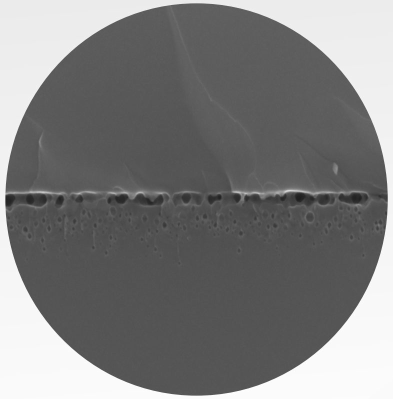

# Engineered Ge substrates for new power-hungry space applications

Kristof Dessein

umicore

# Engineered Ge substrates for new power-hungry space applications

umicore
materials for a better life

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The view expressed herein can in no way be taken to reflect the official opinion of the European Space Agency.

# Introduction

## Incubent technology

# Introduction

## Future power demand

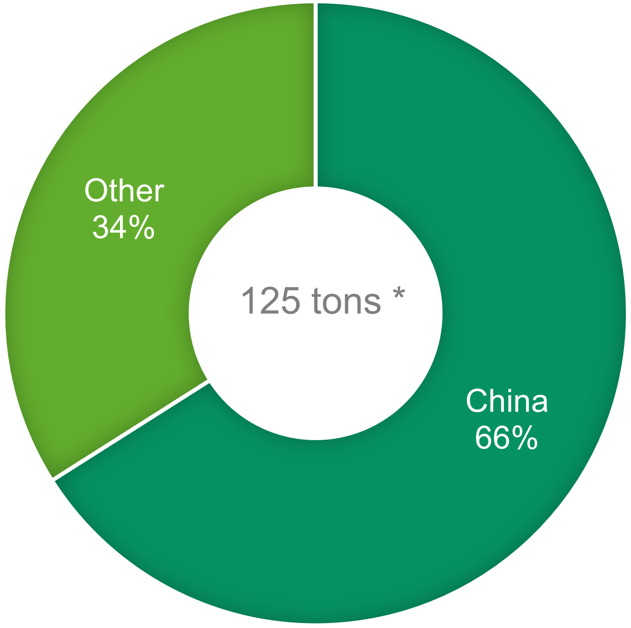
