIA

World-class infrastructure



Hyperspectral imaging lab & demo room

Integrated imagers lab

Smart sensor lab

Exascience lab

RF & high-power lab

Photonics labs

NERF labs

Measurement & testing lab

Material and device characterization labs

300mm cleanroom
- (High-NA) EUV, Attolab, advanced patterning
- State-of-the-art etch, implant, cleaning, metrology, deposition, ... equipment from leading-edge OEMs
- Ballroom type of cleanroom (7,200m², Class 1,000)
- 24/7operational

Bio labs
- Cell & tissue culture labs
- Optical labs
- Wet chemistry labs
- Clinical labs
- Pre-PCR lab
- Neuropixels lab

200mm cleanroom
- Silicon pilot line for prototyping and low-volume manufacturing
- iSiPP200 and iSiPP50G photonics prototyping platform
- 200mm GaN-on-Si platform
- Quantum computing lab
- 5,200m²

GaN Lab

Energy Storage & Conversion
- Materials and interphases
- Battery lab (coin cells)
- Electrolyzer lab (atmospheric single cell)

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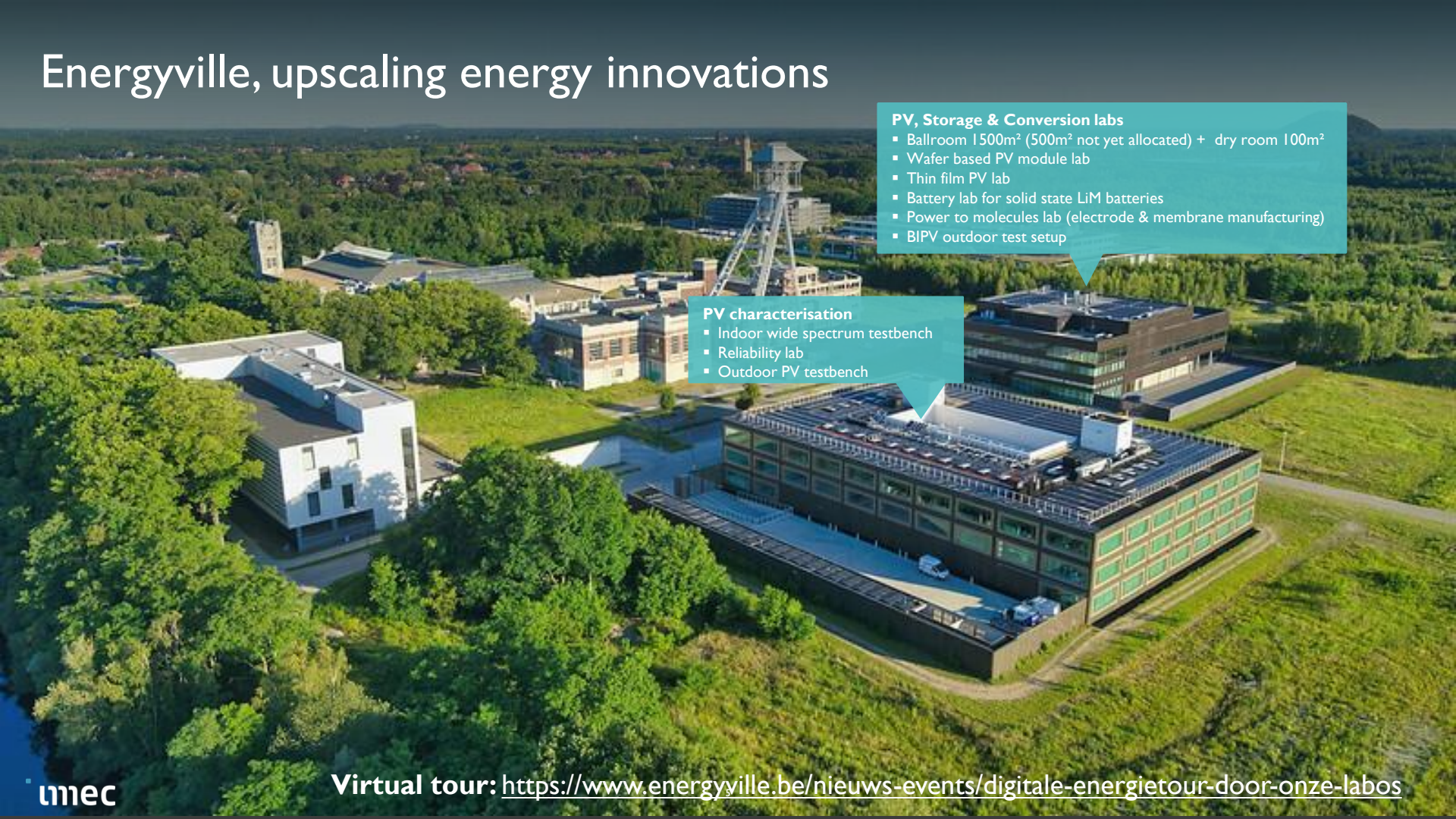
Energyville, upscaling energy innovations



Virtual tour: https://www.energyville.be/nieuws-events/digitale-energietour-door-onze-labos

imec

Imec's strategic guidelines

Imec will continue to drive
semiconductor functional scaling
expanding its nanotechnology expertise.

imec

Imec thrives on connecting
the grand challenges
with our strength in
pioneering nanotechnology
creating a **sustainable** society.

imec

SMART
MOBILITY

SMART
HEALTH

SMART
INDUSTRIES

SMART
CITIES

SMART
ENERGY

SMART
EDUCATION

SMART
INFOTAINMENT

SMART
AGROFOOD

SUSTAINABLE DEVELOPMENT GOALS

What we offer

R&D
COLLABORATION

DEVELOPMENT

VENTURING
STARTUPS & FUNDS

What we offer

R&D
COLLABORATION

DEVELOPMENT

VENTURING
STARTUPS & FUNDS

R&D collaboration models answering your needs

Get access to our state-of-the-art infrastructure

Benefit from our large international network of expertise

Enhance competitiveness with our in-depth technological knowledge

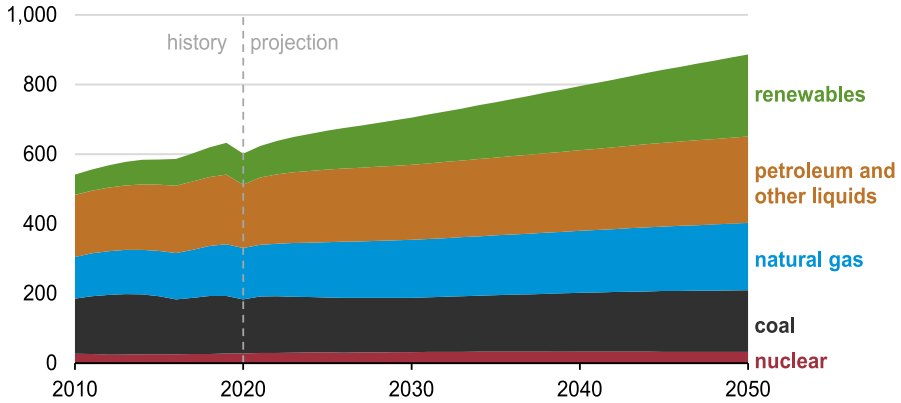
Lower your research costs and risks through pre-competitive collaboration

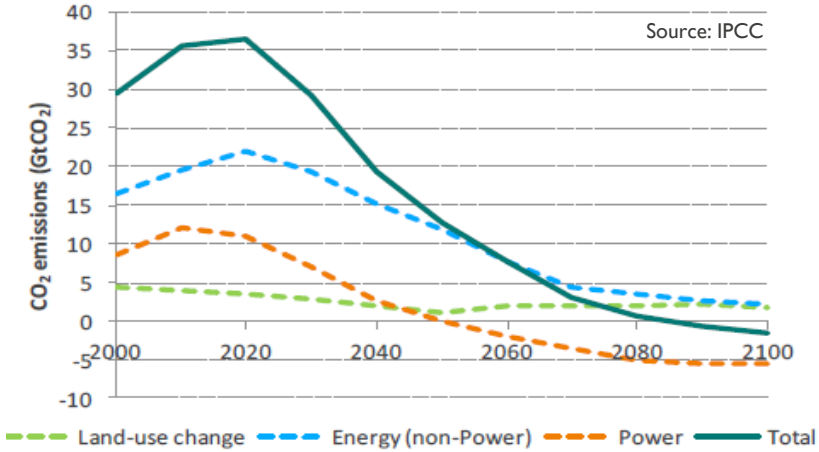
Accelerate your product roadmap & reduce your time to market

THE ENERGY CHALLENGE

MATCHING GROWING CONSUMPTION AND LIMITS ON EMISSIONS

Global primary energy consumption by energy source (2010–2050)
quadrillion British thermal units





ENERGY TRANSITION

Towards a future with
energy at a marginal cost
without harmful emissions

ENERGY RESEARCH @IMEC

Providing technology to transition to a carbon neutral society

Energyville, a leading energy R&D collaboration

Energyville, a leading energy R&D collaboration

imec is partner in EnergyVille
A Flanders-based energy research consortium in Genk (BE)

vito

- Energy technology
- Thermal energy systems
- Battery management
- Sustainable cities

KU LEUVEN

- Electrical engineering
- Building physics
- Mechanical engineering

imec

- Photovoltaic research
- (Solid-state) batteries
- Power to Molecules
- Power devices
- Energy yield forecasting
- Energy management

UHASSELT

- Innovative materials
- PV and system reliability

ENERGY TRANSITION
A CLOSER LOOK

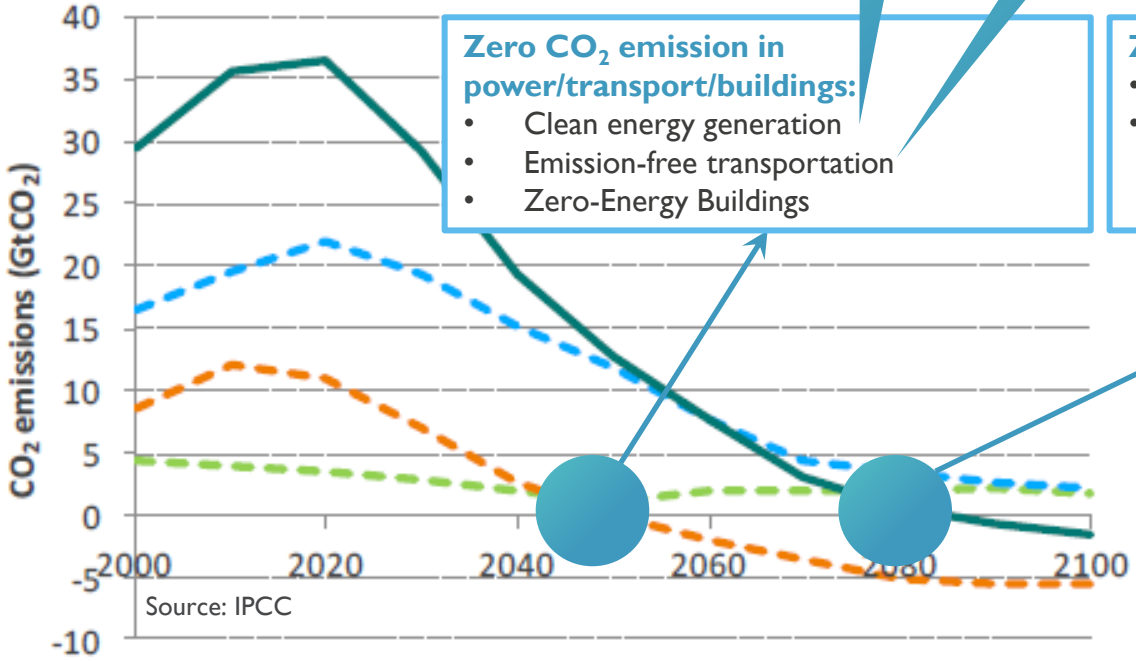
PV

storage

conversion

Zero CO_2 emission in power/transport/buildings:
- Clean energy generation
- Emission-free transportation
- Zero-Energy Buildings

