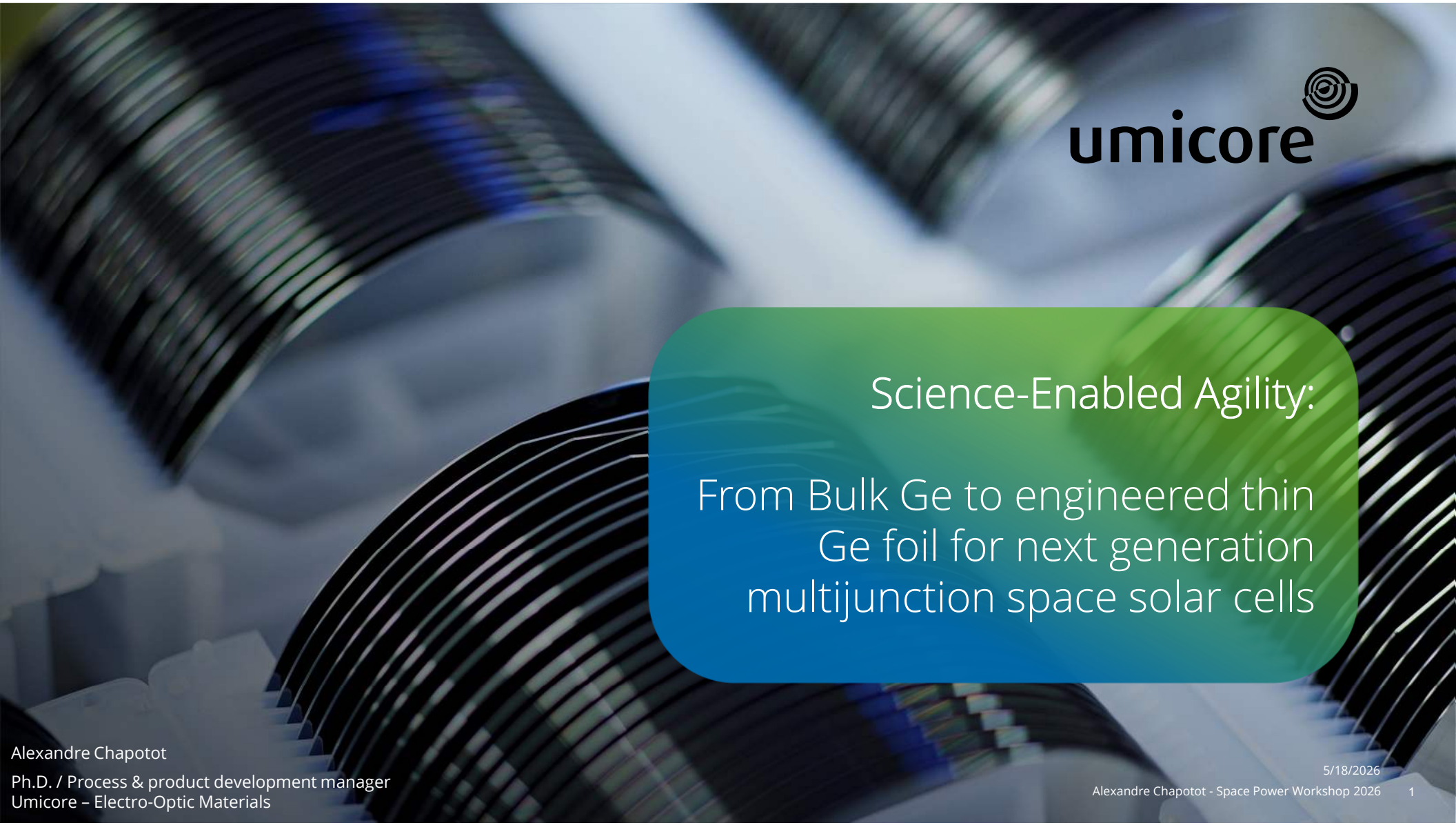


Science-Enabled Agility:

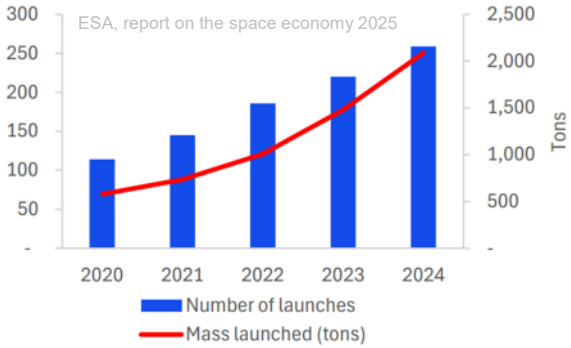
From Bulk Ge to engineered thin Ge foil for next generation multijunction space solar cells

Alexandre Chapotot

Ph.D. / Process & product development manager
Umicore – Electro-Optic Materials

Space market

Stretched between constant market growth and low availability of critical materials



- 259 orbital launches in 2024 (+18% vs 2023)
- +41% increase of mass launched
- Stable GEO launches : 24 launches
- Increased LEO launches (+20%, 219 launches)

Ge-based triple junction space solar cells are the reference technology for space solar power generation

US and Europe are strong players in this market

Market is expecting to continue the on-going growth

New space needs more affordable, and available thinner and lightweight solar cells

Space market

Stretched between constant market growth and low availability of critical materials

- EU's CRMA: Ge recognized as CRM
- 2 Strategic projects related to Ge
- STL ramping up to diversify Ge sourcing
- Multiple new avenues for Ge

Multiple initiatives to build a strong and resilient Ge supply chain in western world

Getting out of the chinese dependancy is a must have by 2030 for EU

Resilience is key

ESTIMATED BENEFITS FOR STRATEGIC VALUE CHAINS

The REE value chain	Dependency on single 3rd country 2025*	Projected dependency on single 3rd country in 2030 with implemented projects*
REE extraction	95%	42%
Rare earth processing/recycling	100%	60%
Permanent magnets	90%	80%

Space and defence raw materials		
Tungsten	31%	26%
Gallium	71%	17%
Germanium	45%	0%

European Commission

Strategic Projects under the Critical Raw Materials Act

STRATEGIC PROJECT

ReGAIN Project

Description of project

The ReGAIN project is a substitution project, focusing on the expansion and transformation of Umicore's Ge wafering facility located in Olen, Belgium. This project entails the industrialization of a new technology supporting the re-use of germanium substrates. These thin film germanium substrates are serving the space solar cell and micro-electronics industry. These innovative substrates allow the industry to significantly reduce its consumption of germanium, enabling the required growth of the end markets like space power.

Benefit for the EU

This project will contribute to the security of the EU's supply of strategic raw materials by substituting a substantial amount of germanium through the use of thin film germanium substrates. This increases the capability of the EU to produce affordable, flexible and lightweight solar cells, which is crucial for European non-dependence and competitiveness in the field of space solar power generation. Furthermore, this project will produce substrates that are re-usable and come with a lower environmental footprint.

Project Name: ReGAIN

Project Type: Substitution

Strategic Raw Material: Germanium

Project Promoter: Umicore

Project Country: Belgium

Estimated Starting Date of Production: 2026

UNFC Classification: E2 // F2 // G3

Website of the Strategic Project: https://eom.umicore.com/en/

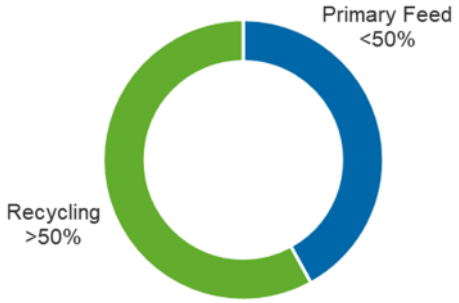
Luxembourg: Publications Office of the European Union, 2025
PDF ISBN 978-92-68-26258-0 doi:10.2873/5958024 ET-01-25-086-EN-N

Umicore EOM's position in the Ge value chain

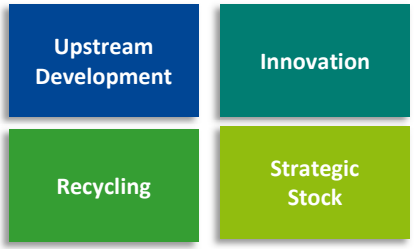
How do we differentiate ourselves ?