Credit: *ESA*

Credit: *ESA – P. Carril*

# Introduction

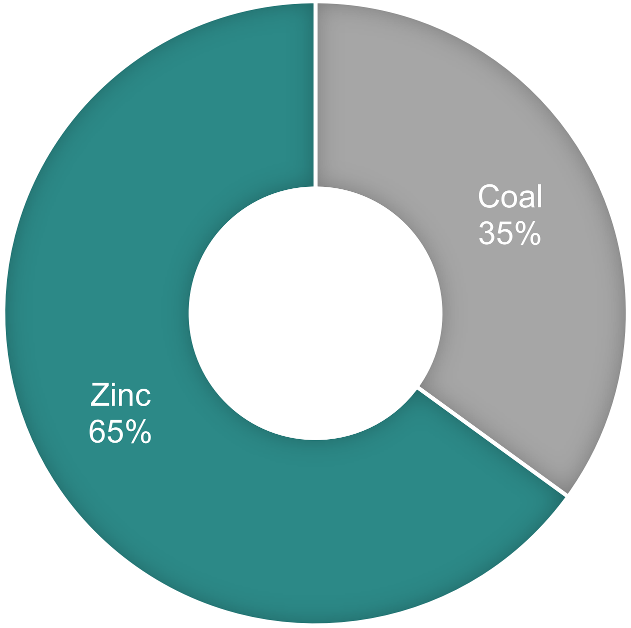
## Ge is significant cost driver

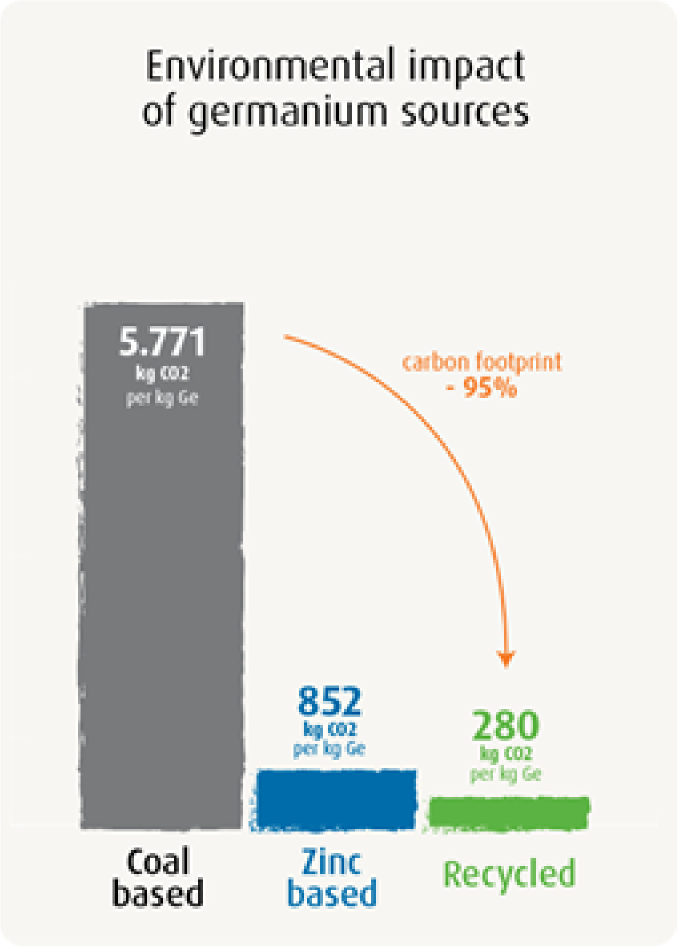
COUNTRY OF ORIGIN



* Annual fluctuations are in the order of ± 15%

SOURCE TYPE



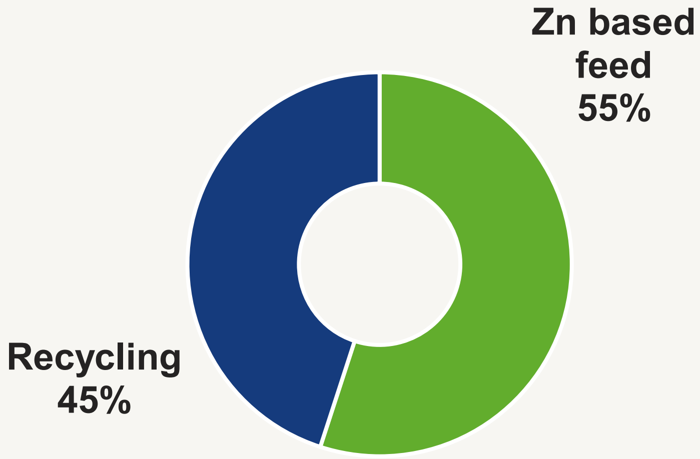


*Robertz, B., Verhelle, J. & Schurmans, M. JOM (2015) 67: 412*

# Introduction

## Sustainable Ge from Umicore

### EOM Primary vs Secondary Sourcing



Umicore: 100% Sustainable Germanium supply

Umicore is the only Germanium producer with 100% sustainable germanium,

