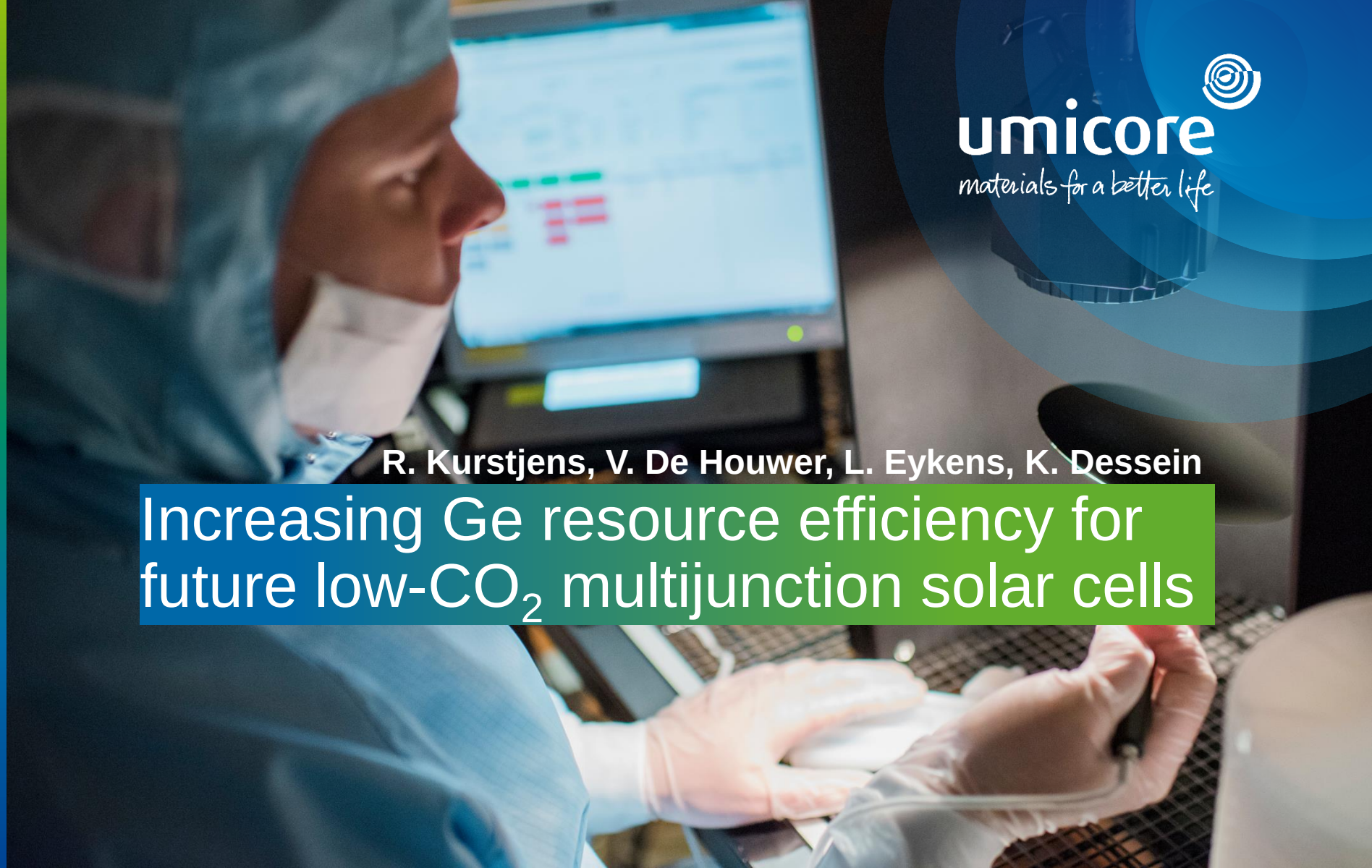


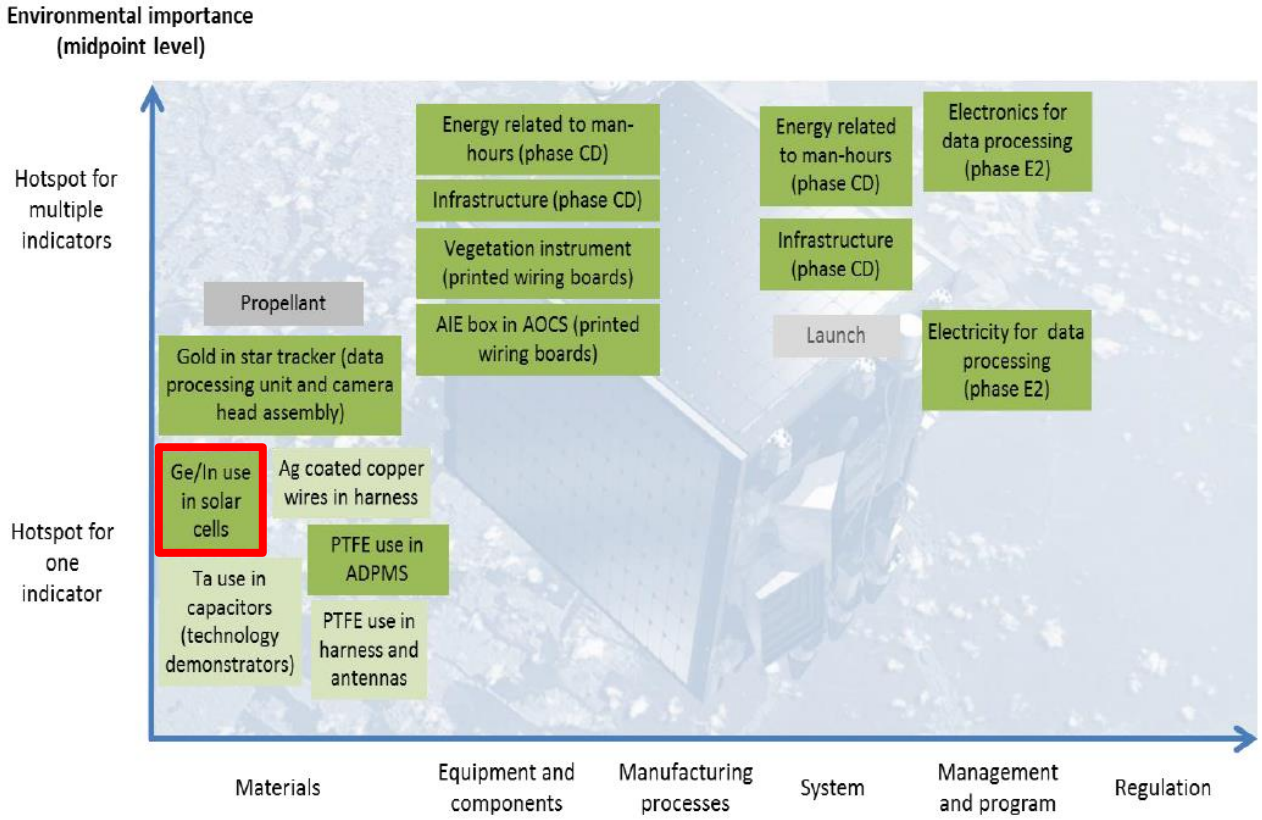
umicore
materials for a better life

R. Kurstjens, V. De Houwer, L. Eykens, K. Dessein

Increasing Ge resource efficiency for future low-CO_2 multijunction solar cells

Ge as environmental hotspot in space missions

Hotspots of Proba V



ESA Effective Use of Germanium

Contract number: 4000128156/19/NL/FE

The work presented here was supported by the European Space Agency under the Effective Use of Germanium project

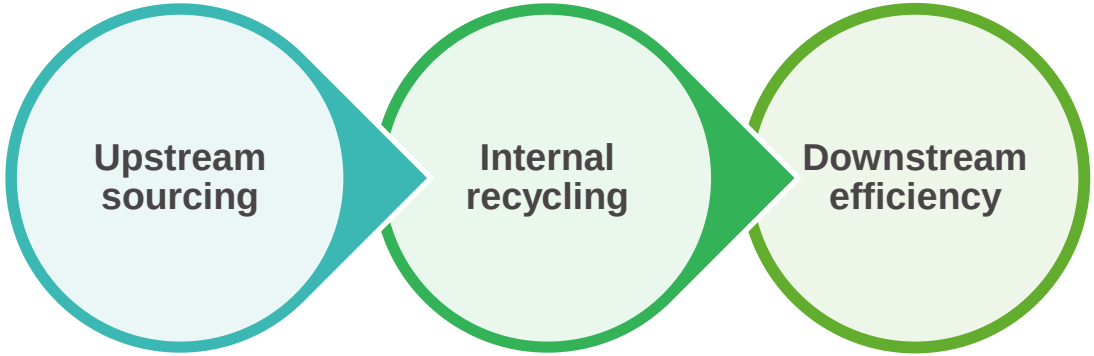
Project partners:

Key external service providers:

Key goals:

1. Recycling of backgrinding waters of Azur Space
2. Ge-on-Ge engineered substrates as alternative growth substrates

Umicore’s vision on Sustainability



- Main focus is on sustainable sourcing of Germanium
- Key differentiator for Umicore is to establish a germanium supply chain with minimal CO_2 impact

→ **Umicore’s target is to reach 100% sustainable Ge**

Environmental impact

Global Warming Potential of Germanium from 3 main sources

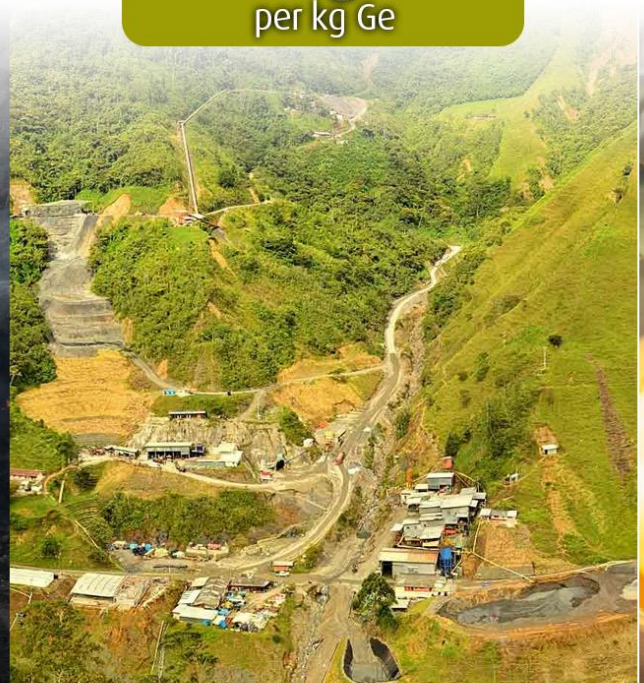
Robertz, B., Verhelle, J. & Schurmans, M. JOM (2015) 67: 412.
https://doi.org/10.1007/s11837-014-1267-6