Zero CO_2 emission in total:
- Decarbonization of industry
- "Recycling" CO_2

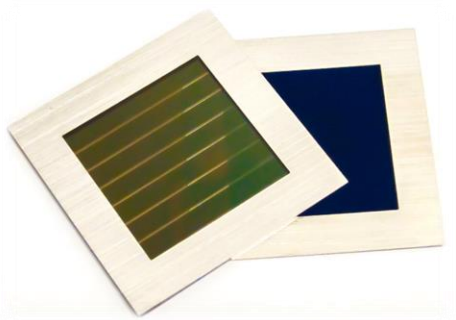


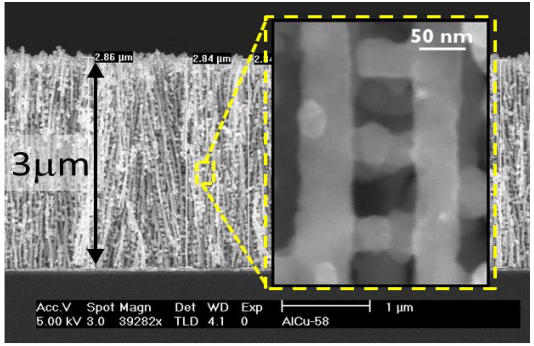
We are talking about

TeraWatts

TeraWatth

ENERGY@IMEC





Generation

PV technology

- Tandems cells/modules
- Integrated PV
- Design and O&M

Storage

Batteries

- Novel electrolytes/electrodes
- Battery cell technology

Conversion

Power-to-Molecules

- Hydrogen generation
- CO_2-conversion

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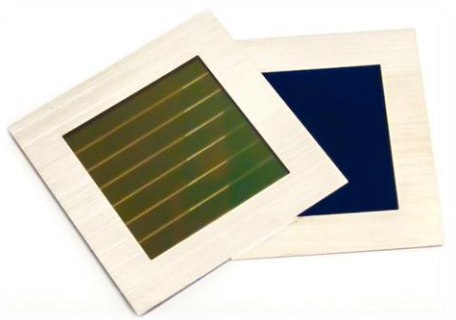

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Power-to-Molecules

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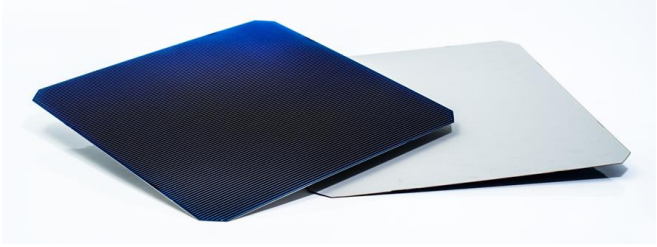
- CO_2-conversion

IMEC PV TECHNOLOGY HIGHLIGHTS

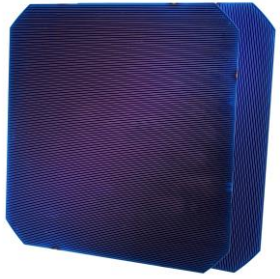
Better monofacial Si solar cells

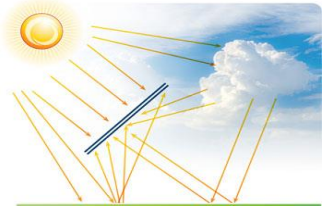
~23%, certified, industrial size, industrial processes

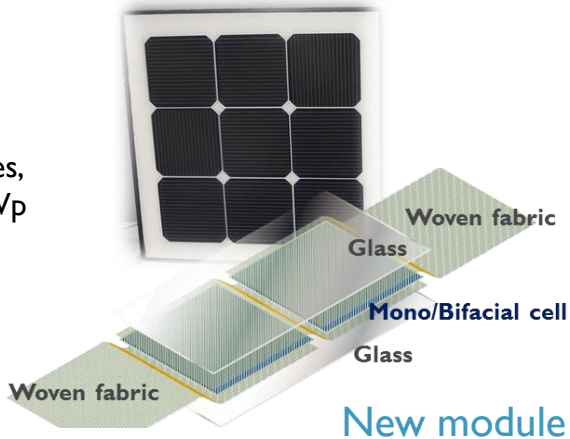


Better bifacial Si solar cells

~23%, industrial size, industrial processes, >95% bifacial, more kWh/kWp







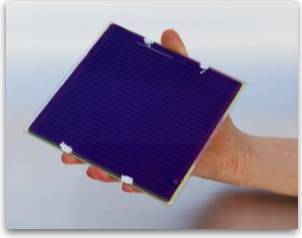
New module interconnection techniques

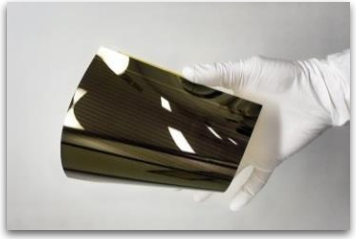
Simplified manufacturing, higher reliability, allowing mass customization

Perovskite thin film PV

Focus on large area, high efficiency, stability, industrialization

Achieving ~13% for 30x30cm²





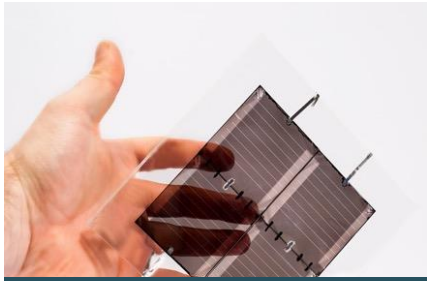
Silicon-thin film tandem solutions

achieving 30.1%

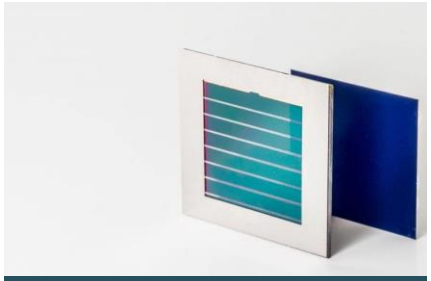
imec Energy Ville SOLLIANCE SOLAR RESEARCH

PV TECHNOLOGY

Cell: focus on back-end (advanced metallization)
Module: interconnection technologies



New silicon PV and thin film PV material and device developments



Tandem cells

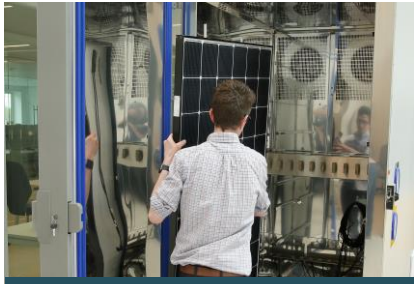
High efficiency PV cell and **module** technology

PV power converters (including modelling, testing and reliability)

Integration of PV in building façades, vehicles and infrastructure

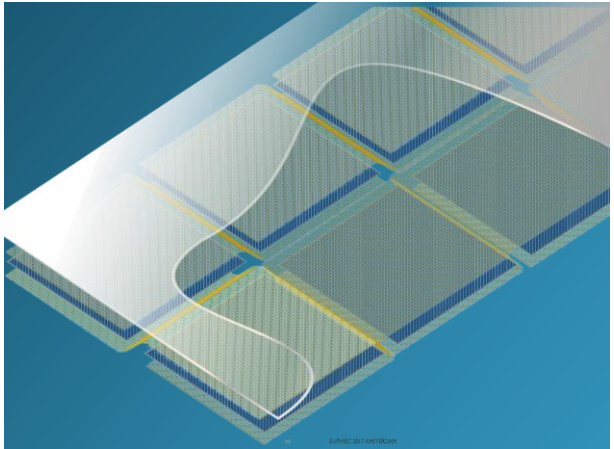
PV cell and module analysis and performance optimization

PV energy yield metrology, simulation & forecasting

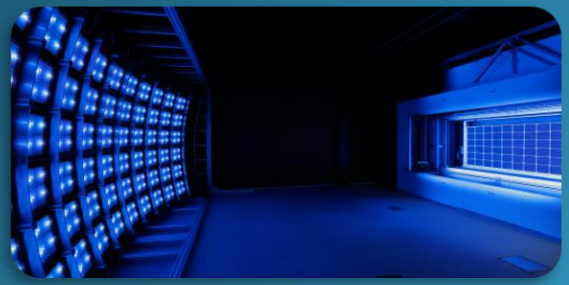


PV module reliability, recycling and re-use

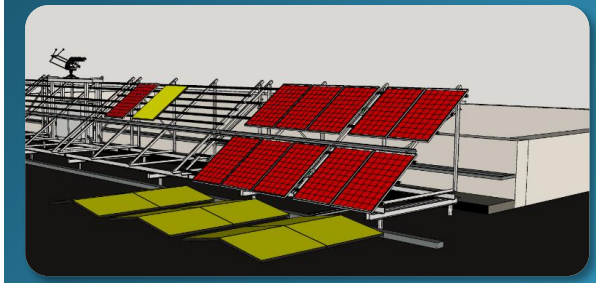
WAFER-PV MODULES AND SYSTEMS OVERVIEW



Novel module interconnection and integration technologies



PV module characterization and reliability



Accurate energy yield simulations

imec EnergyVille

MODULE ASSEMBLY CAPABILITIES

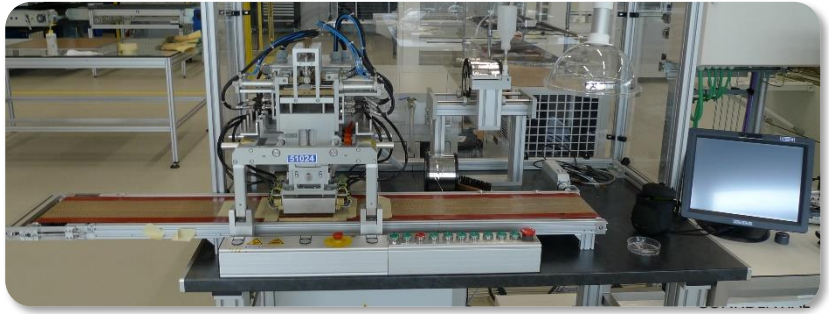
Lamination

- Modules up to 1.1x1.8 m2, 15 cm thick (can be curved)
- Single- or double-membrane, accurate pressure control
- Uniform heating (±1°C) up to 180°C

Automated module manufacturing

for new technologies (shingling, woven fabrics,...)

- Up to full-size modules
- Pick & place, dispensing, lasering, soldering



Semi-automated tabbing-stringing

- Industry-like soldering process

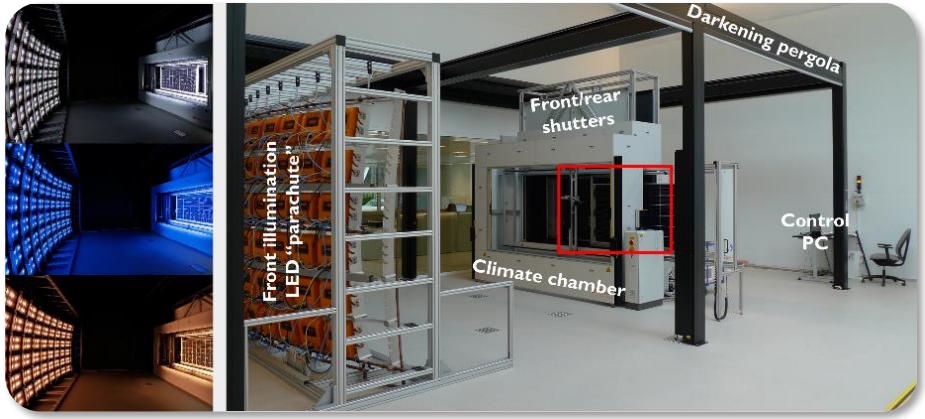
imec Energy Ville

MODULE CHARACTERIZATION AND TEST CAPABILITIES

Solar simulation (up to 1.1x2.0 m2)

- 18-LED tunable spectrum
- Module temperature control 10 - 80°C
- Light intensity control (0.1 - 1.2 sun)
- Rear illumination (bifacial modules)

(also EL inspection & EQE-Reflection)



Reliability testing (up to full-size modules)

- Thermal cycling, damp heat, 3xUV testing
- PID (>1000V)

Outdoor testing

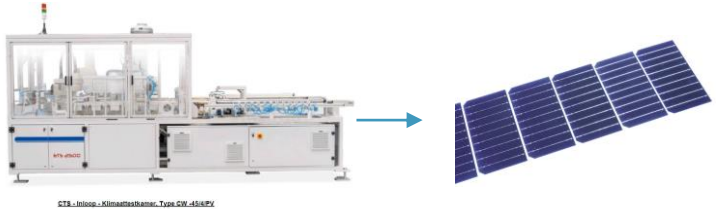
- Open rack South
- BIPV (facade) East, South and West

imec EnergyVille

PLANNED INVESTMENTS IN 2022/2023

Thanks to PV4Industrie4.0 (EFRO) project with U Hasselt + Soltech

- **Multi-BB stringers (imec + Soltech):**
  - Soltech: production stringer for M10 PERC 10BB
  - Imec: R&D stringer for PERC/TOPCon/HJT/IBC



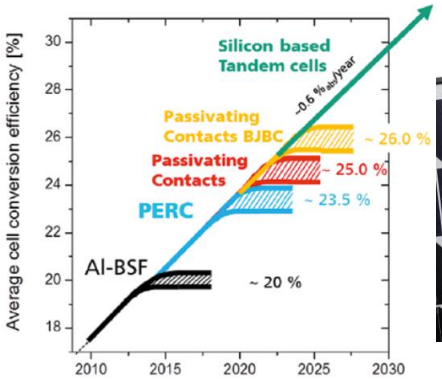
- **Large area climatic chamber (U Hasselt):**
  - modules up 2.5m, total mass up to 600 kg
  - for TC, DH, HF, PID, etc. testing

- **Large area A+A+A+ flasher (imec):**
  - working area up to 2.6x1.4m
  - A+A+A spectrum (300-1200nm),

- **Fiber gratings and other tools (U Hasselt):**
  - Goal: make our own fiber gratings for in-situ sensing

Compatible with latest cell technologies

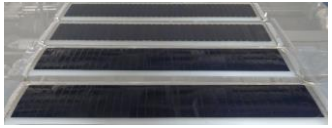
- **Industry needs:**
  - compatibility with latest cell technologies (PERC, TOPCON/HJT, IBC, Pk tandems)
  - reduced cell-to-module (CTM) losses
  - robust and cost-effective technologies



M. Hermle, Solar Industry Forum 2017, EUPVSEC Amsterdam

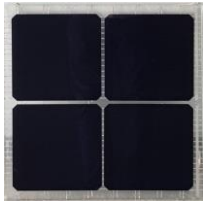
- **Our focus:**
  - Market research (technology watch, etc.)
  - State-of-the-art stringing technologies:
    - patented imec's multiwire (TWILL, 3D weave)
    - multi-BB IR soldering
    - shingling for Pk tandems
  - accelerated reliability testing (TC, DH, HF, ML, in-situ sensing, etc.)