and can additionally offer 100% recycled germanium

**100% Sustainable Germanium GUARANTEED**

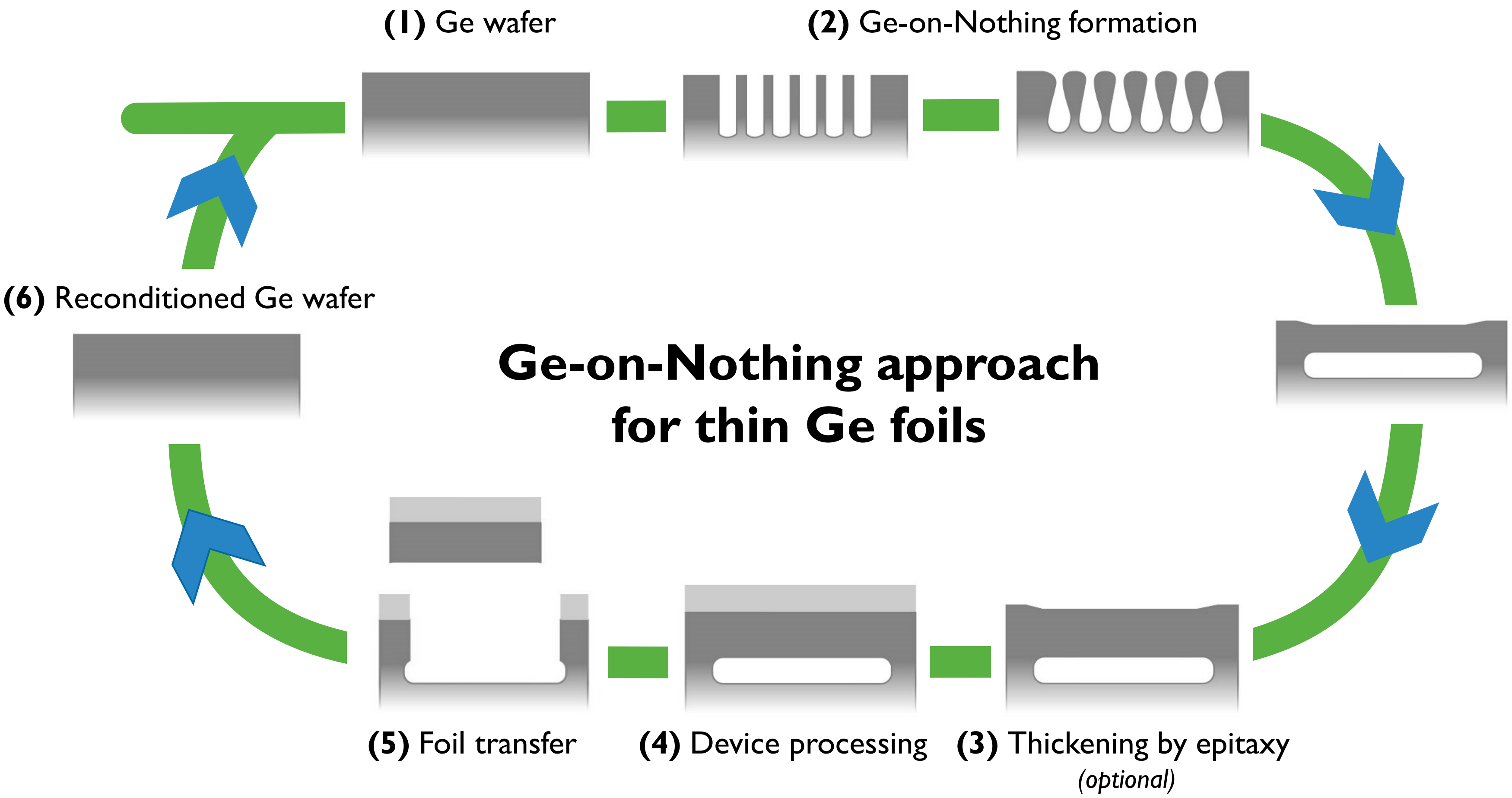
**100% Recycled Germanium AVAILABLE ***

* Limited availability

Going for...
Lighter
Flexible
Cheaper
Ge substrates

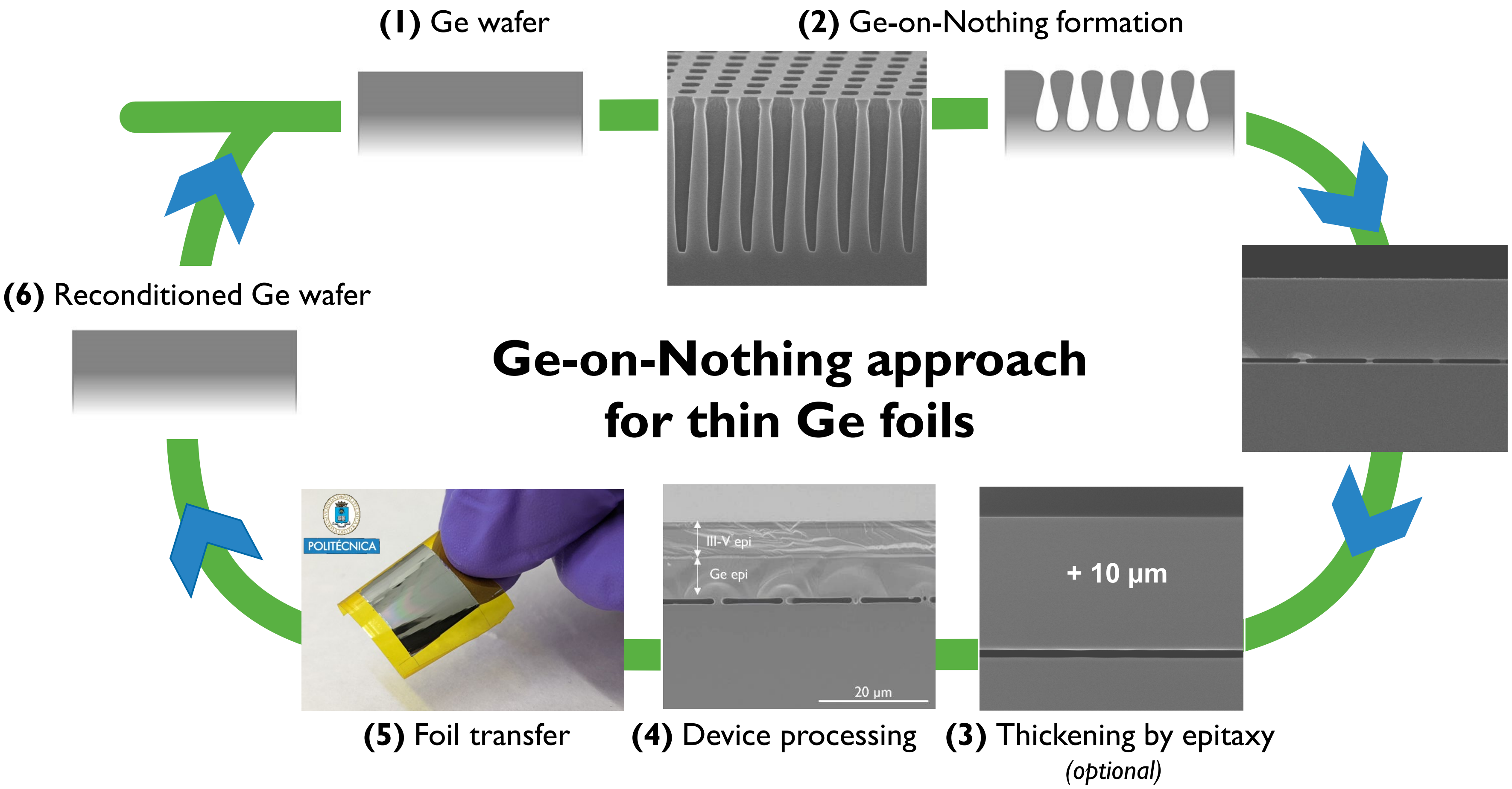
# Ge-on-Nothing approach

## Technological testbed



# Ge-on-Nothing approach

## Technological testbed



**(1)** Ge wafer

**(2)** Ge-on-Nothing formation

**Ge-on-Nothing approach for thin Ge foils**