COAL BASED

5.771 kg CO2
per kg Ge

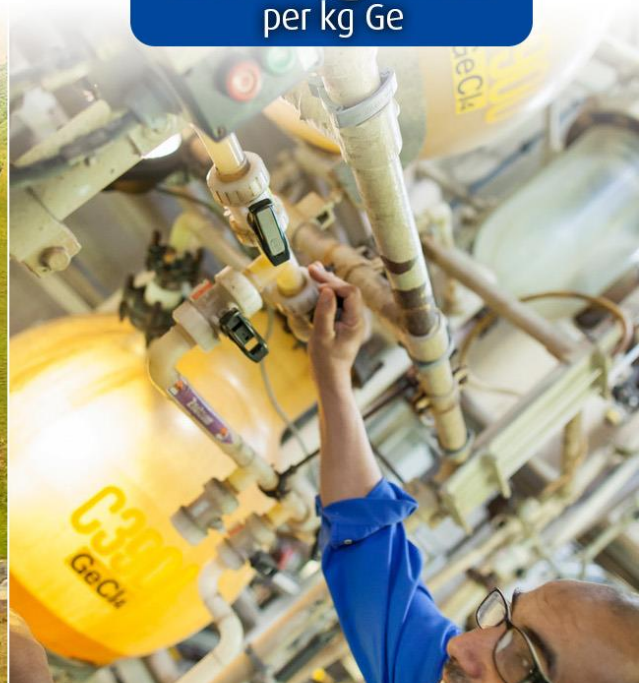
ZINC BASED

852 kg CO2
per kg Ge



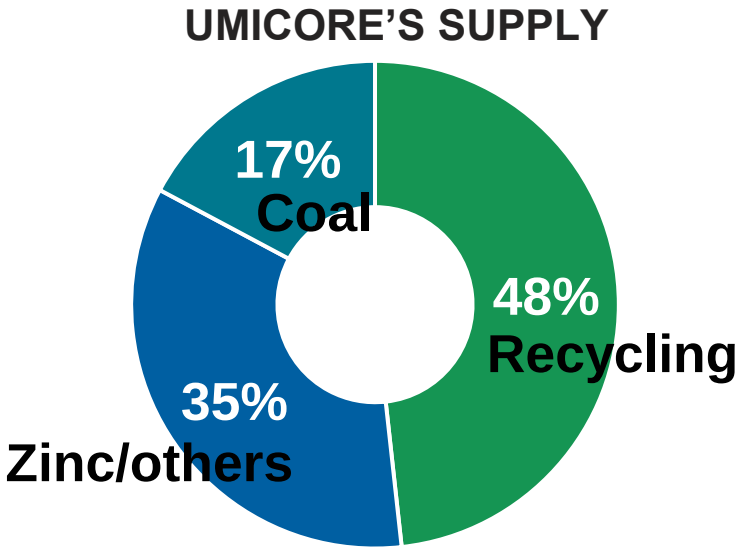
RECYCLED

280 kg CO2
per kg Ge



Germanium sourcing & supply

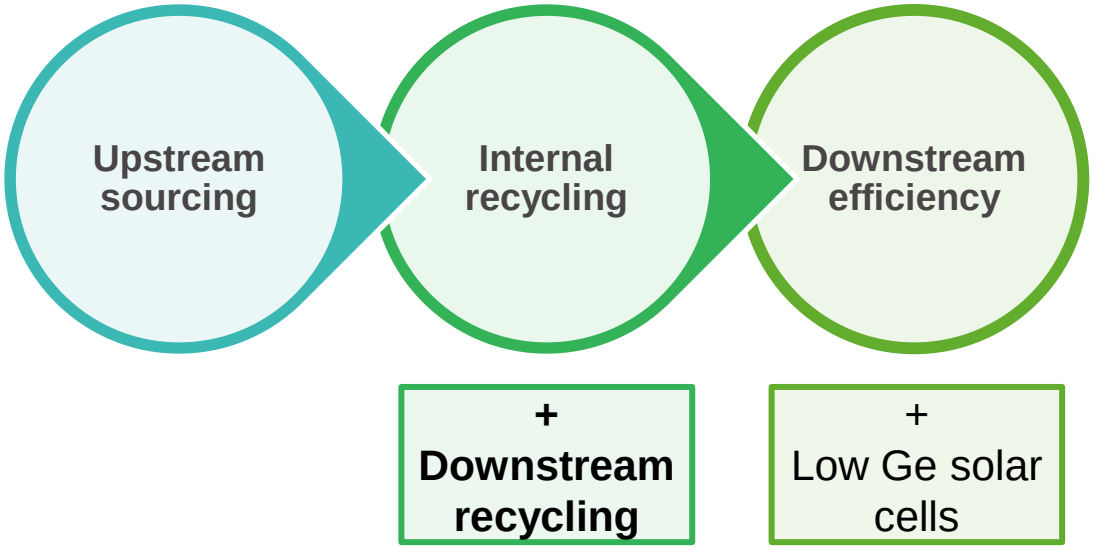
We focus on developing recycled Germanium sources



With almost half already coming from direct recycling and more than one third coming from sustainable sources such as Zinc mining waste, **Umicore is considered the most sustainable manufacturer of Ge.**

Umicore’s vision on Sustainability

ESA Effective Use of Germanium



Importance of germanium recycling

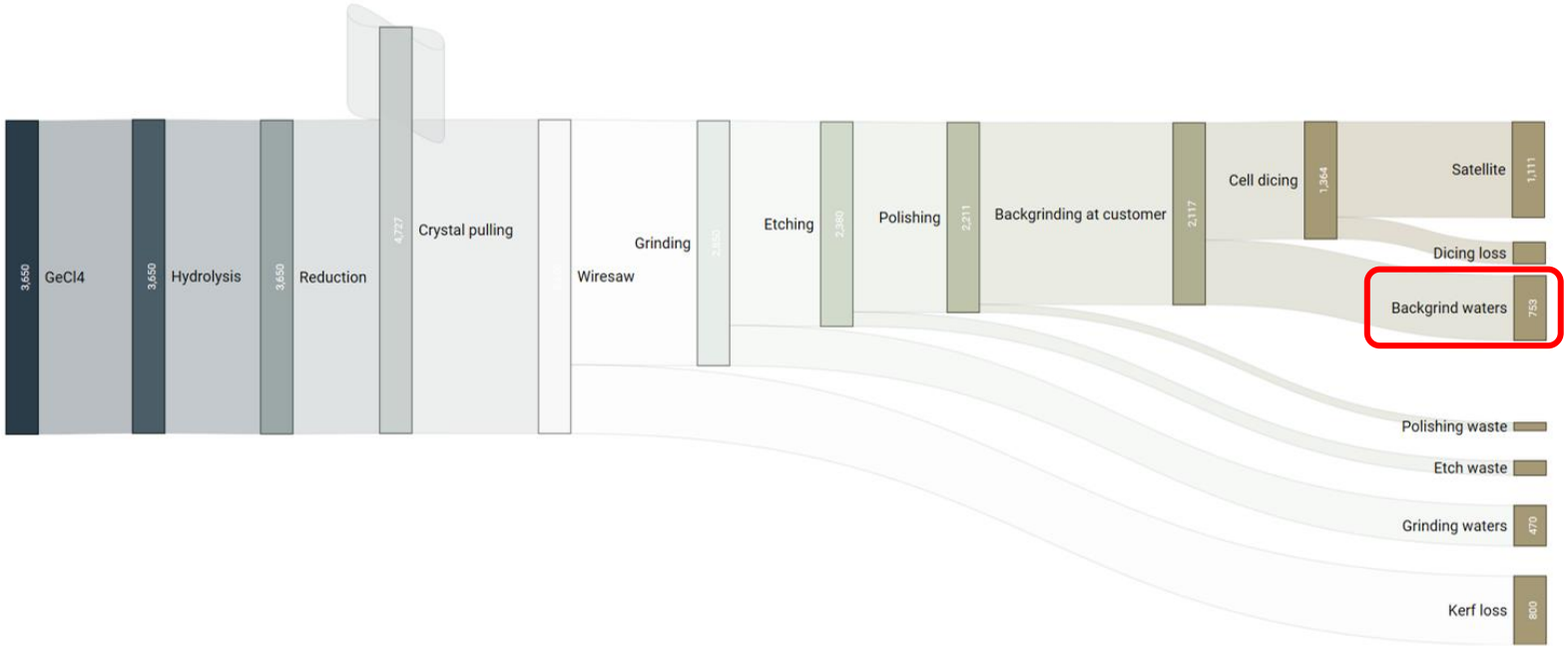
CO_2 impact lower for entire production line