Multi-BB IR soldering



shingled strings

Busbarless TOPcon + imec's TWILL technology



Busbarless IBC + imec's 3D weave

OPTIMIZED DESIGN OF SEMI-FABRICATES AND MODULES FOR INTEGRATED PV

BIPV, VIPV, UPV, IIPV, Agri-PV, Space PV, etc.

- **Industry needs:**
  - Increase adoption of integrated PV to support energy transition (self-consumption, etc.)
  - Better integration (aesthetics, modularity, etc.)
  - Lower engineering and manufacturing costs

- **Our focus:**
  - Tailor module designs based on end-user requirements (aesthetics, safety, costs, etc.)
  - Flexible automated manufacturing (pick-and-place)
  - Digitalization (support BIM modeling, industry4.0)
  - Strong partnerships with regional and global PV manufacturing value chain

Building-integrated PV (BIPV)

Vehicle-integrated PV (VIPV)

Urban PV (UPV)

Infrastructure-integrated PV (IIPV)

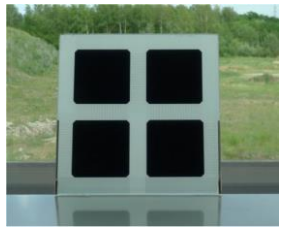
Agrivoltaics (Agri-PV)

Space PV (SPV)

BIPV curtain wall demo

Sound barrier wall demo

VIPV sunroof concept

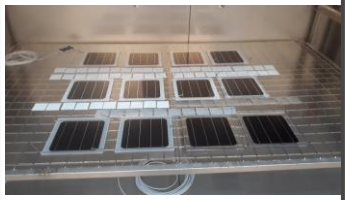


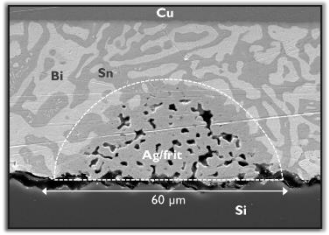
Agri-PV demo

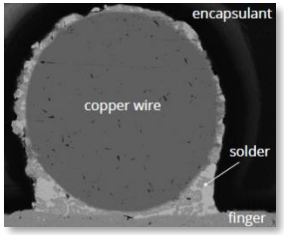
ADVANCED RELIABILITY TESTING

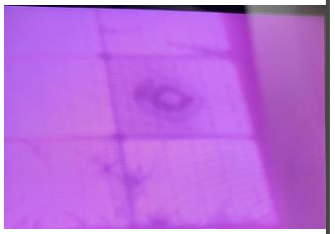
Climatic chambers (modules up to 2m height)

- IEC61215/IEC61730:
  - Thermal cycling, damp heat, humidity freeze, 3x UV
  - Sequential testing
  - Low T storage at -40C for 48h
  - PID >1000V
- Automotive
  - ECE R43: High T storage at 100C for 120h
  - ISO 4892-2: 1000 W/m^2 for 2h



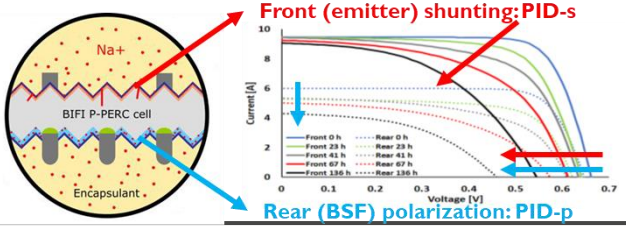






Examples of work conducted:

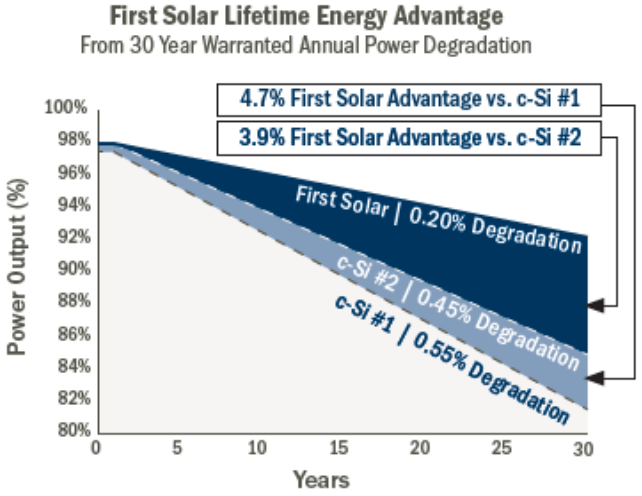
- Accelerated reliability testing of various module types
- 227g ball drop testing of glass and glass-free modules
- Evaluation of new encapsulants, backsheets, etc.
- PID testing of bifacial modules (PERC, TOPCon, SHJ)



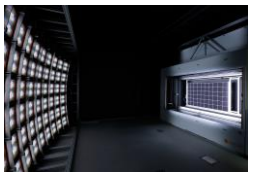
ADVANCED CHARACTERIZATION AND MODELING

To support lower initial and annual degradation rates

- **Industry needs:**
  - Lower initial and annual degradation rates
  - Better understanding of root-causes of failures and degradation

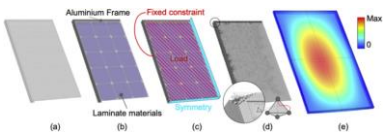


- **Our focus:**
  - Failure mode and effect analysis (FMEA)
  - State-of-the art characterization tools:
    - Optical/electrical (BTimaging, Wavelabs, LOANA, ...)
    - Mechanical (rheometer, in-situ stress, etc.)
    - Thermal (in-situ temperature measurements, etc.)
    - Reliability (climatic chambers, mechanical load, etc.)
  - Advanced modeling:
    - Solar cells (Quokka2/3, Sentaurus, etc)
    - PV modules (SunSolve, CTMcalc, etc.)
    - Finite Element Modeling (COMSOL Multiphysics)



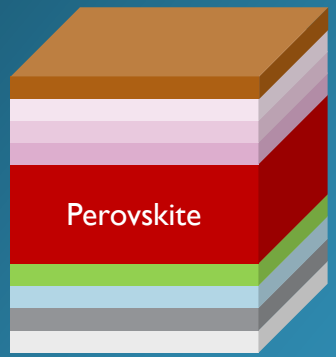
Wavelabs Sinus2100

2-axis tracker

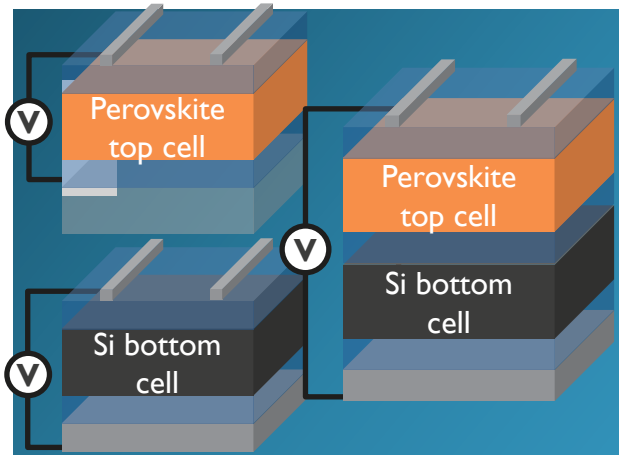


FEM modeling of module

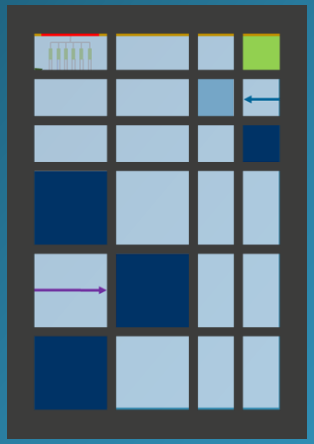
THIN FILM PHOTOVOLTAICS



Device structure: materials, upscaling & reliability



Tandem devices



Integration in various applications

imec Energy Ville SOLLIANCE

SOLLIANCE IS…

THIN FILM SOLAR RESEARCH
SOLLIANCE

imec

TNO innovation for life

JÜLICH FORSCHUNGSZENTRUM

TU/e

UHASSELT

TU Delft

UNIVERSITY OF TWENTE.

university of groningen

SOLLIANCE IS A PARTNERSHIP OF EUROPEAN RESEARCH ORGANIZATIONS AND INTERNATIONAL INDUSTRIAL PARTNERS WORKING IN THIN FILM PHOTOVOLTAIC SOLAR ENERGY

SOLLIANCE IS >5000M² OF COMPLEMENTARY TF PV FACILITIES

Solliance/imec in Genk (BE)

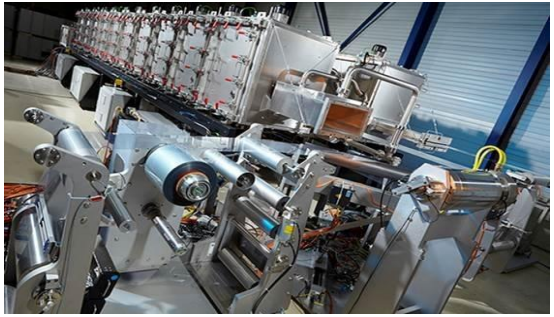

Solliance/imec facilities in Genk, BE

imec

Solliance/TNO building in Eindhoven (NL)


Solliance/TNO facilities in Eindhoven, NL

TNO



Imec key facilities for perovskites

35x35 cm^2 linear sputtering and (co-)evaporation cluster system

30x30 cm^2 picosecond laser scribing

Blade coater (20x20 cm2)

30x30 cm^2 slot die coating

Module encapsulation

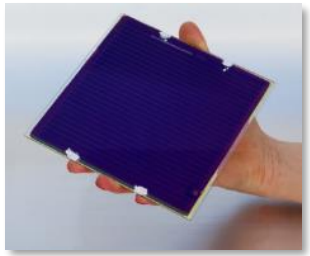
View on processing facilities

STATUS PEROVSKITE TECHNOLOGY

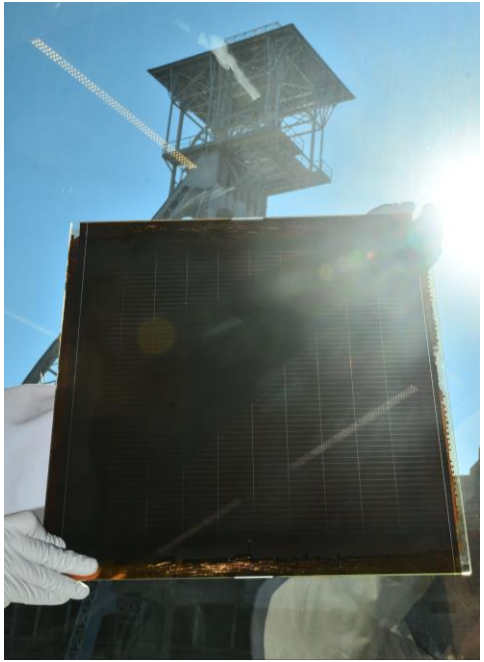
30 X 30 CM PROCESSING TECHNOLOGY AVAILABLE