**(3)** Thickening by epitaxy *(optional)*

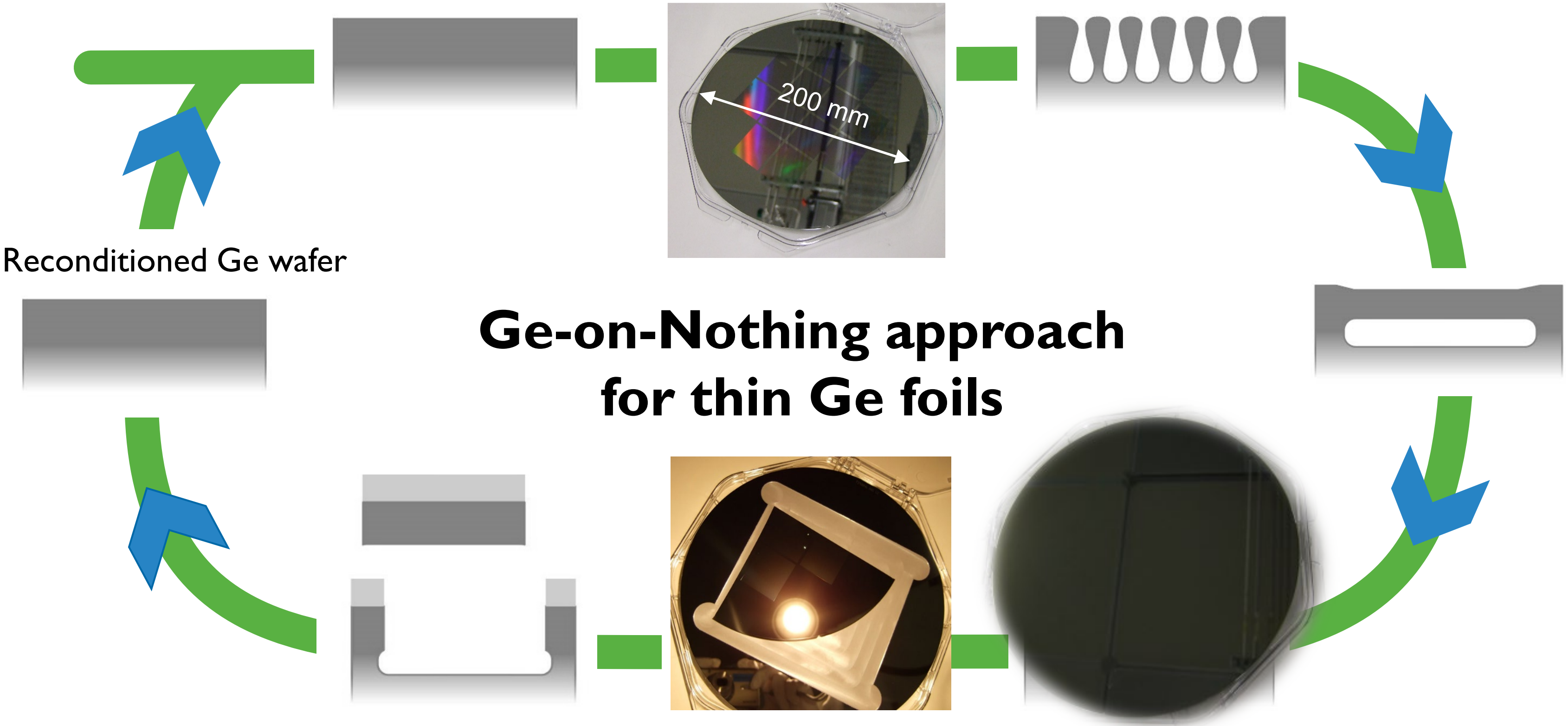
**(4)** Device processing

**(5)** Foil transfer

**(6)** Reconditioned Ge wafer

# Ge-on-Nothing approach

## Technological testbed on 8”



**(1)** Ge wafer

**(2)** Ge-on-Nothing formation

**(3)** Thickening by epitaxy *(optional)*

**(4)** Device processing

**(5)** Foil transfer

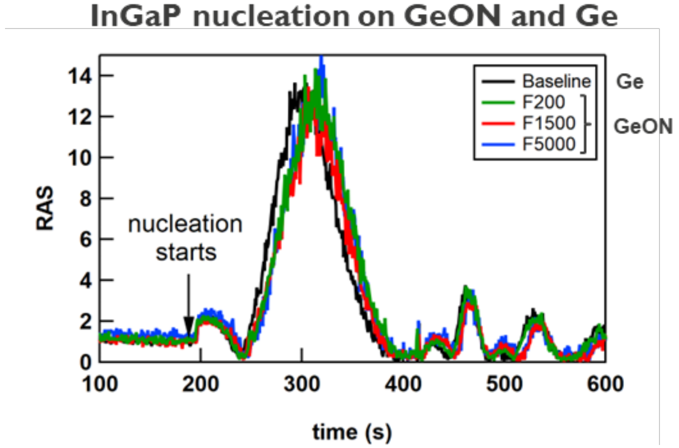
**(6)** Reconditioned Ge wafer

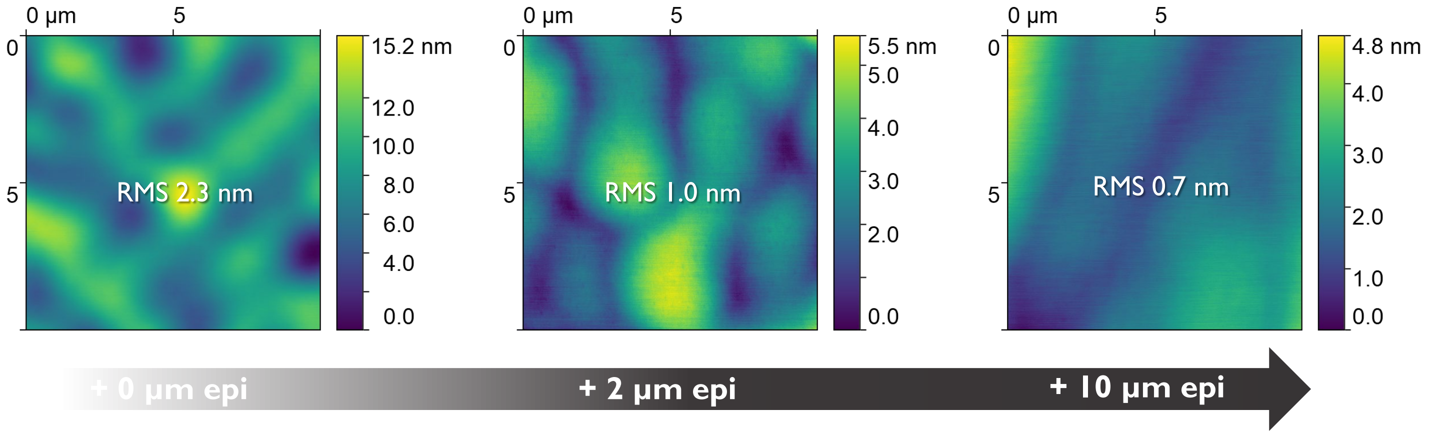
**Ge-on-Nothing approach for thin Ge foils**