Germanium is included in list of EU's Critical Raw Materials (CRM)

Win-win for customer & Umicore
➔ insusceptible to germanium price fluctuations
➔ lower end-product price

Sankey diagram

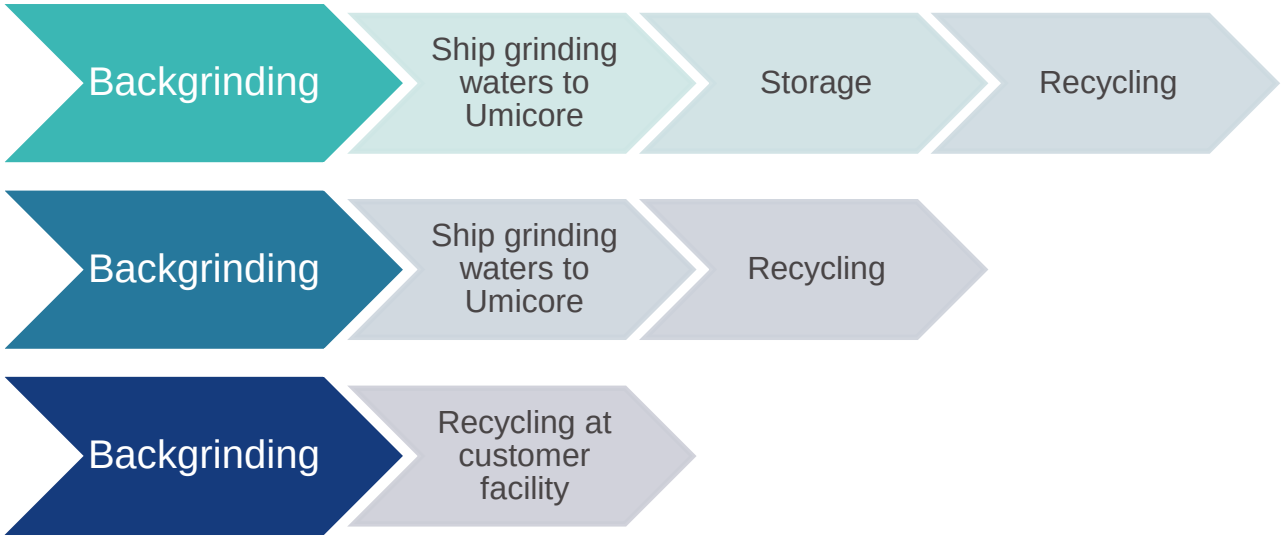
100 000 wafers, 150 mm diameter, 225 µm delivered to customer, 145 µm after backgrinding



All Ge losses incurred in Umicore's internal flow are recycled.
Ge losses incurred at the customer weren't fully recycled yet.

Recycling Ge from backgrinding of customers

Early tests have shown that recycling will need to occur at the customer



0 % Ge recovered (dissolved in water)

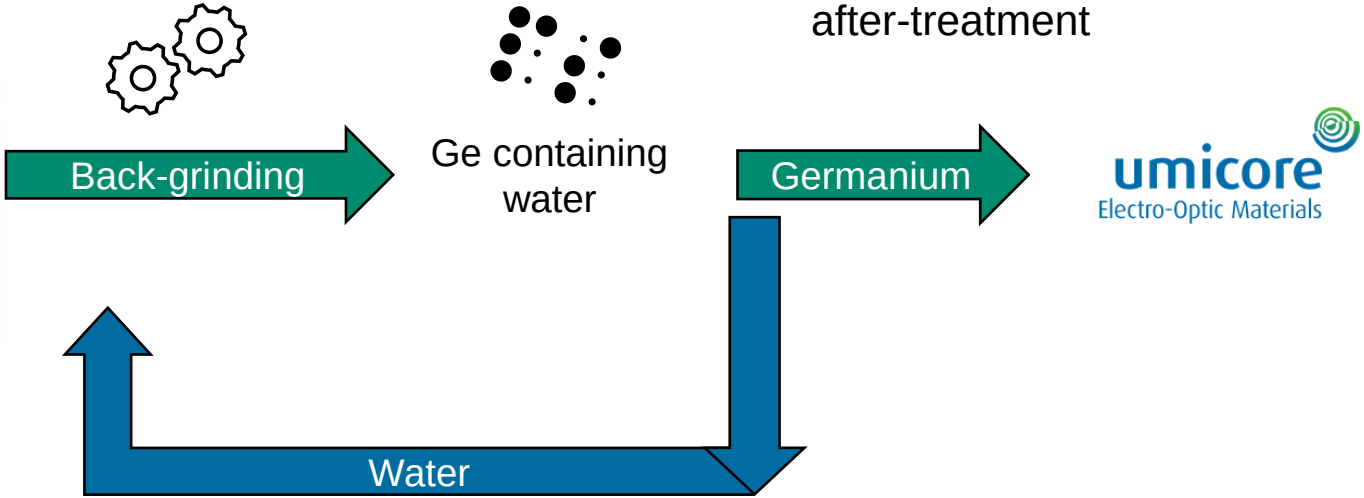
30 % Ge recovered (dissolved in water)

90 % Ge recovered (bench top setup)