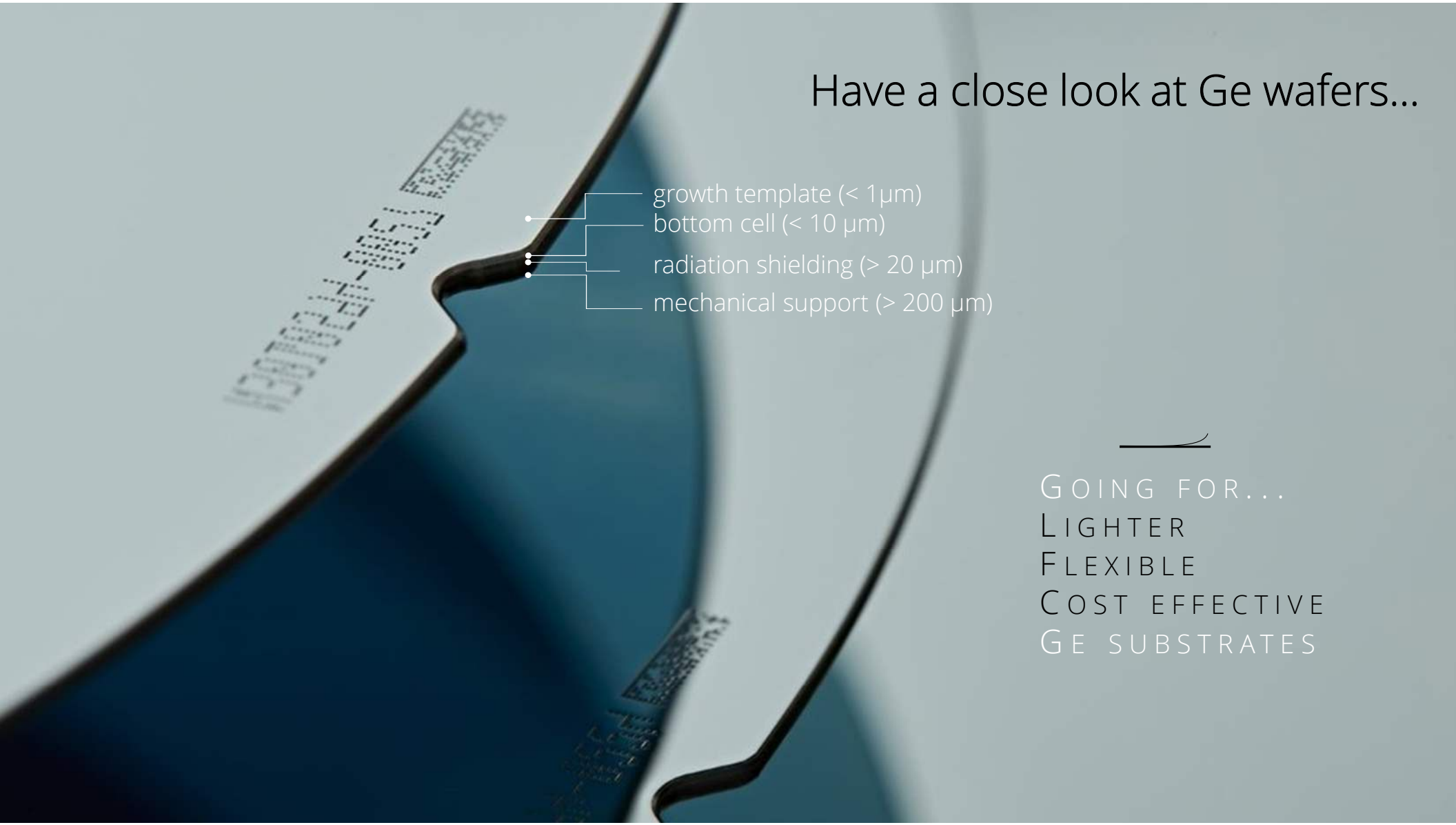
- Decades of experience in germanium refining & recycling
- Largest germanium producer & recycler outside of China
- Extensive customer base in US and Europe
- Recognised as one of the most sustainable companies in the world
- Long term partnerships with American & European government agencies & research institutes (ESA, NREL, IMEC, ISE …)