- Solliance focuses on
  - upscaling
  - efficiency
  - stability
  - semi-transparent
- Glass or metal based ridged modules
- Sheet to Sheet & Roll-to-roll for flexible modules

10cm²
Module on PET foil



15x15cm²
Module on glass

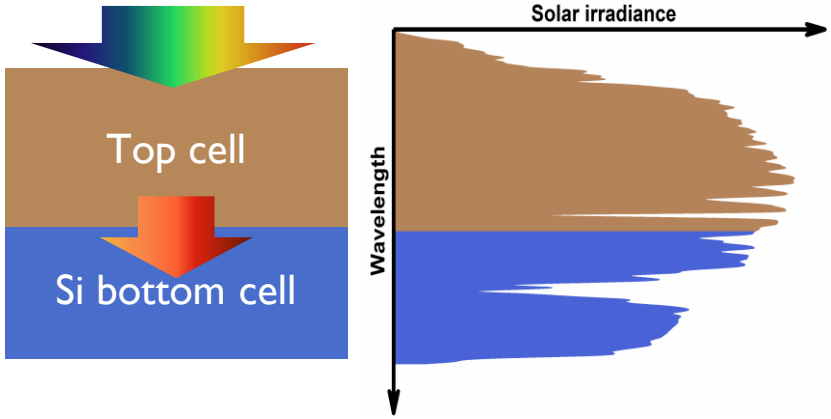


30x30cm²
Module on glass (>**13%**)

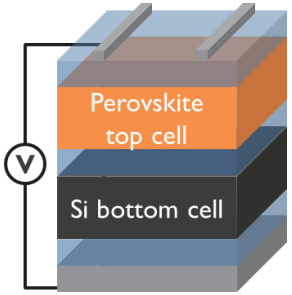
imec Energy Ville SOLLIANCE SOLAR RESEARCH

COMBINE SILICON WITH PEROVSKITES

TOWARDS +30% TANDEMS



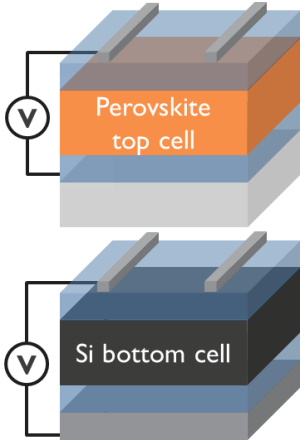
- More efficient usage of the solar spectrum
- Surpass the theoretical limit of Si-PV
- Enhance overall energy yield
- Imec works on both 2T and 4T concepts



Two Terminal (2T)

PRO
- Less parasitic absorption
- Less exterior electronics

CON
- Critical current matching
- Perovskite quality influenced by the surface of bottom cell



Four Terminal (4T)

PRO
- Independent fabrication and optimization of subcells
- Easy assembly
- Higher energy yield than 2T

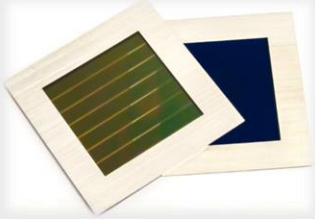
CON
- More exterior electronics
- More parasitic absorption

Key results: upscaling both 2T and 4T tandems

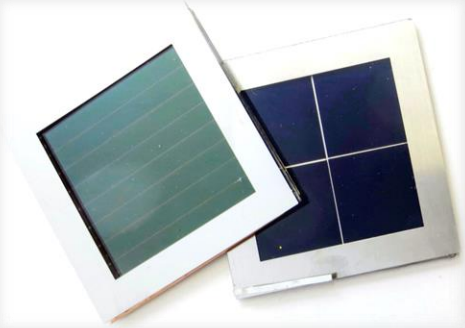
Scalable 4T Pk/Si tandems

Cell-on-cell,
0.13 cm^2, 27.1%

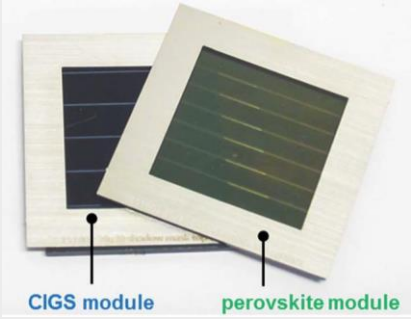
Pk module-on-cell,
4 cm^2, 25.3%



Module-on-module,
16 cm^2, 20.2%



4T Pk/CIGS tandem

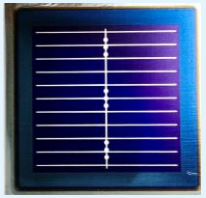


16 cm^2, 21.3%

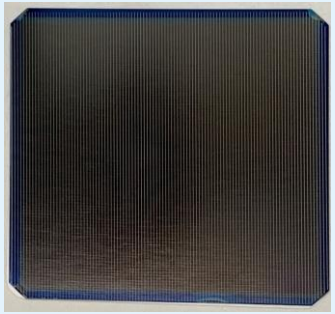
(24.5% at 0.13 cm^2 cell-on-cell level)

Scalable Pk/Si 2T tandems

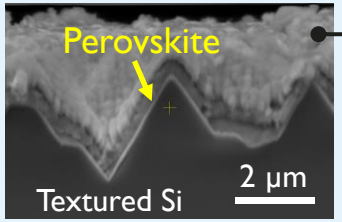
~25%
~1 cm^2
Pk/Si cell



~17%
~16 cm^2
Pk/Si cell

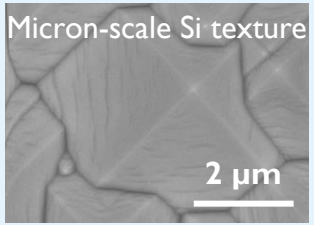


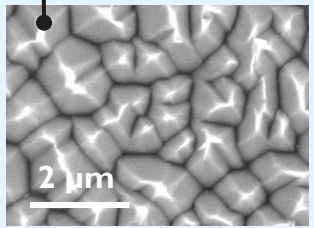
Full wafer size (M2)
Pk/Si tandem demo

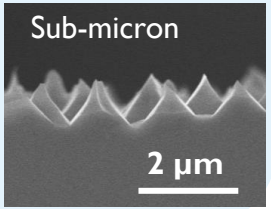


Hybrid Pk coating: tailoring the Pk depo to Si surface texture

Sub-micron texturing: tailoring Si surface texture to std Pk depo







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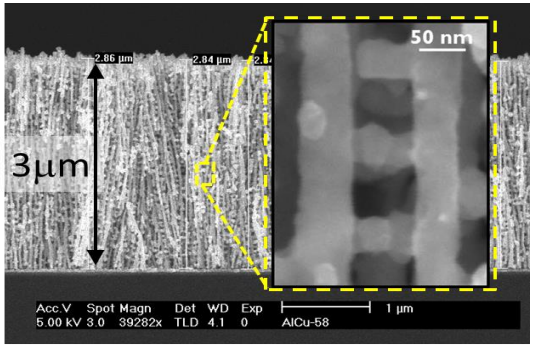
Electrochemical Storage and Conversion Group



Storage

Batteries

- Novel electrolytes/electrodes
- Battery cell technology

Conversion

Power-to-Molecules

- Hydrogen generation
- CO_2-conversion

Generation

PV technology

- Tandems cells/modules
- Integrated PV
- Design and O&M

IMEC NANOTECHNOLOGY FOR DISRUPTION IN ELECTROCHEMICAL STORAGE AND CONVERSION TECHNOLOGY

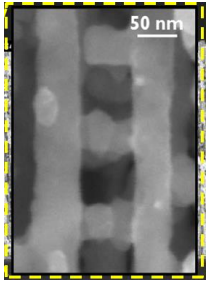
Imec's nanotechnology know-how and expertise brings a very **different angle** to the design of electrodes and reactor components: attention to 'true miniaturization' and control of the interfaces.

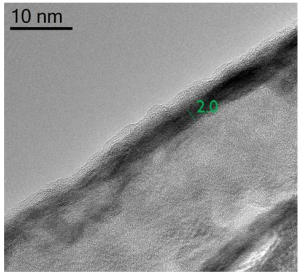
→ **Aiming for disruption in performance**
- to lower the cost of, for example, production of green hydrogen

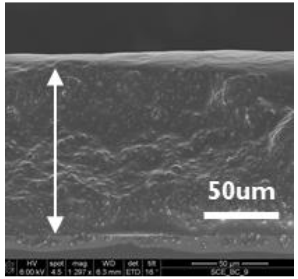
→ **Guided by a technology platform roadmap**
- with increasing complexity in materials and components for next generation technologies

→ **Leading to upscale manufacturable processes**
- From proof-of-concept in lab to system development

- Nanomaterials
- Surface/Interface engineering
- Thin-film coating techniques
- Electrochemistry
- Nanoionics



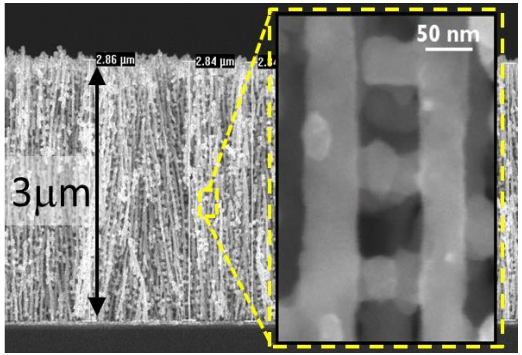




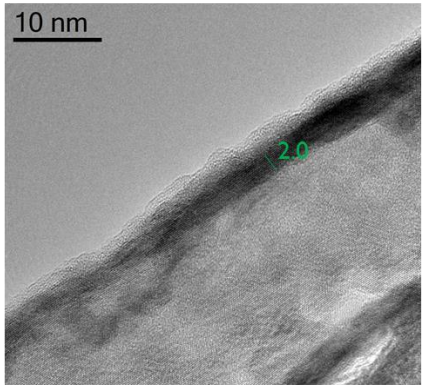
EXPERTISE ON NANO-SCALE (ELECTRO)CHEMICAL FABRICATION

CENTERED AROUND THREE TECHNOLOGY BUILDING BLOCKS

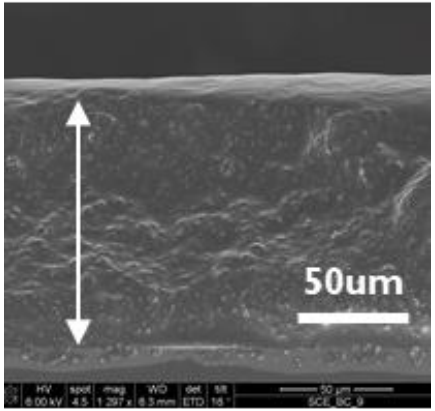
Bottom-up (nano-) structured electrodes with engineered architecture and high-surface area