# Ge-on-Nothing approach

## Technological testbed

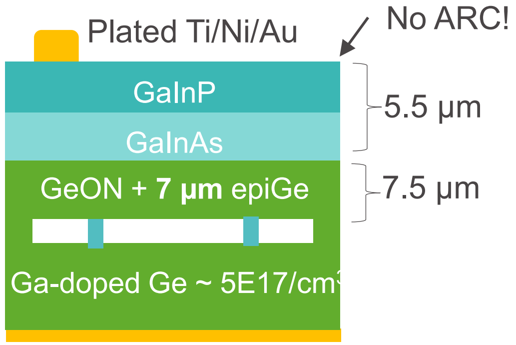
- 6 deg. wafer **miscut** towards (111) is preserved
- **No dislocations**
- Minority-carrier **lifetime** of undoped 10-µm foils with a-Si:H surface passivation > 25 µs
- Virtually identical III-V **nucleation** on Ge vs. GeON
- HRXRD confirms layers are **lattice-matched**





# Ge-on-Nothing approach

## Technological testbed



Plated Ti/Ni/Au

No ARC!

GaInP

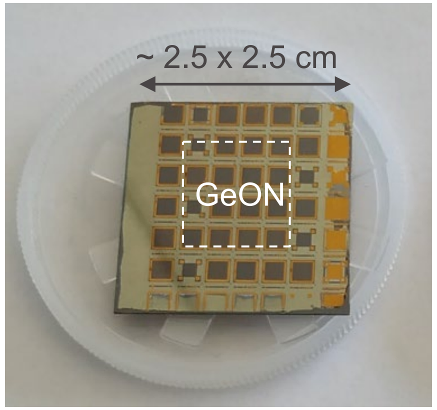
GaInAs

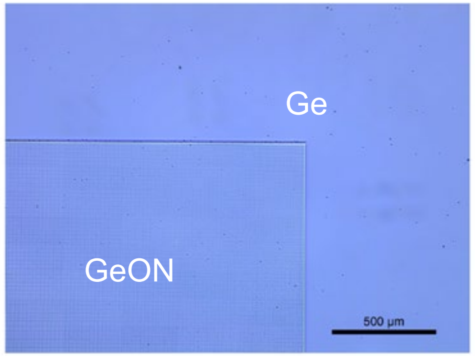
5.5 µm

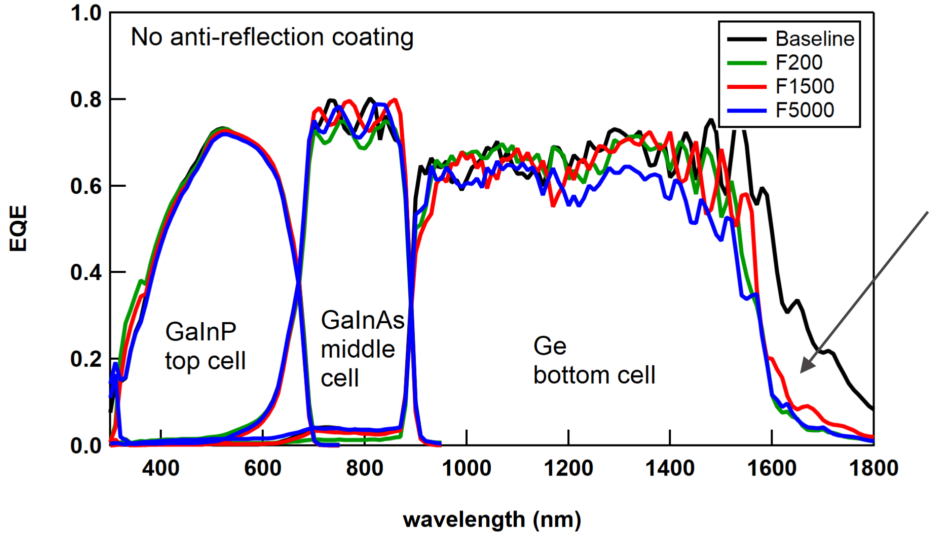