Umicore's Ge sourcing portfolio

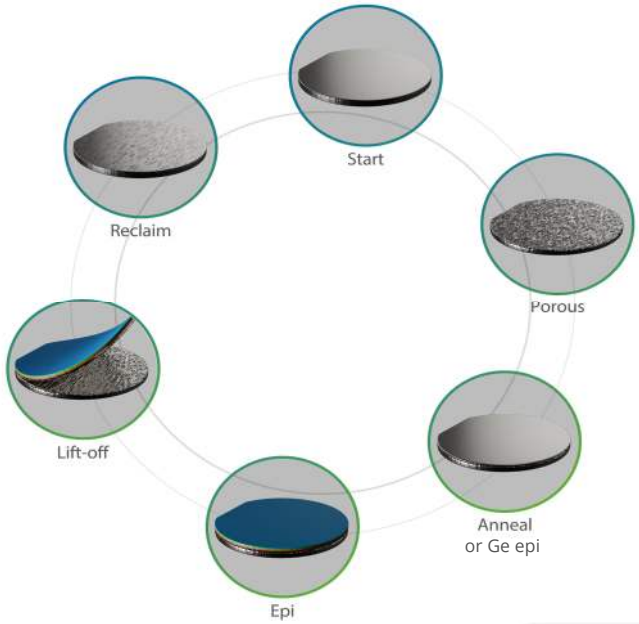


4 pillars of Sourcing Strategy

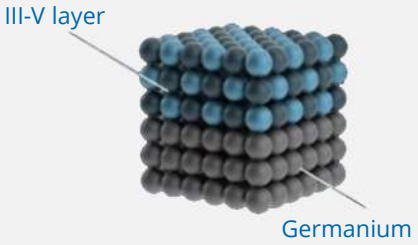



Have a close look at Ge wafers...
growth template (< 1µm)
bottom cell (< 10 µm)
radiation shielding (> 20 µm)
mechanical support (> 200 µm)
GOING FOR...
LIGHTER
FLEXIBLE
COST EFFECTIVE
GE SUBSTRATES

Why Engineered Ge substrates?