Thin-film interphase engineering with tailored (electro)chemical properties

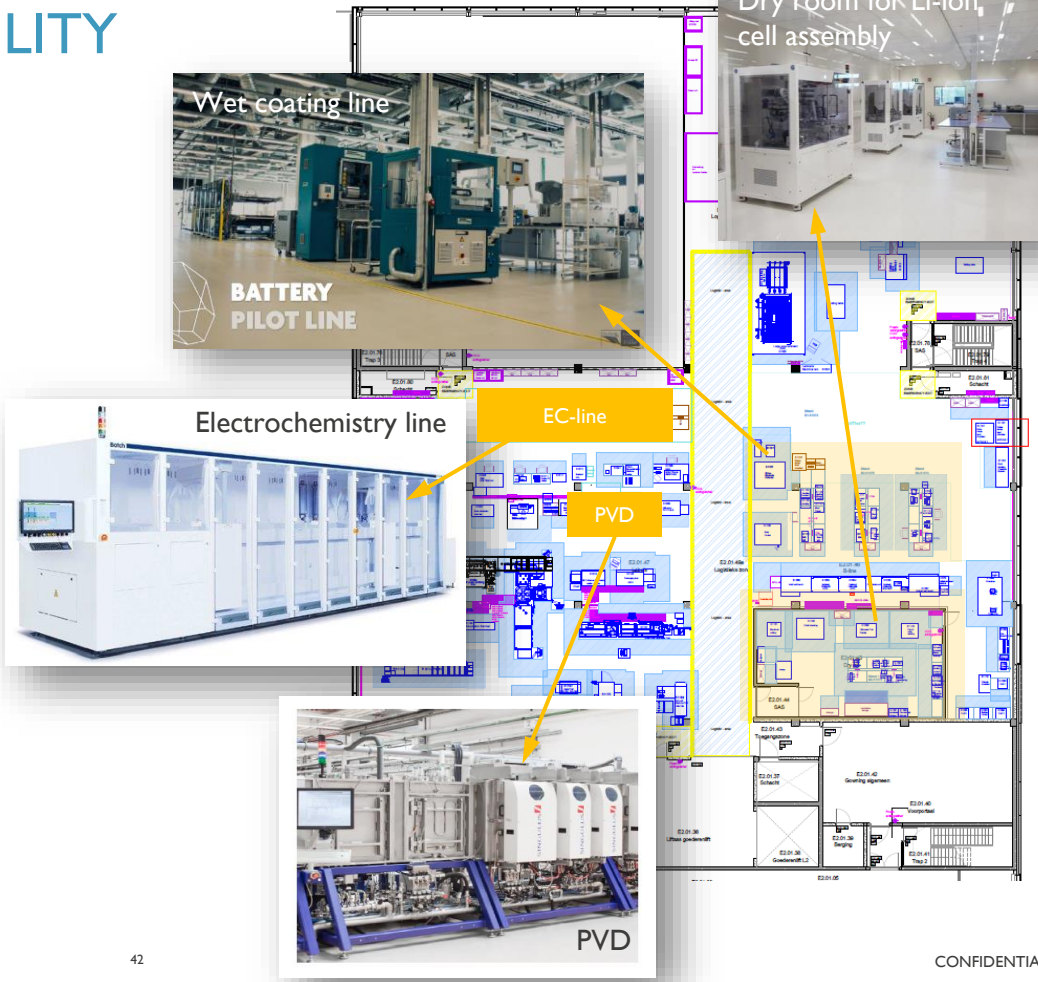


nano-composite membranes and electrolytes with configurable chemistry and tunable nano-porosity



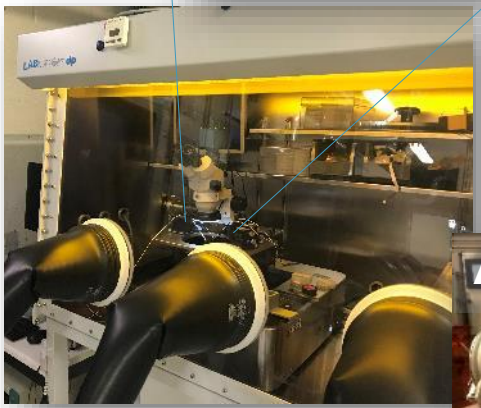
SCALING OUR TECHNOLOGY TOWARDS MANUFACTURABILITY AND PROTOTYPING

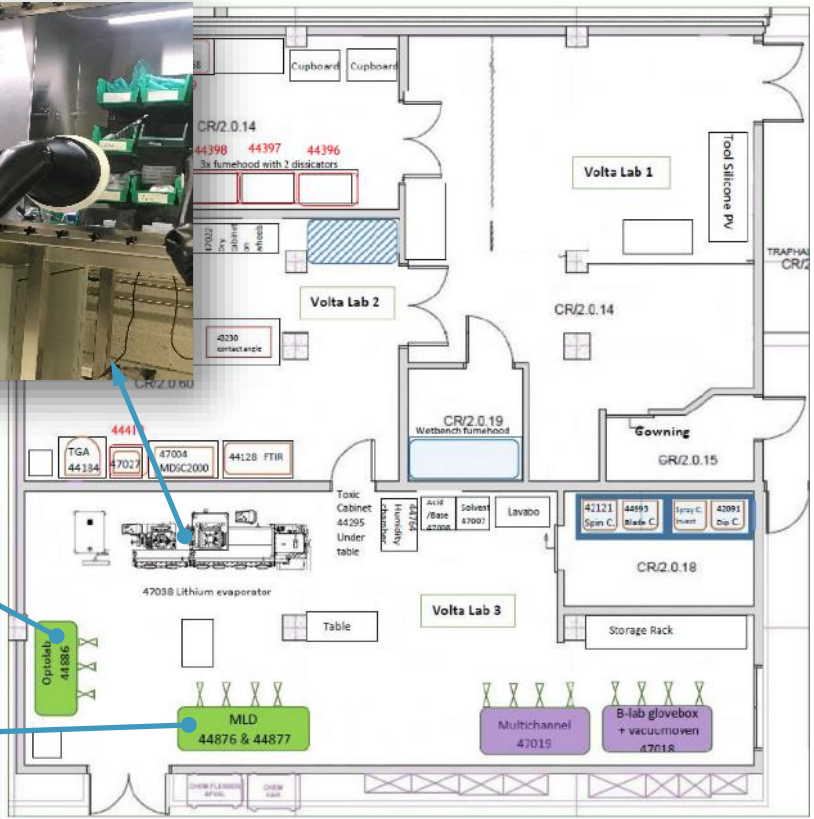
EnergyVille is a collaboration between the Belgian research partners KU Leuven, VITO, imec and UHasselt in the fields of sustainable energy and intelligent energy systems.



MATERIALS AND INTERFACE LAB – IMEC LEUVEN

THIN-FILM BATTERIES AND ARTIFICIAL INTERPHASE COATINGS





ENERGY@IMEC

Generation

PV technology

- Tandems cells/modules
- Integrated PV
- Design and O&M

Storage

Batteries

- Novel electrolytes/electrodes
- Battery cell technology

Conversion

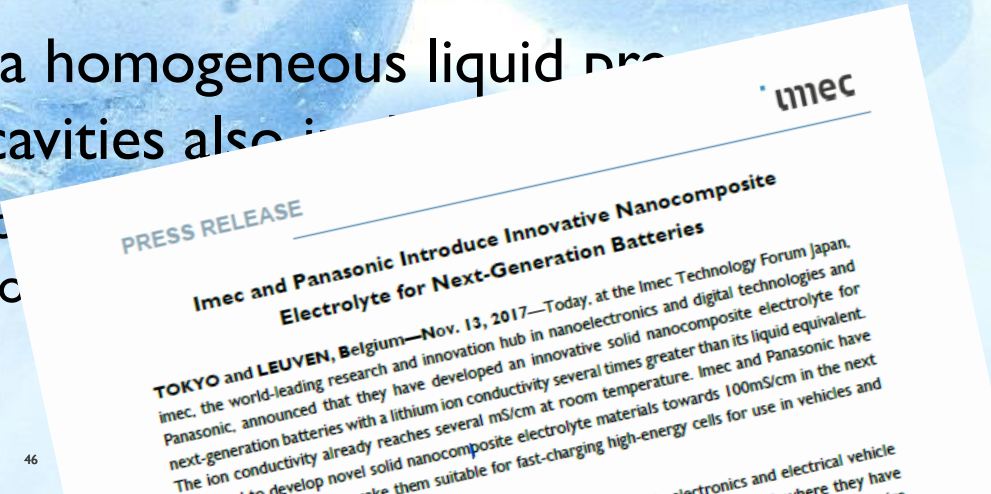
Power-to-Molecules

- Hydrogen generation
- CO_2-conversion

IMEC'S SOLID NANO-COMPOSITE ELECTROLYTE (SCE)

ENABLING HIGH CAPACITY – HIGH RATE SOLID STATE CELLS

1. We engineer the ion conductivity beyond that of liquid in a solid nanocomposite electrolyte using a proprietary process
   - we are working towards solid electrolytes with ion conductivities towards 100 mS/cm for FAST CHARGING and HIGH POWER cells
2. The electrolyte is made from a homogeneous liquid pre
   solution allowing to fill small cavities also i
   - A materials strategy is defined to
     HIGH ENERGY cells with (1) mo


imec

PRESS RELEASE

Imec and Panasonic Introduce Innovative Nanocomposite Electrolyte for Next-Generation Batteries

TOKYO and LEUVEN, Belgium—Nov. 13, 2017—Today, at the Imec Technology Forum Japan, imec, the world-leading research and innovation hub in nanoelectronics and digital technologies and Panasonic, announced that they have developed an innovative solid nanocomposite electrolyte for next-generation batteries with a lithium ion conductivity several times greater than its liquid equivalent. The ion conductivity already reaches several mS/cm at room temperature. Imec and Panasonic have to develop novel solid nanocomposite electrolyte materials towards 100mS/cm in the next ke them suitable for fast-charging high-energy cells for use in vehicles and

lectronics and electrical vehicle here they have

APPLICATION SPECTRUM OF Li-ION BATTERIES

Rechargeable Li-ion batteries

Power on board

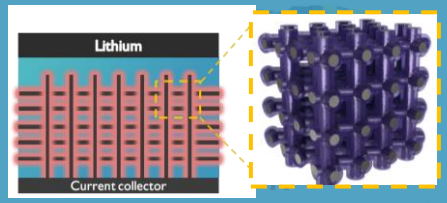
distributed wireless sensors and communicators...

Power in the Package

Wearable and Flexible

Smart carts, patches, wearables and flexible electronics...

Portable electronics

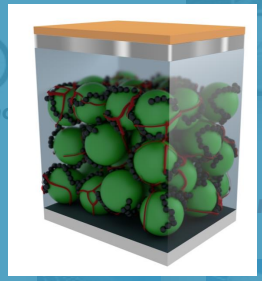


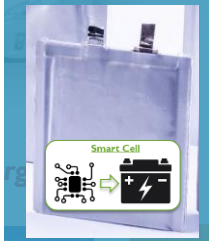
Formable solid-state batteries

Smart watch, phones, tablets, PCs

Vehicles

Bikes, autom





Large capacity Solid-state cells

storage

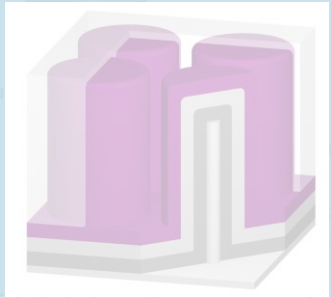
< mWh < < Wh < < kWh < < MWh

IE-04 IE-03 IE-02 IE-01 IE+00 IE+01 IE+02 IE+03 IE+04 IE+05 IE+06

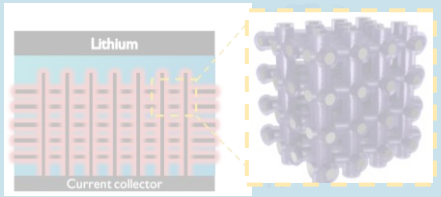
imec Energy Ville

APPLICATION SPECTRUM OF Li-ION BATTERIES

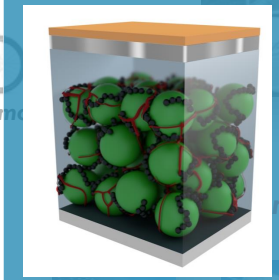
Rechargeable Li-ion batteries

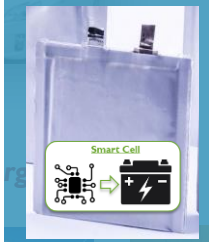


Power in the Package



Formable solid-state batteries





Large capacity Solid-state cells

< mWh < < Wh < < kWh < < MWh

IE-04 IE-03 IE-02 IE-01 IE+00 IE+01 IE+02 IE+03 IE+04 IE+05 IE+06

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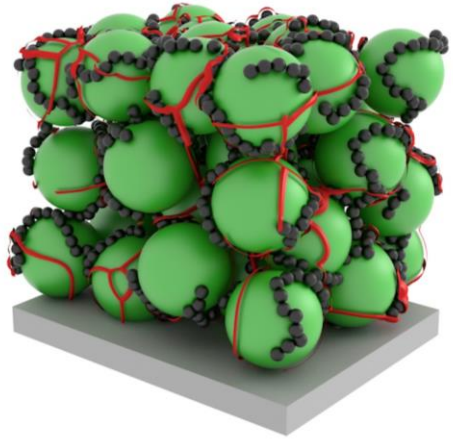
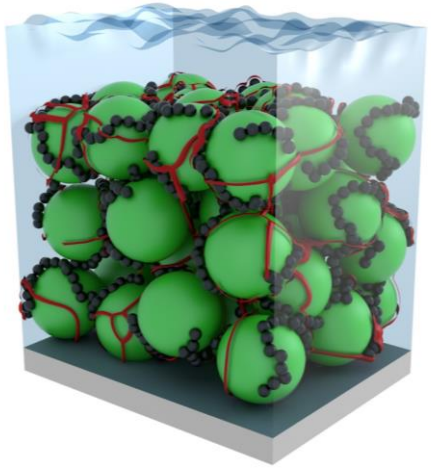
UNIQUE LIQUID-TO-SOLID APPROACH