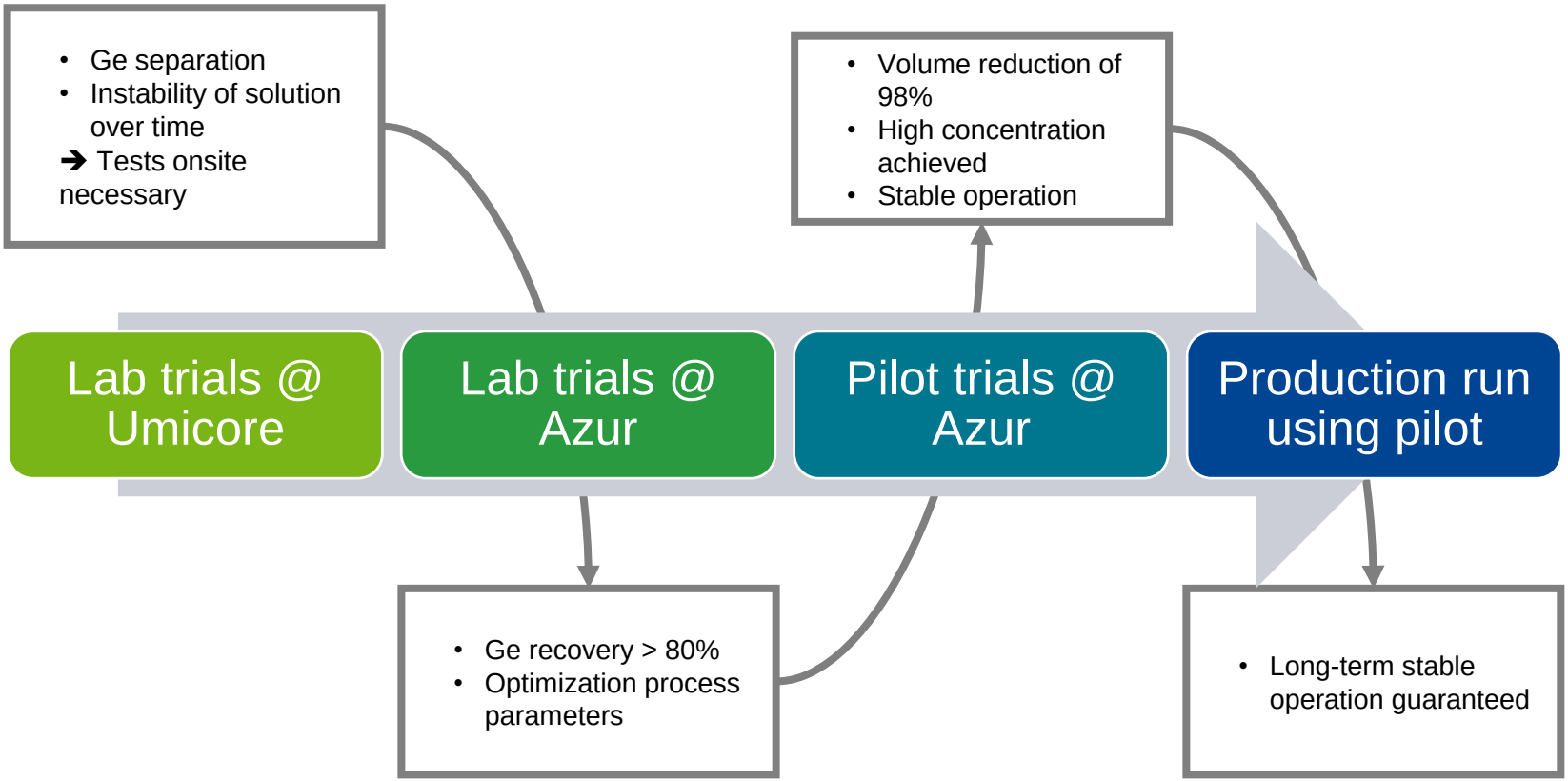
Recycling flowsheet

Objectives:

- Min. yield of 80%
- High concentration
  ➔ Economically viable after-treatment

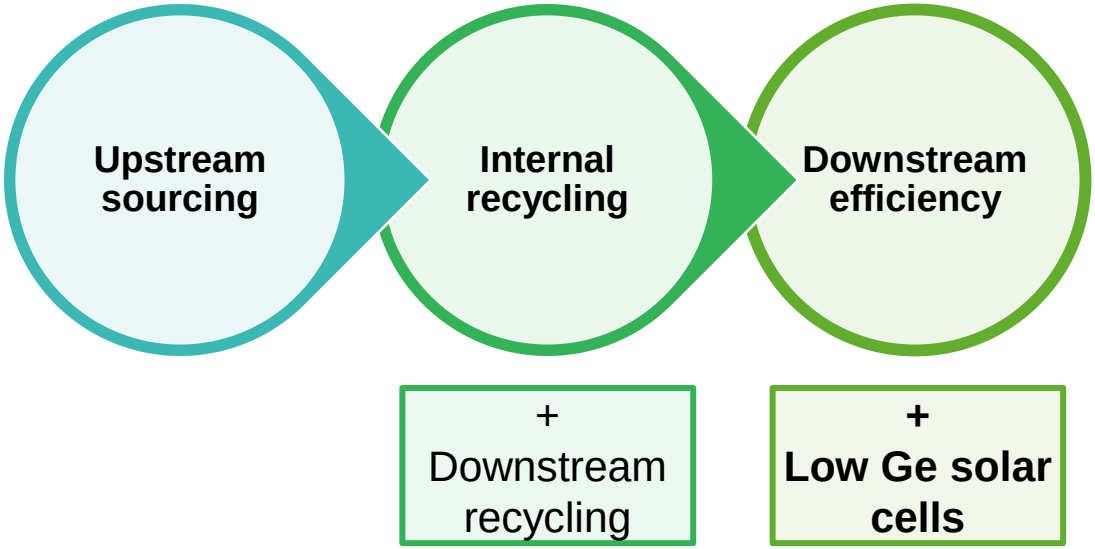


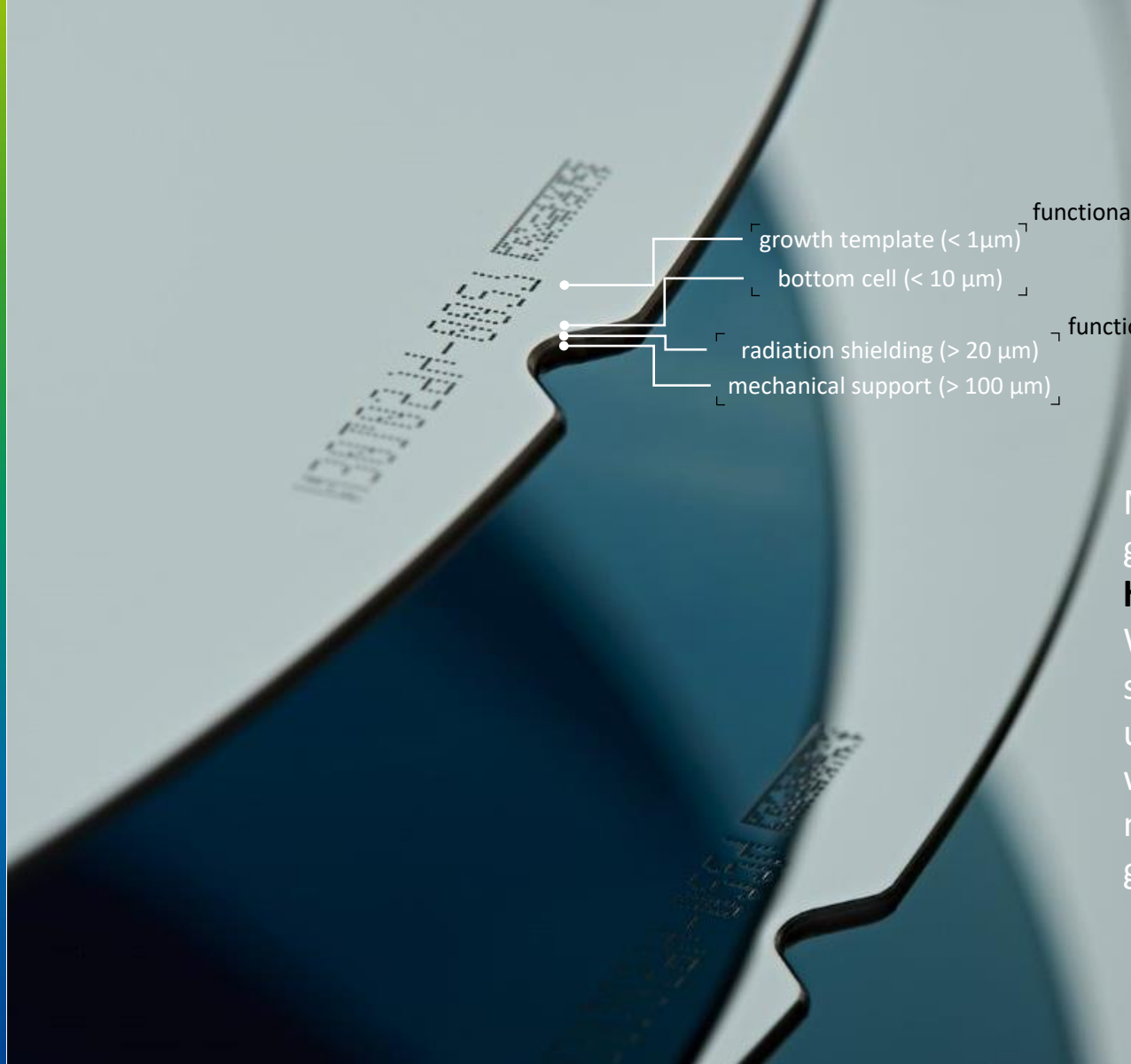
Summary of experimental work



Umicore’s vision on Sustainability

ESA Effective Use of Germanium





Most customers think that germanium substrates are too **heavy** and too expensive.

We are developing an engineered substrate that will allow them to use as little germanium as they want so that they can manufacture L I G H T and cheap germanium-based solar cells.

Sustainability as a differentiator

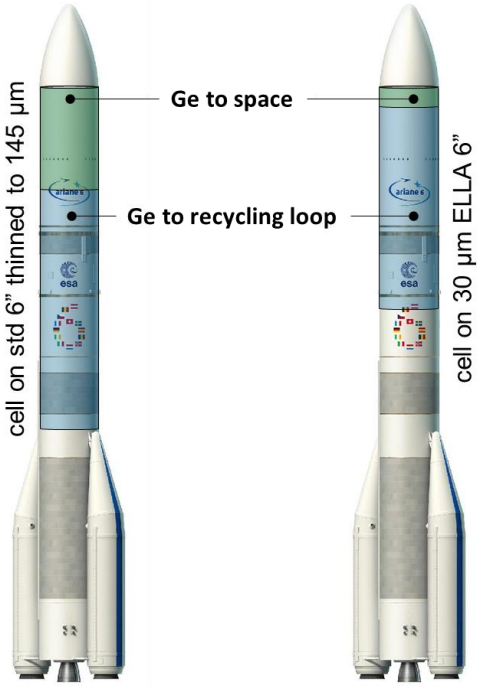
Reduce dependency of space sector on Ge as a critical raw material