Cost reduction

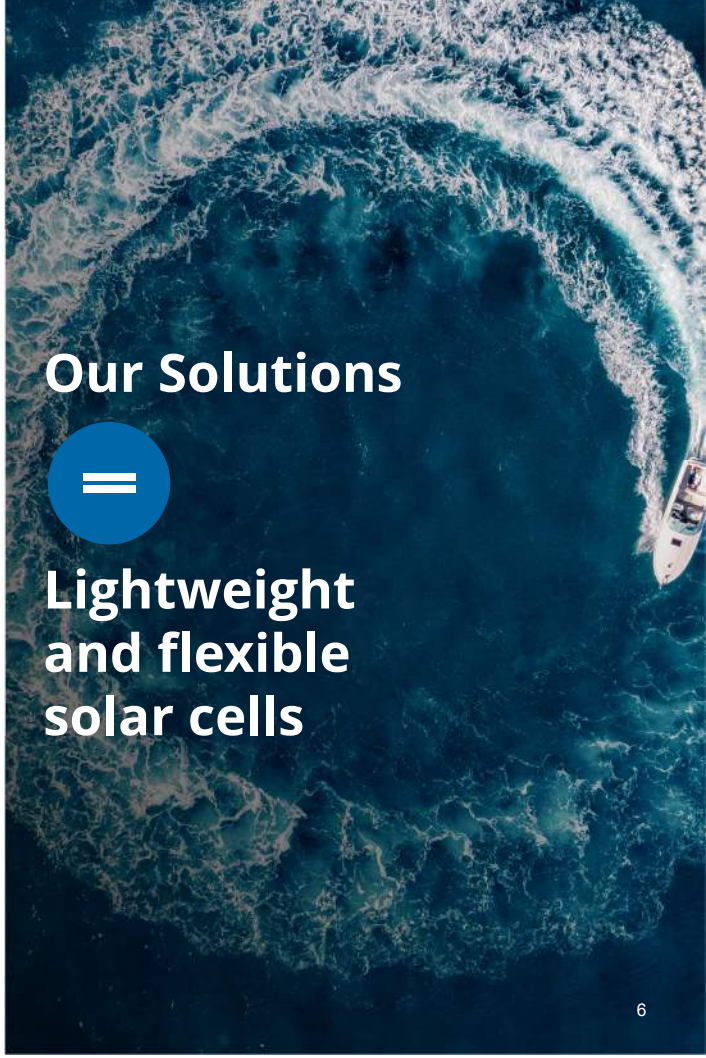


III-V epi-readiness

>90% Ge consumption reduction

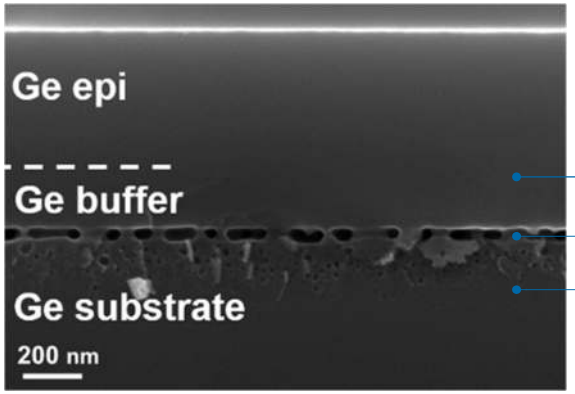
Direct reclaim and reuse after detachment

Lightweight and flexible solar cells



Innovation: reusable Ge wafers

Single PGe + Ge-epi



Based on single porous layer and Ge epitaxy → drop-in replacement solution for III-V epitaxy (similar to a bulk substrate)

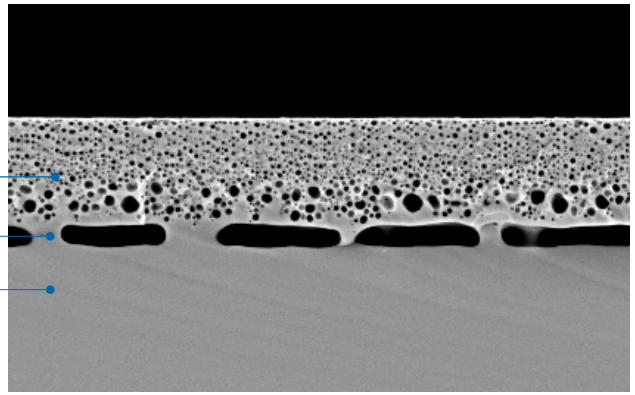
High demand request for Ge epi active layer from downstream partners and customers (3J/4J solar cells)
Major focus: Fast time-to-market

Ge foil (~1 µm)

Detachment plane

Mother Ge substrate

Bi-Porous Ge



Based on bi-porous layer and annealing
Potential for lower-cost solar cells without the need for active Ge