ADDRESSING MAJOR ISSUES OF SOLID-STATE BATTERIES: MANUFACTURING AND MECHANICAL COMPLIANCE



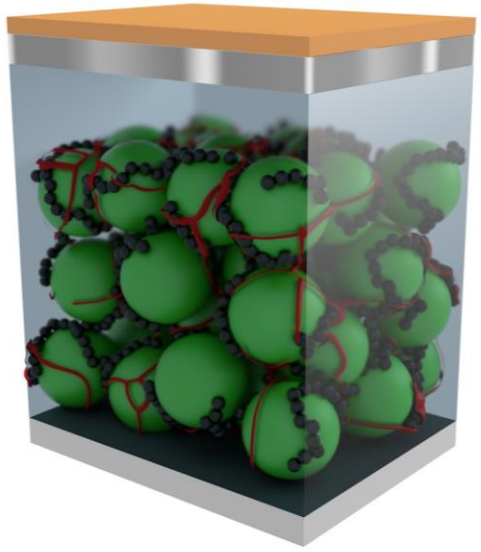
1. Porous cathode

Conventional battery manufacturing



2. Impregnation with liquid precursor

Compatible with conventional battery processing



3. Solidification and lamination with our lithium nano-anode

Elastic materials = mechanically compliant solid-state cell

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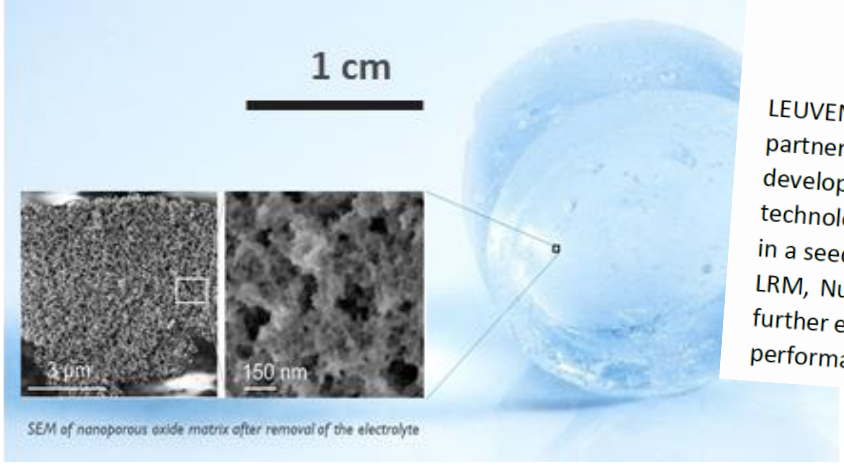
NANOTECHNOLOGY FOR SOLID-STATE BATTERIES

SOLITHOR SPINOFF COMPANY OF IMEC

Nano-Composite Electrolyte material developed at imec, enabling the cost-effective manufacturing of solid-state Lithium Metal Batteries



SEM of nanoporous oxide matrix after removal of the electrolyte

Press release Monday 16 May 2022

SOLiTHOR

imec

Imec spin-off SOLiTHOR closes a €10M seed investment round to develop a new disruptive solid-state battery cell technology

Breakthrough approach to solid-state batteries will break the barriers for the electrification of transport

LEUVEN (Belgium) - 16 May 2022 – SOLiTHOR, the newly created spin-off company from imec – partner in the top European energy R&D innovation hub EnergyVille – is spearheading the development, manufacturing and commercialisation of innovative solid-state lithium (Li) battery cell technology to reliably and economically offer high energy storage solutions. SOLiTHOR raised €10M in a seed investment round led by imec.xpand supported by a strong investment syndicate including LRM, Nuhma and FPIM. The proceeds will be used to develop the technology required to enable further electrification of our transport industry with solutions that address current issues in autonomy, performance, longevity and safety.

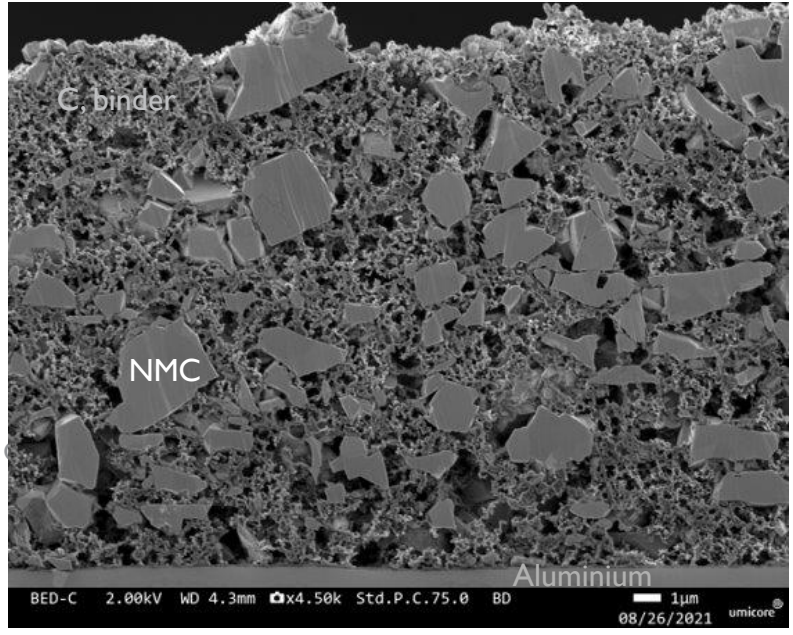
Imec spin-off SOLiTHOR closes a €10M seed investment round to develop a new disruptive solid-state battery cell technology

THIN-FILM MODEL SYSTEM TO SUPPORT INDUSTRY DEVELOPMENTS

TO ENGINEER *ARTIFICIAL INTERPHASE* COATINGS AND STUDY THE INTERFACES

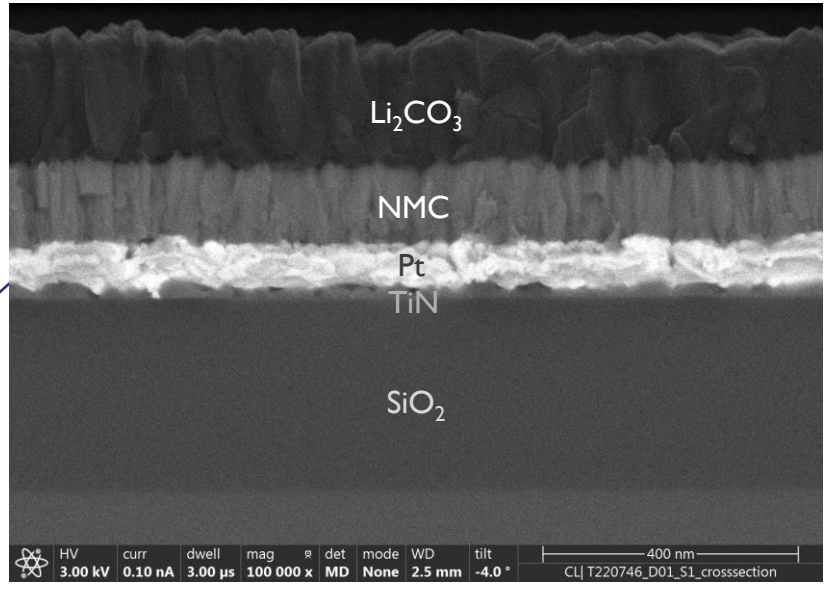
Powder composite electrode

Zillion *ill-defined interfaces*



Thin-film model system

Single *well-defined interfaces*



THIN-FILM MODEL SYSTEM TO SUPPORT INDUSTRIAL DEVELOPMENTS

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Powder composite electrode

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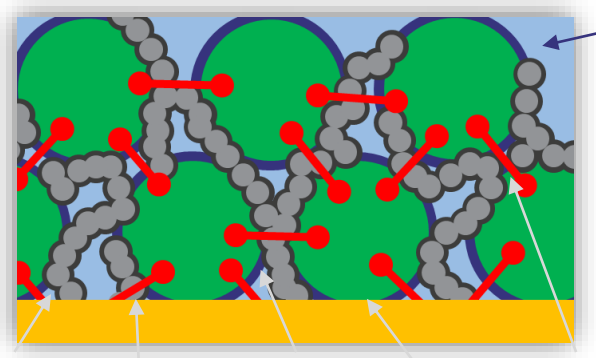
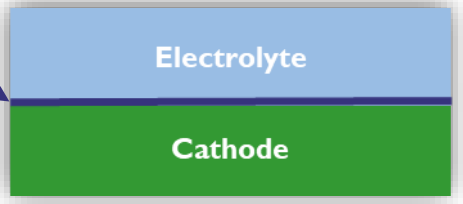


Electrolyte/Cathode interface

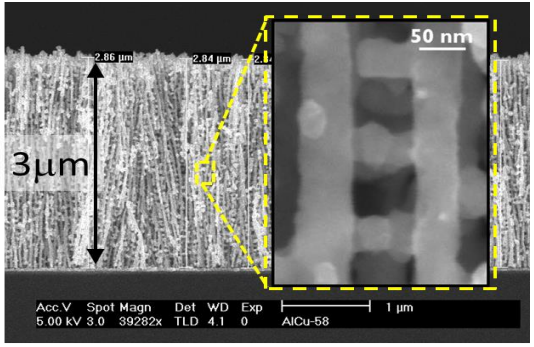
Thin-film model system

One *well-defined defined interfaces*



We make experimental model systems using thin film deposition (PVD,ALD) and patterning to simulate and optimize the individual interfaces and to extract kinetic and transport properties which can be input for theoretical models

ENERGY@IMEC



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- Integrated PV
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Power-to-Molecules

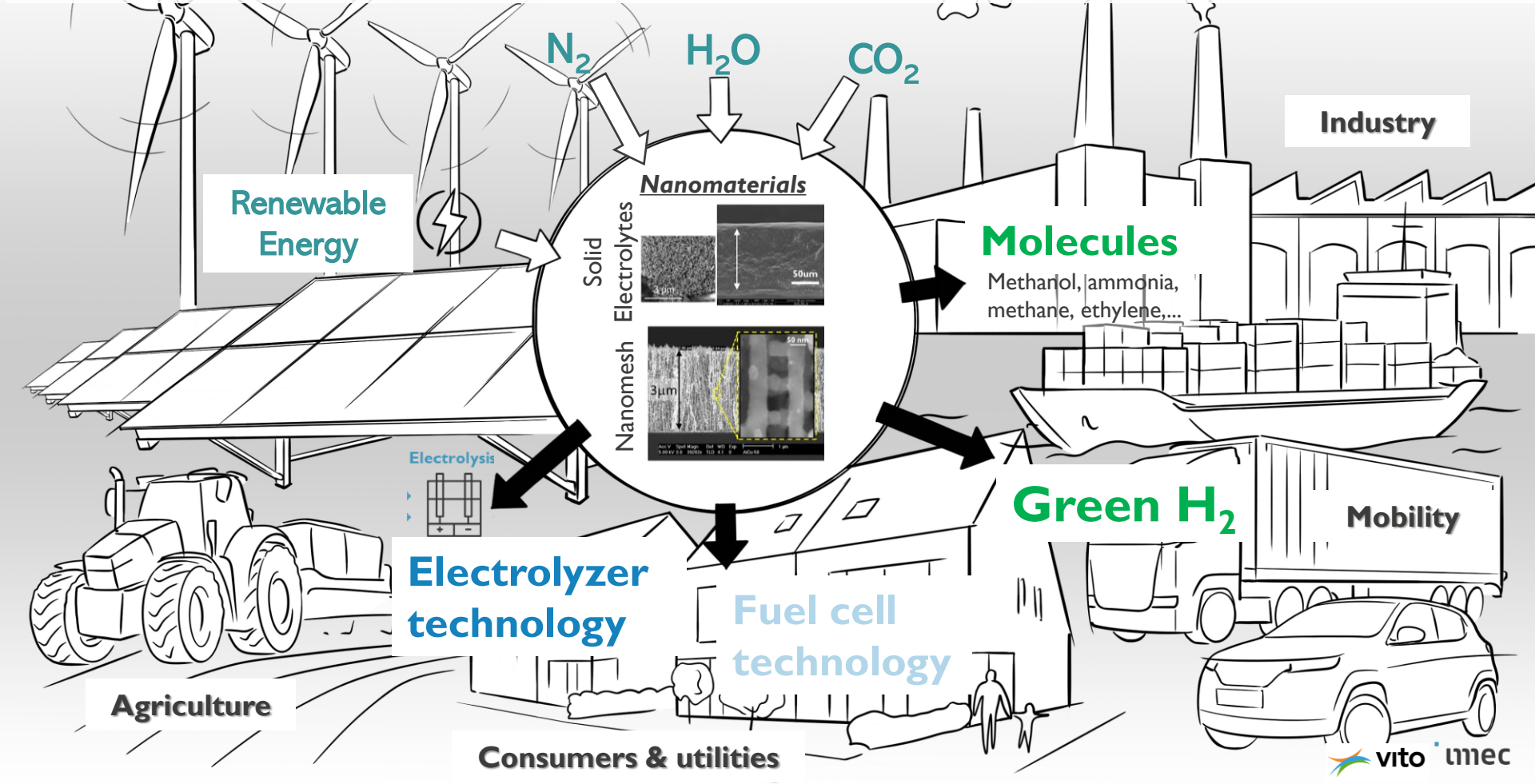
- Hydrogen generation
- CO_2-conversion

POWER-TO-MOLECULES ACTIVITIES

Check out “Power-to-Molecules (P2M)” from imec on Vimeo.
https://vimeo.com/437796118