GeON + **7 µm** epiGe

7.5 µm

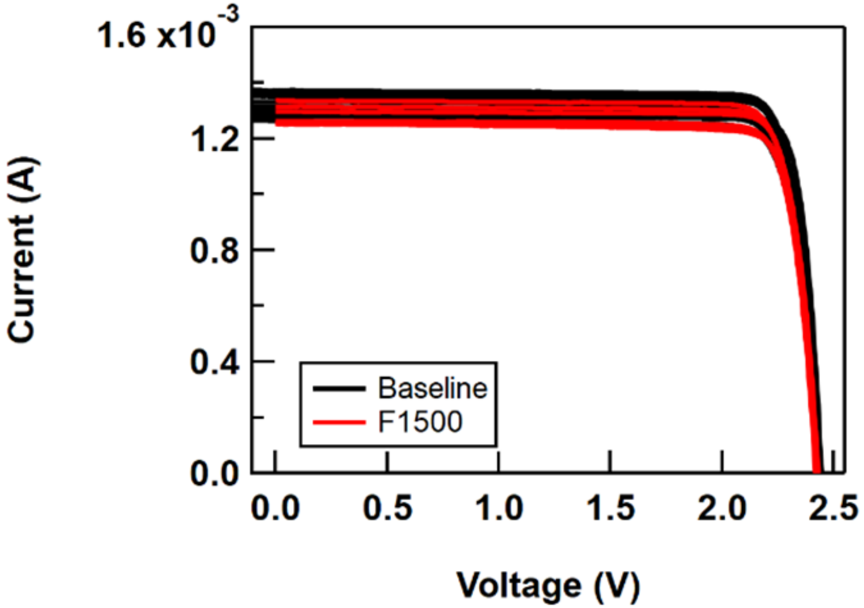
Ga-doped Ge ~ 5E17/cm³





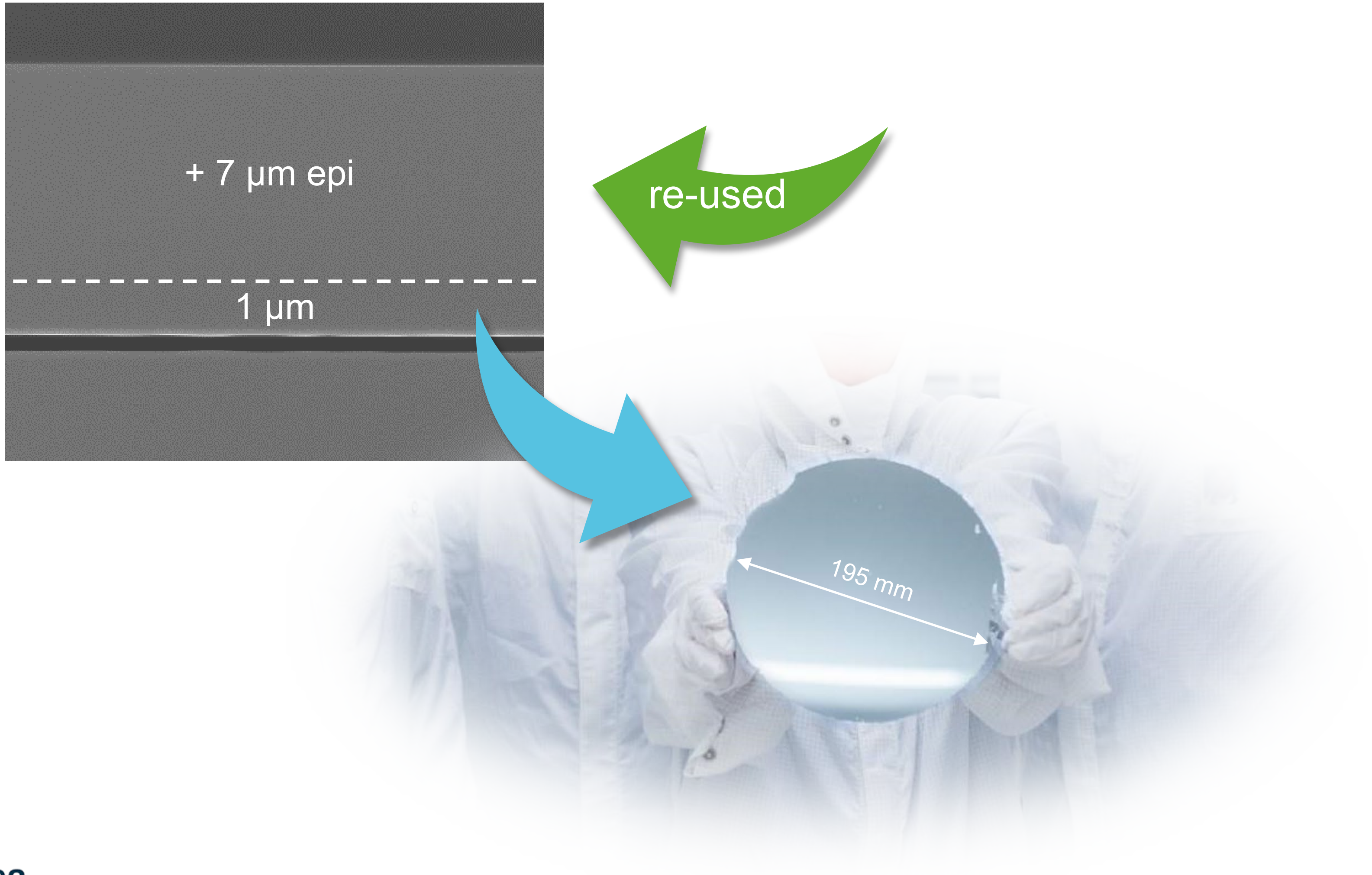


7 µm vs. Bulk Ge



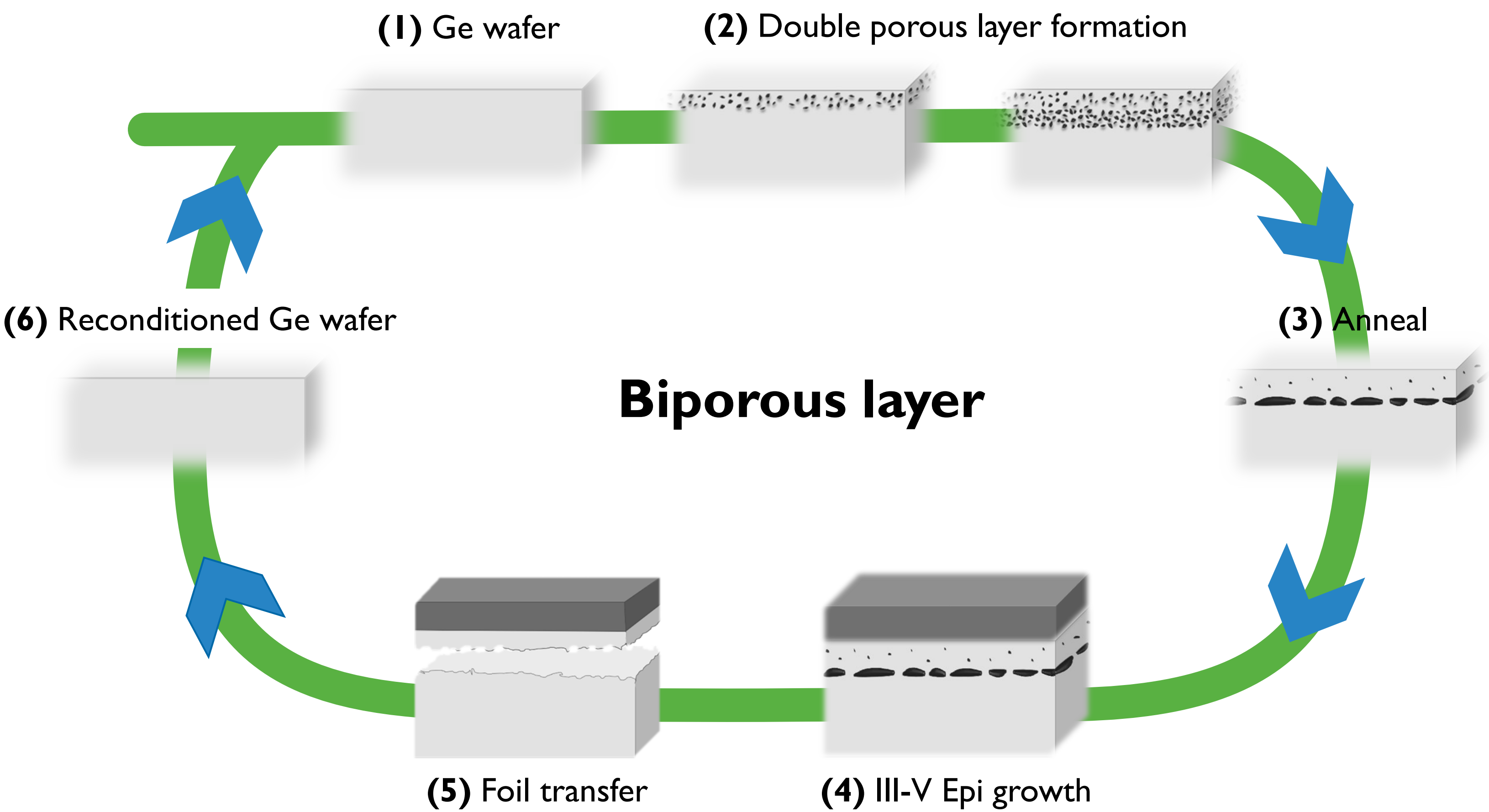
# Ge-on-Nothing approach

## Full wafer re-use demonstrated



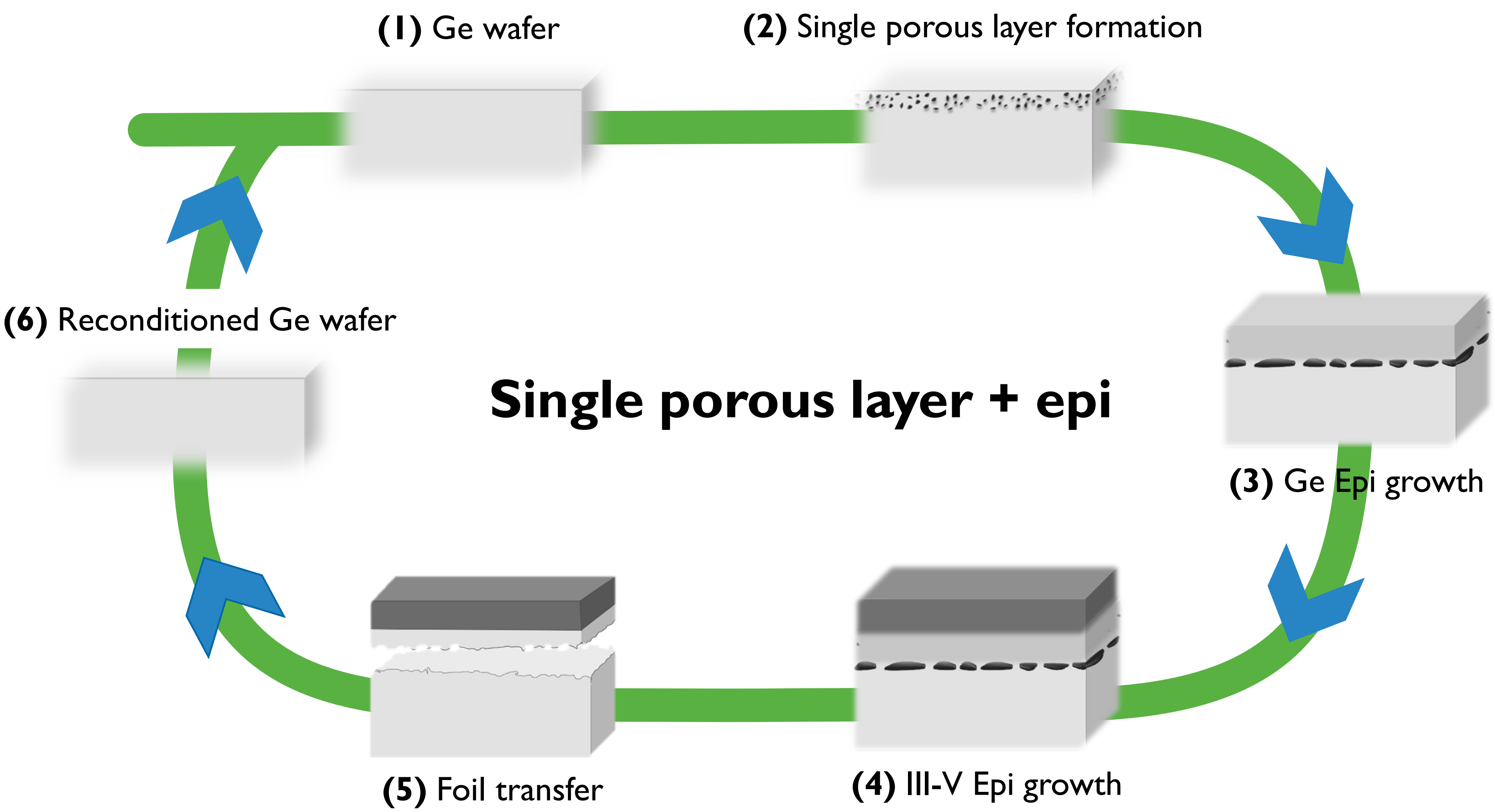