Major focus: Cost & complexity reduction

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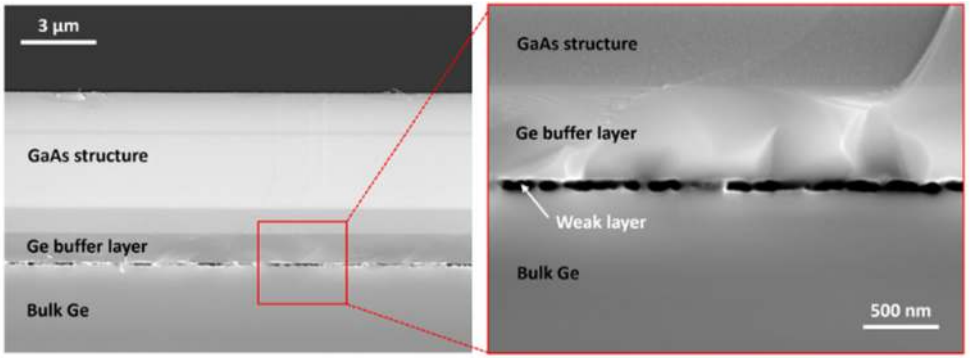
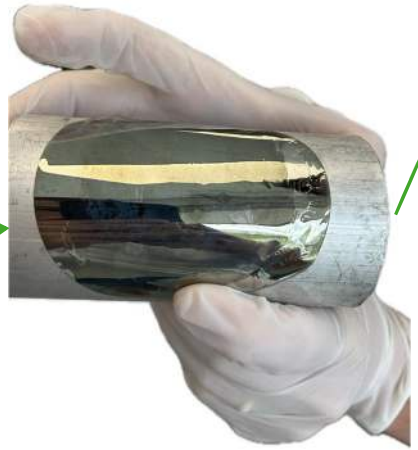
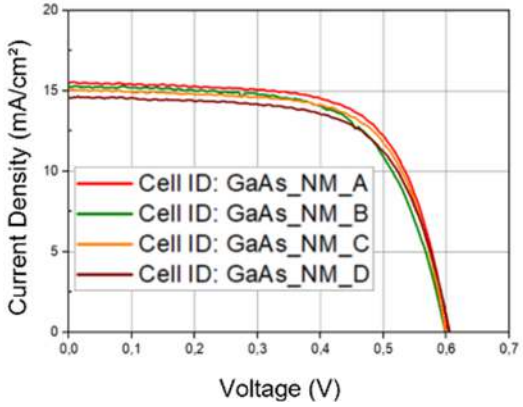
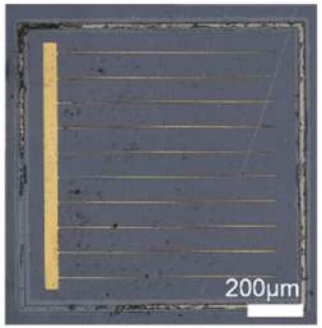


Wafer-scale detachment
assisted by Ni stressor layer



Solar cell characterization
after detachment





- ☑ Wafer-scale detachment
- ☑ Functional detached solar cells

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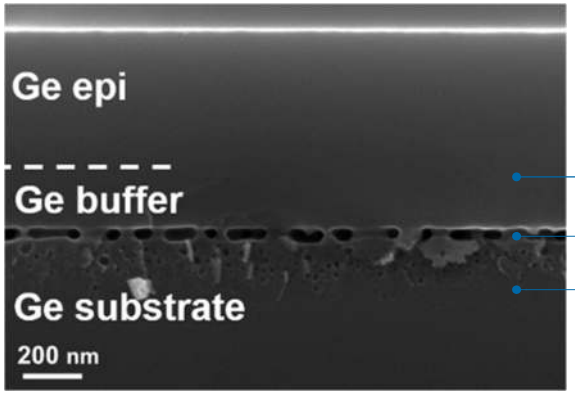
Innovation: reusable Ge wafers

Single PGe + Ge-epi



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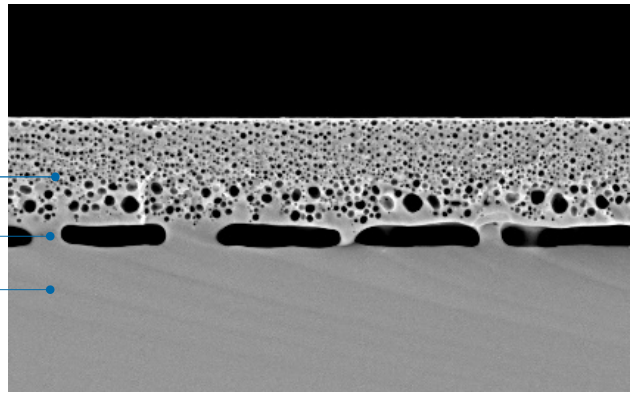
Bi-Porous Ge