Power to molecules (and back)

Check out “Power-to-Molecules (P2M)” from imec on Vimeo.
https://vimeo.com/437796118



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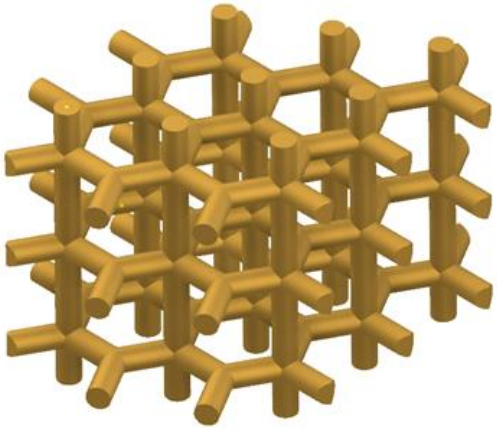
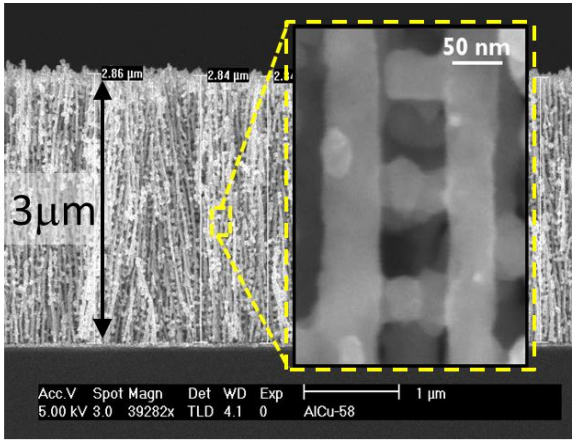
INTRODUCING OUR NANOMESH ELECTRODES

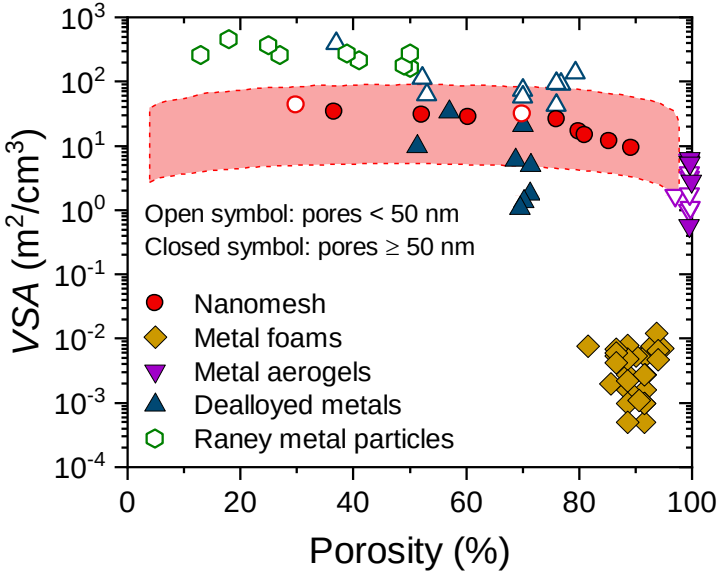
HIGH SURFACE AREA + HIGH POROSITY + MECHANICALLY ROBUST

- Very large surface area and large porosity allows miniaturization of MEA
  - The surface area of a **soccer field in a can of coke** while still 75% empty
- Regularly spacing and highly interconnected nanowire scaffold





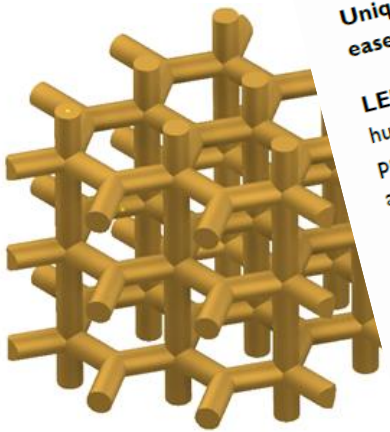
ACS Appl. Mater. Interfaces 2018, 10, 44634−44644



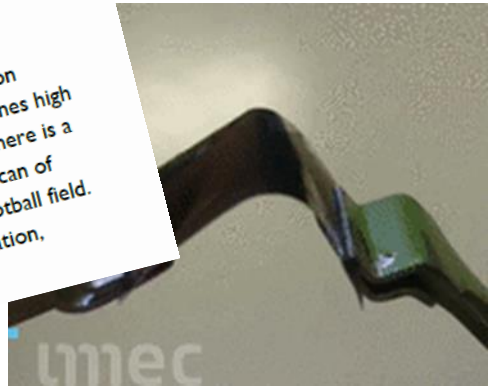
"NANOMESH" ELECTRODE

NEW NANOMATERIAL C… …TAL BATTERIES

- We have … …gular" nanospacings between … …fferent from "sponges")
- The nanon… …nd can help us solve the issue of … …e batteries



…standing and flexible



PRESS RELEASE

Novel nanomaterial promises improvements in batteries and many more sustainable applications

Unique nanomesh combines high porosity, unprecedented surface-to-volume ratio and ease of manufacturing

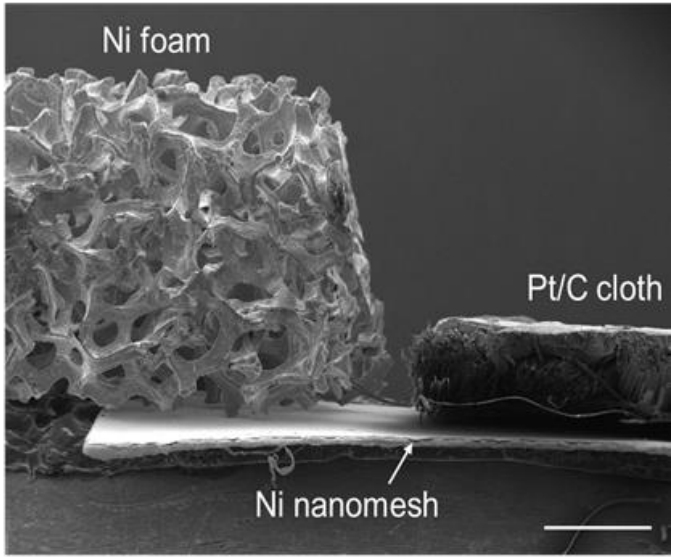
LEUVEN (Belgium), MARCH 12, 2019 — Today, imec, a world-leading research and innovation hub in nanoelectronics, energy, and digital technologies and KU Leuven, both partners in EnergyVille, present a novel nanomesh material that could mean a breakthrough in a variety of sustainable-application sectors. The new nanomesh material is a three-dimensional nanometer-scale (metal) grid structure with highly regular internal dimensions. Thanks to a combination of its unique material properties and the ease of manufacturing, it holds the promise to become widely applicable in (sustainable) industrial applications. Think about more efficient batteries, better catalytic convertors, fuel cells and hydrogen production.

The nanomesh material is a 3D structure of nanowires that are horizontally interconnected on multiple levels, showing highly regular internal spacings and dimensions. As a result, it combines high porosity with an unprecedented surface-to-volume ratio. For each micrometer thickness, there is a 26-fold increase of available surface area. To visualize this: when filling a volume of a small can of soda, it would remain 75% empty while containing a surface area equal to the size of a football field. On top of that, the internal and external dimensions can be tuned to almost any specification, making it potentially compatible with a multitude of application requirements.

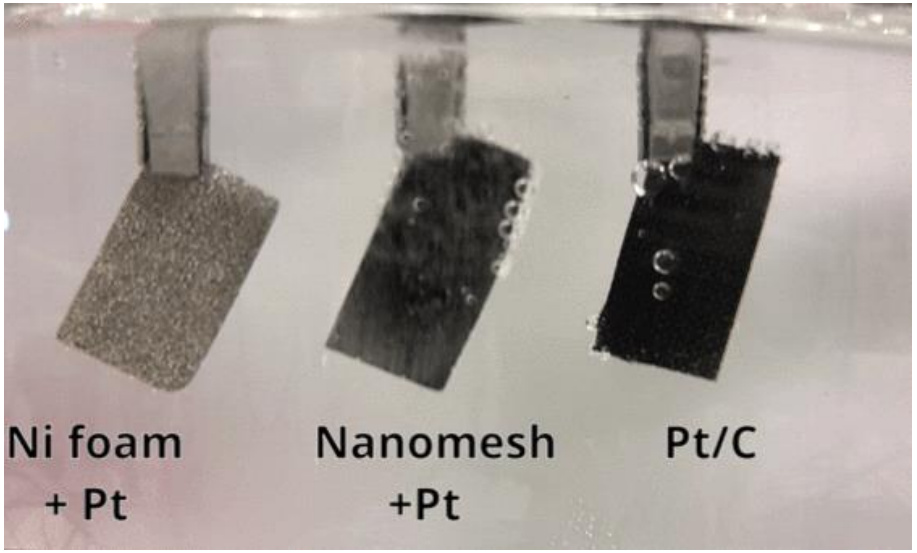
NANOMESH @ WORK

NICKEL NANOMESH VERSUS NICKEL FOAM AND CARBON CLOTH FOR WATER ELECTROLYSIS

- The 4.75 μm thick nanomesh layer has an area enhancement of 126X
- The 1.5mm thick foam has an area enhancement of ~10x

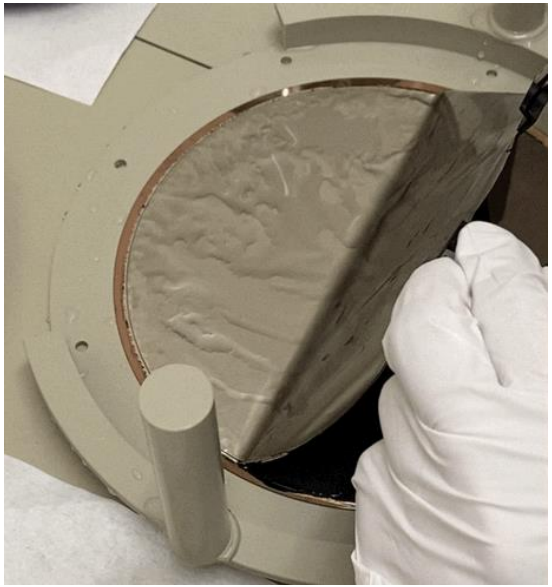


Example of HER at Ni nanomesh, Ni foam and C-cloth



flexible 4.75 μm thick nanomesh (76% porosity, 64 nm pore size, 126 cm^2 footprint-normalized surface area