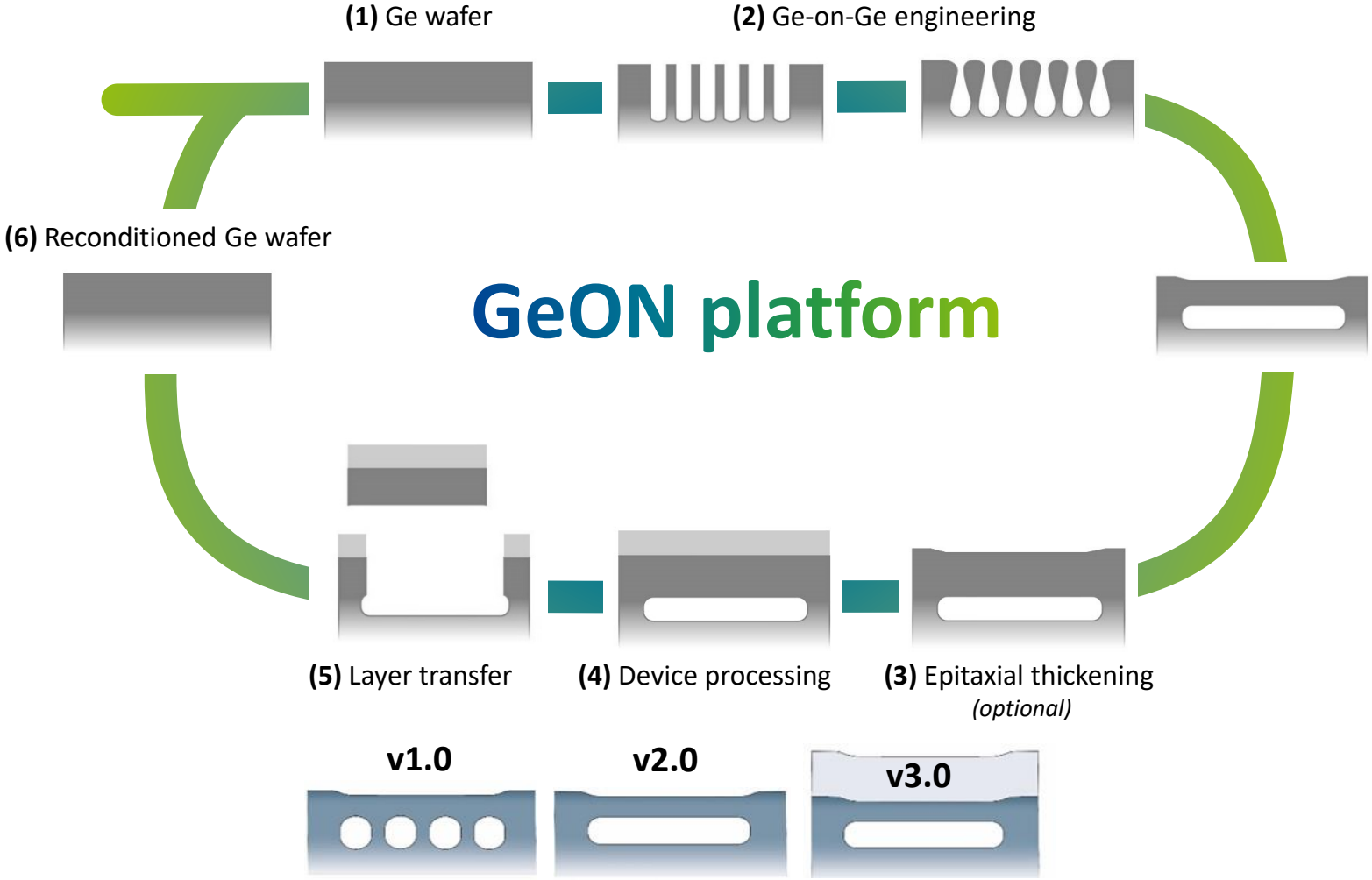
ENABLING & SUPPORT

Reduce, Reuse, Recycle: Growing solar cells on nothing

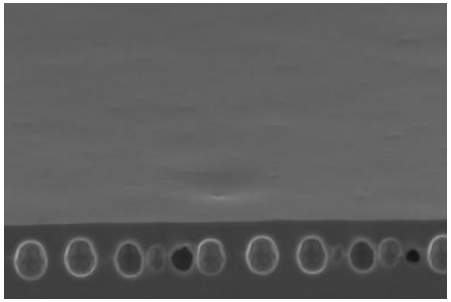
20/03/2020 374 VIEWS 2 LIKES

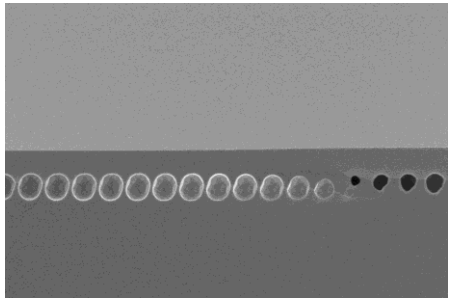
ESA / Enabling & Support / Space Engineering & Technology / Shaping the Future

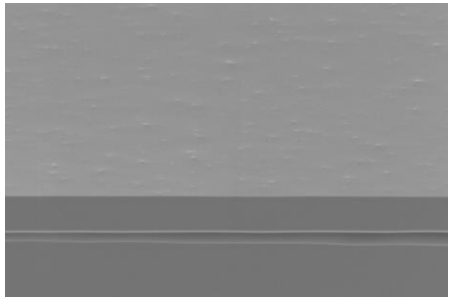


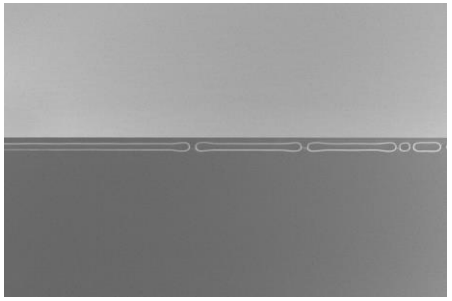

(1) Ge wafer
(2) Ge-on-Ge engineering
(6) Reconditioned Ge wafer
GeON platform
(5) Layer transfer
(4) Device processing
(3) Epitaxial thickening
(optional)
v1.0
v2.0
v3.0