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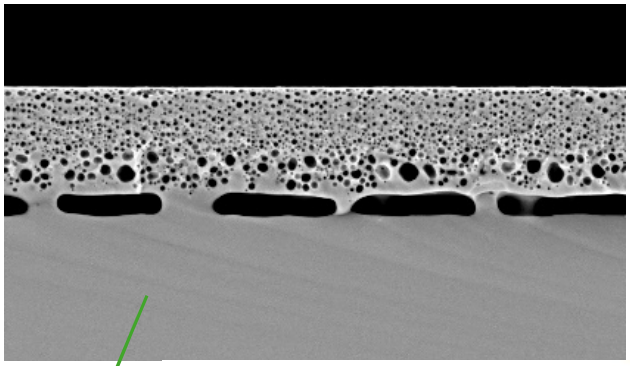
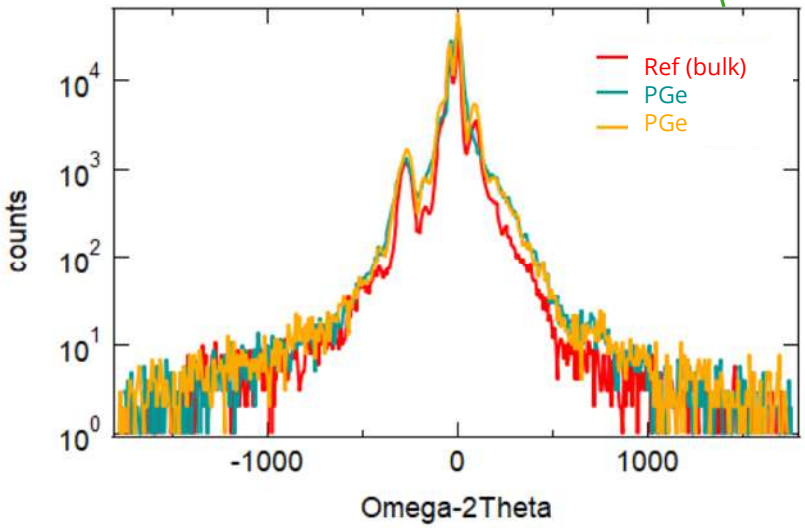
Innovation: reusable Ge wafers

Bi-Porous Ge

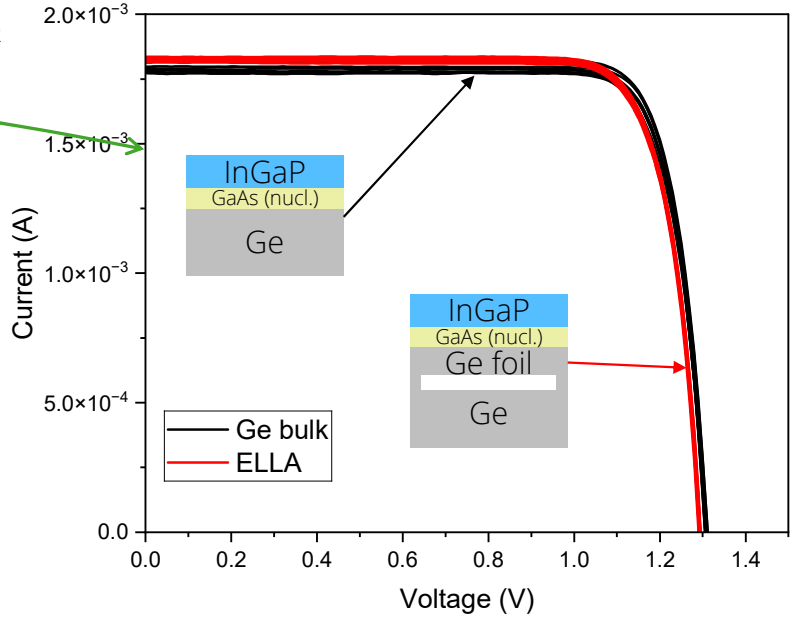


III-V Epitaxy



Solar cell microfabrication & characterization

GaAs (nucl.) / 1J-InGaP



☑ Similar performances between Bulk and Eng. Ge (batch)

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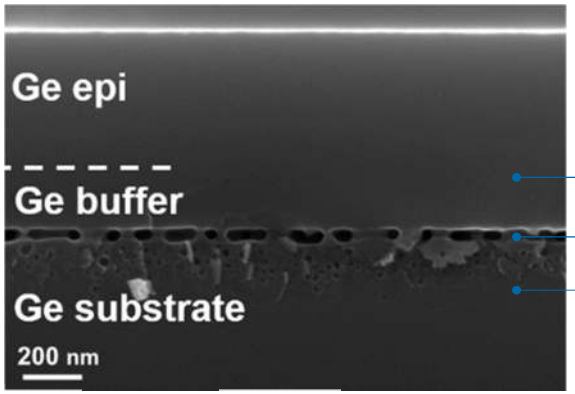
Technical take-aways