NANOMESH UPSCALING



Lab-scale fabrication

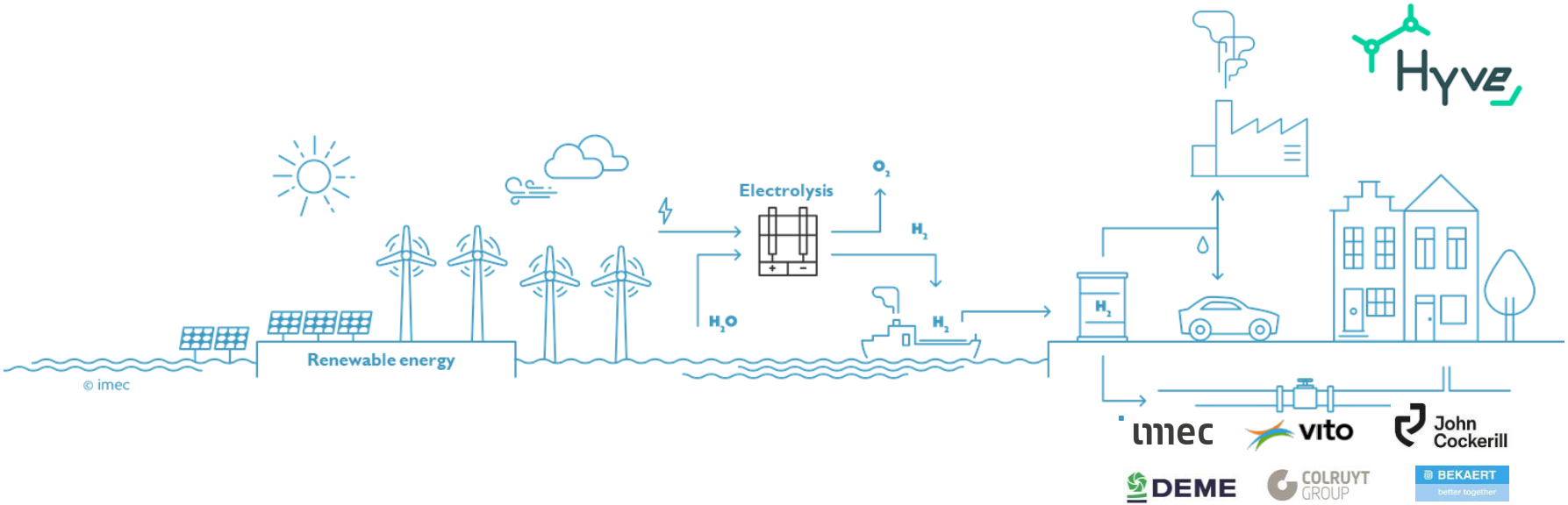
300 cm² nanomesh electrode release from wafer substrate

Pilot-scale fabrication

30x30 cm² sheet processing line (900cm² NM electrodes)

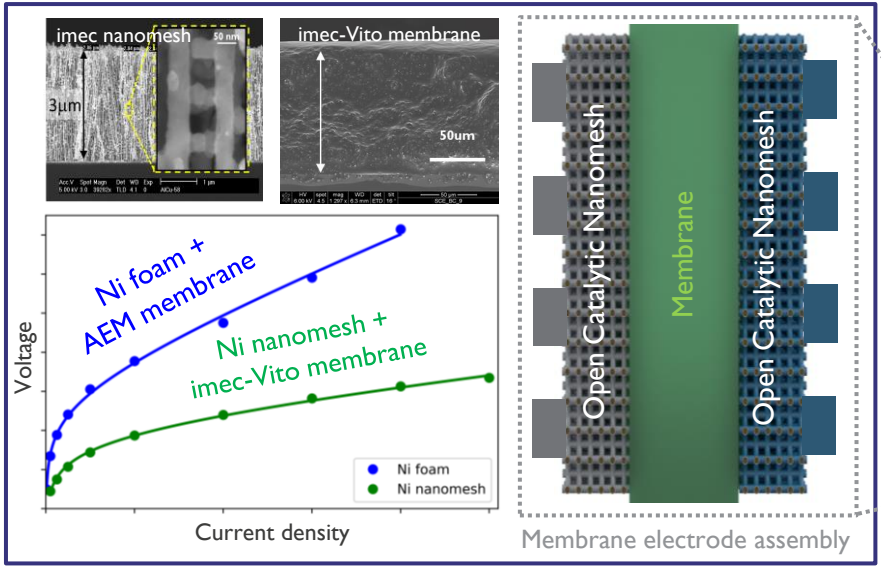
FIRST STOP: GREEN HYDROGEN BY ELECTROLYSIS

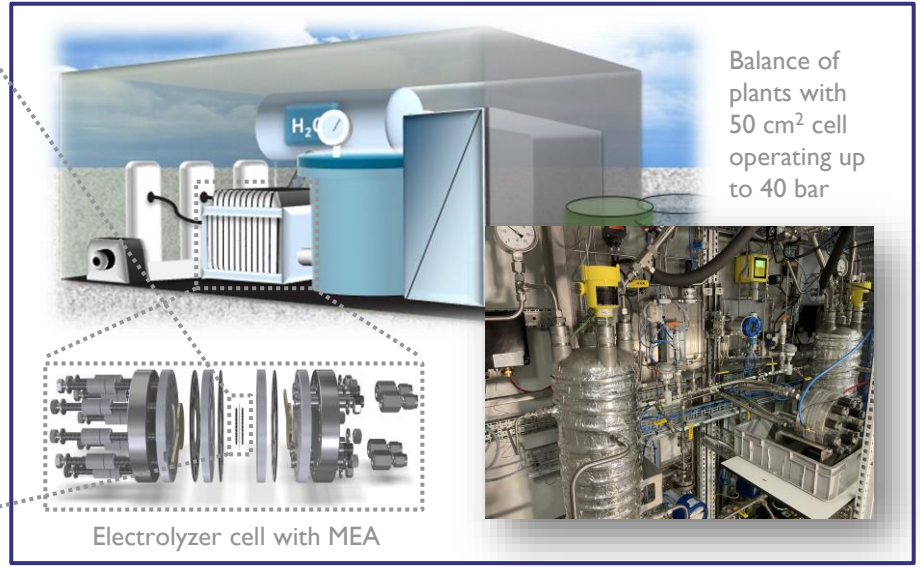
What: Novel MEA and Cell technology for disruption in water electrolyzer technology
How: imec nanomaterial innovations for **catalytic electrodes** and **electrolyte** in collaboration with Vito for membrane technology and system know-how



NANOTECHNOLOGY FOR GREEN H_2

In collaboration with VITO we demonstrated high efficiency on a system level





Membrane electrode assembly (MEA)

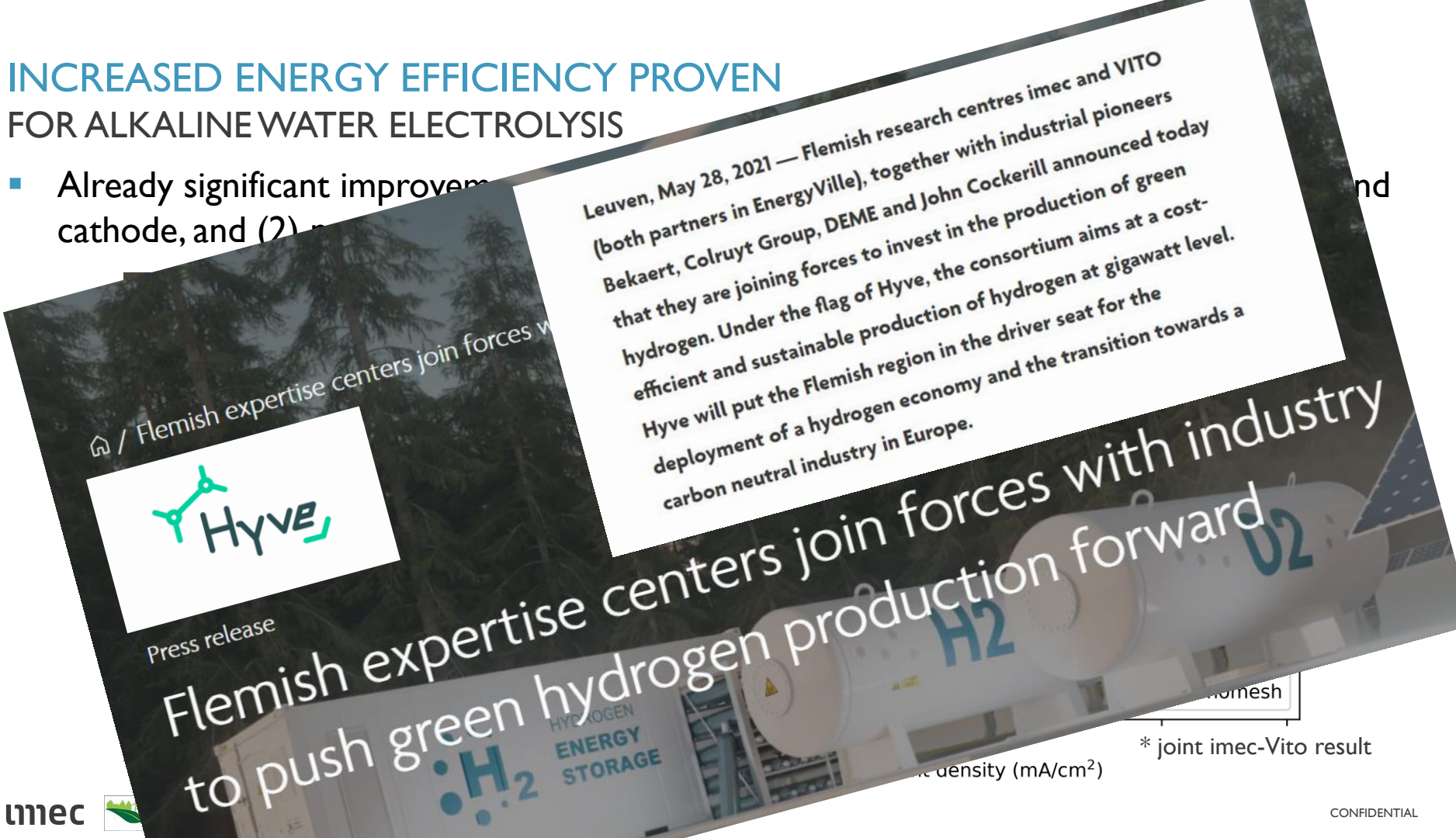
H2-gas generation more efficient compared to conventional materials due to nano-technology offering high effective electrode surface area and short ion transport lengths significantly reducing the electrical losses in the MEA

Balance of Plants operating the electrolyzer cell

H2-gas generation significantly higher compared to classical alkaline electrolyzers when operated at the same cell voltage in realistic operations conditions.

INCREASED ENERGY EFFICIENCY PROVEN
FOR ALKALINE WATER ELECTROLYSIS

- Already significant improvem… …nd cathode, and (2) …

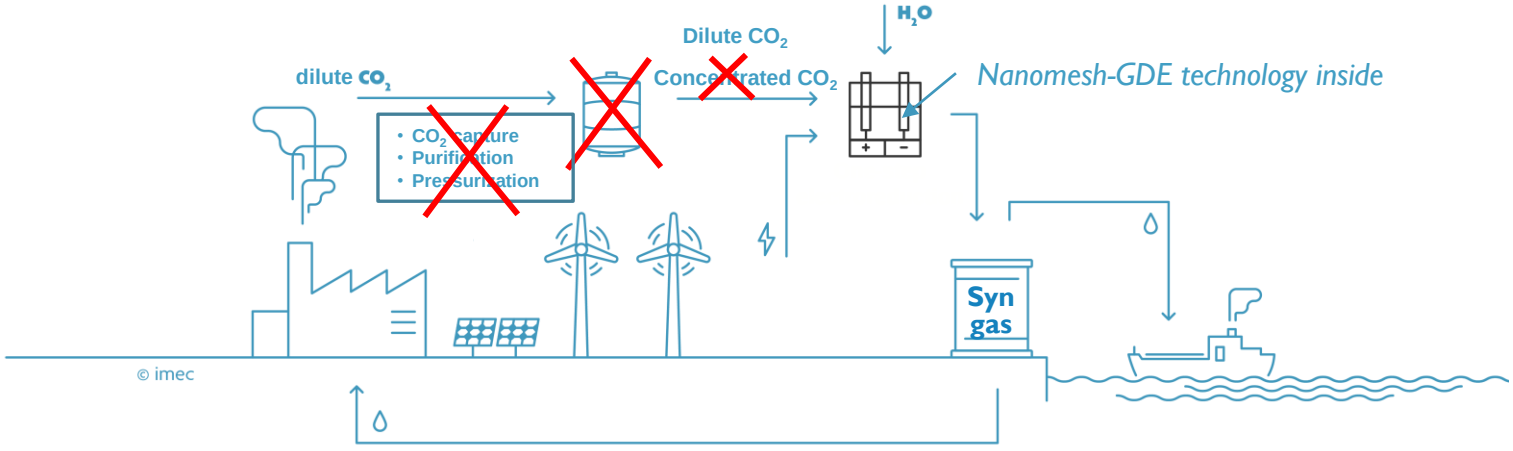


NEXT STOP: DIRECT ELECTROREDUCTION OF CO_2

GAS DIFFUSION ELECTRODE: FROM CONCENTRATION TO DILUTE SOURCE

Today: two step process with capture, purification and pressurization of CO_2 + electrocatalytic conversion of CO_2

Tomorrow: electrochemical conversion of dilute CO_2 source directly from flue or process gas*



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** the flue gas will still need some filtering to remove contaminants such as sulfur which can otherwise poison the catalyst*

- Demonstration of high throughput for typical CO_2 concentrations in flue gas (p(CO_2) ~0.1 bar)
- First step: Syngas as "simple" product, then towards more complex molecules (e.g., methanol)

CONTACT

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