Ge-on-Nothing prototype versions



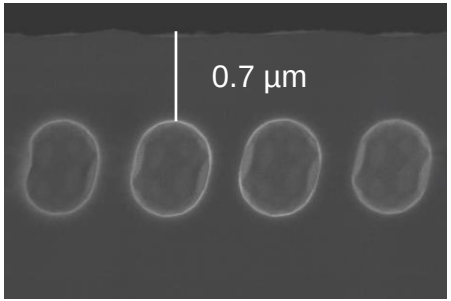


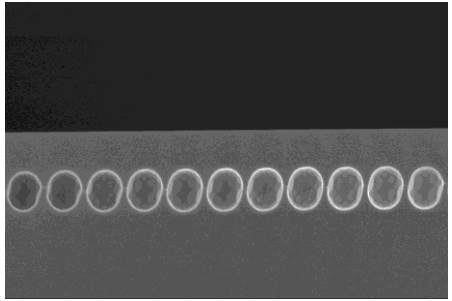


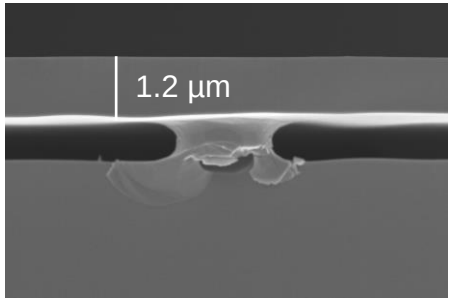


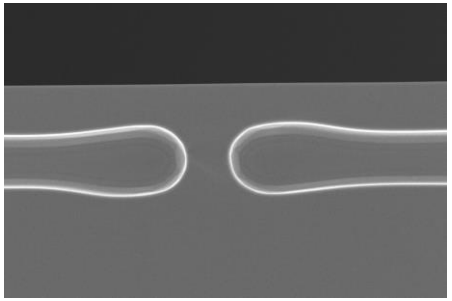
Spherical voids

Foil on merged voids









v1.0

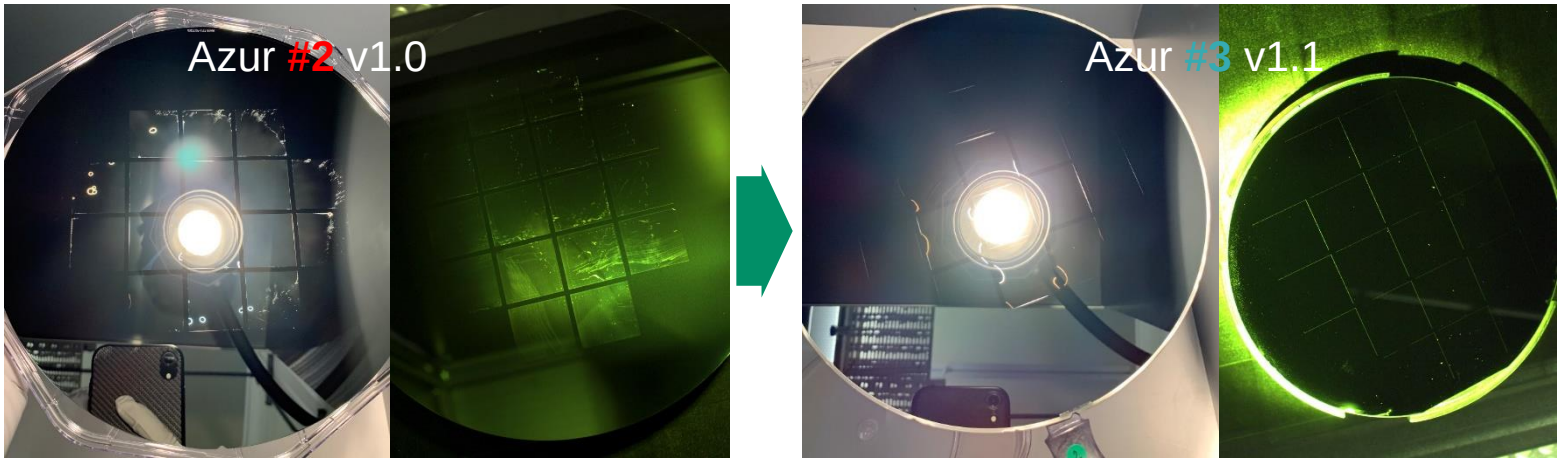
v1.1
sampled to Azur

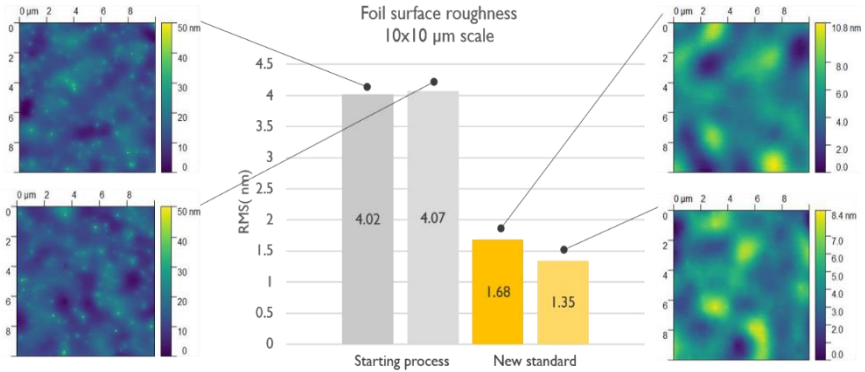
v2.0

v2.1
Sampled to Azur

Process improvement

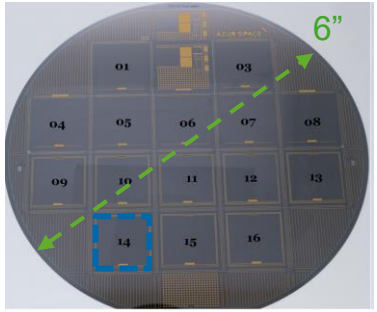
Improved roughness thanks to new litho stack

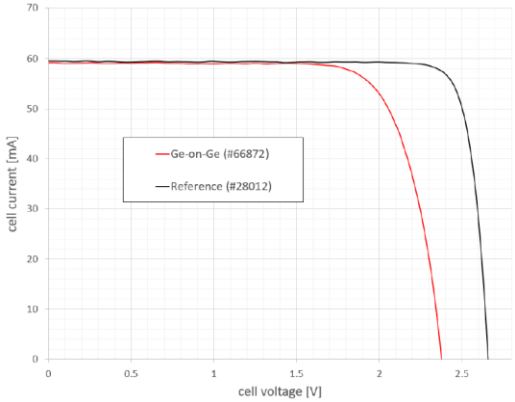


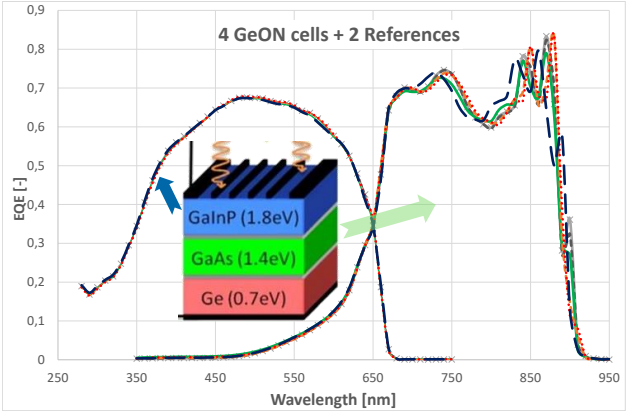


Device results

Sampling to Azur







- v1.1 structure
- 25 x 25 mm² dies
- on (n)-type Ge

- GaInP top cell + Ga(In)As middle cell
- No Ge bottom cell
- 20×20 mm² devices

- ✓ EQE curves superimposed!
- ✓ V_{oc}: only loss due to lack of Ge cell

Conclusions

Key goals were achieved:

1. Recycling of backgrinding waters of Azur Space is now operational
2. The proof of concept of Ge-on-Ge engineered substrates as alternative growth substrates was successful

- Umicore is continuing development of the Ge-on-Ge engineered substrates in the ESA ELLA project
- The Ge-on-Ge engineered substrate is a promising concept that attracts interest from the European value chain

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Thank you