Single PGe + Ge-epi



Suitable for III-V layers

Monocrystalline

Functional detached solar cells

Reusable mother substrate

Lightweight and flexible

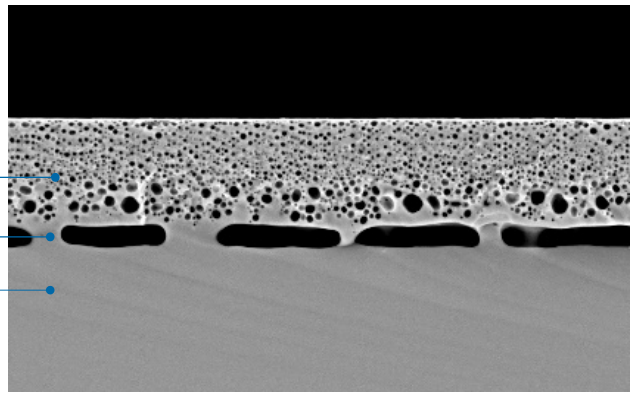
Drop-in replacement product, V1 product

Ge foil (~1 µm)

Detachment plane

Mother Ge substrate

Bi-Porous Ge



Suitable for III-V layers

Monocrystalline

On-going work on detachability

Reusable mother substrate

Lightweight and flexible

Good candidate for LEO market and V2 product

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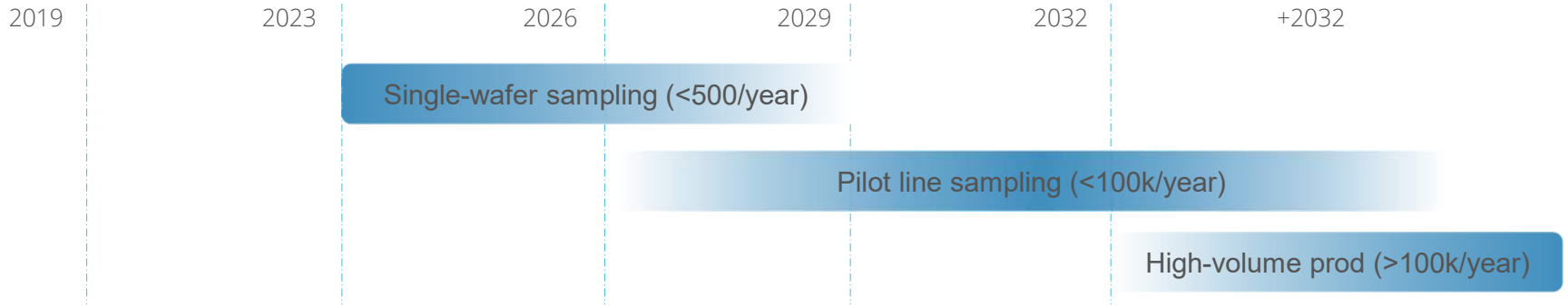
Next phase: ELLA pilot line (ReGAIN)



Conclusions and take-aways

Unique product proposition

World leader in germanium with resilient geographical sourcing and unique recycling capabilities

Technology and innovation leader on engineered Ge sub.

Technical achievements and relevance to the market

2 product types in-sourced at Umicore targeting short- and long-term solutions for space solar cells

Single PGe +Ge epi, more advanced and mature. Targets conventional triple-junctions. Demonstrates functional detached cells at lab-scale. Ready for up-scale and pilot line

Bi-porous Ge, still under development. Targets new structure (without Ge active layer). Demonstrate functional solar cells. Continuous improvements with downstream partners

Path forward to 2032

2026: In-sourcing period
Technologies are in-sourced from partners in Umicore

2026-2029: scale up and pilot installation
Up-scale on 6inch and pilot line installation

2029-2032: Pilot line and high-volume production installation
First batch of wafers commercially available and volume ramp-up

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umicore

THANK YOU

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Umicore – Electro-Optic Materials

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