# Electrochemical etching

## Two approaches



# Electrochemical etching

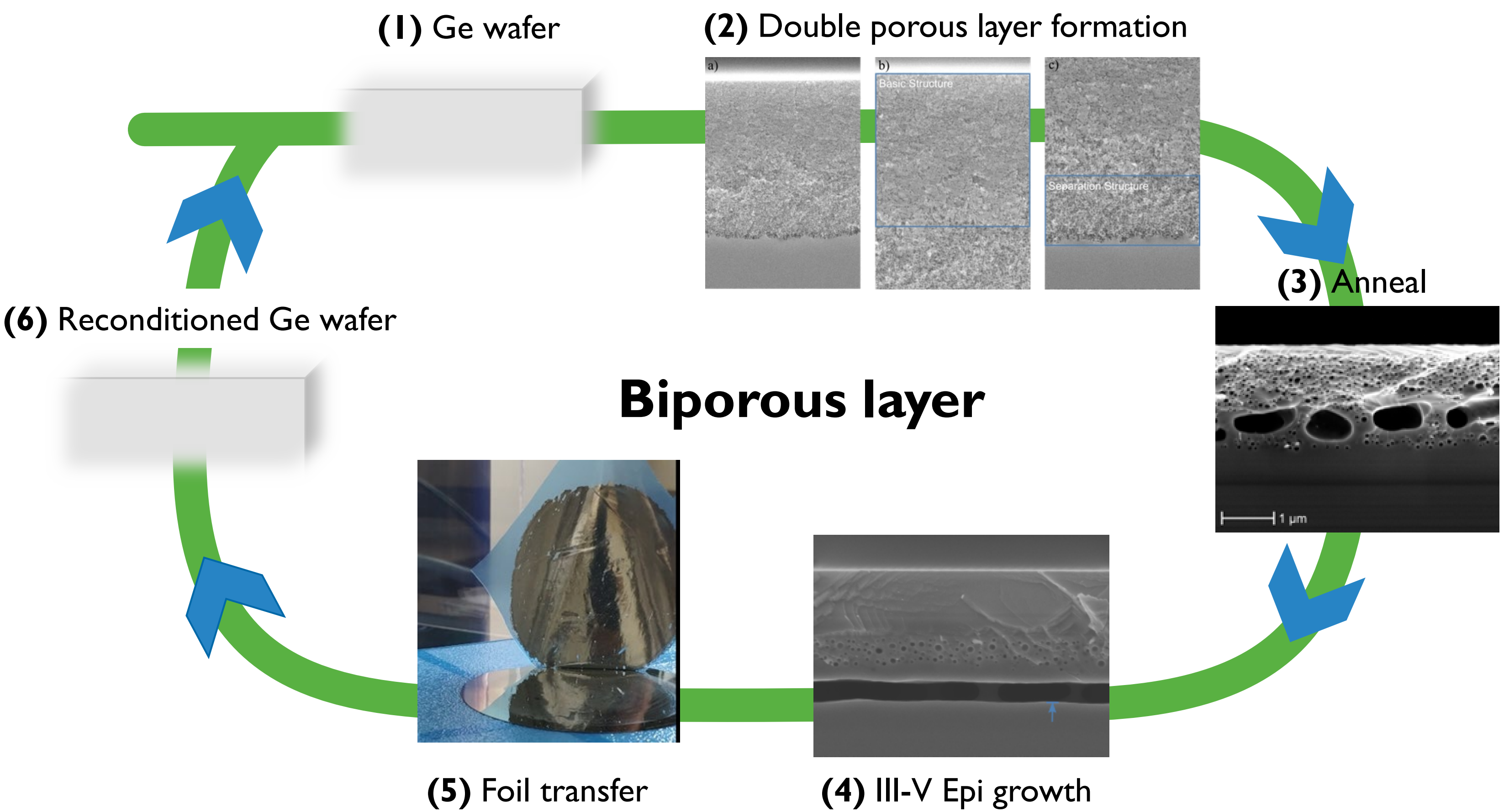
## Two approaches



**Single porous layer + epi**

# Electrochemical etching

## Two approaches



**(1)** Ge wafer

**(2)** Double porous layer formation

**(3)** Anneal

**Biporous layer**

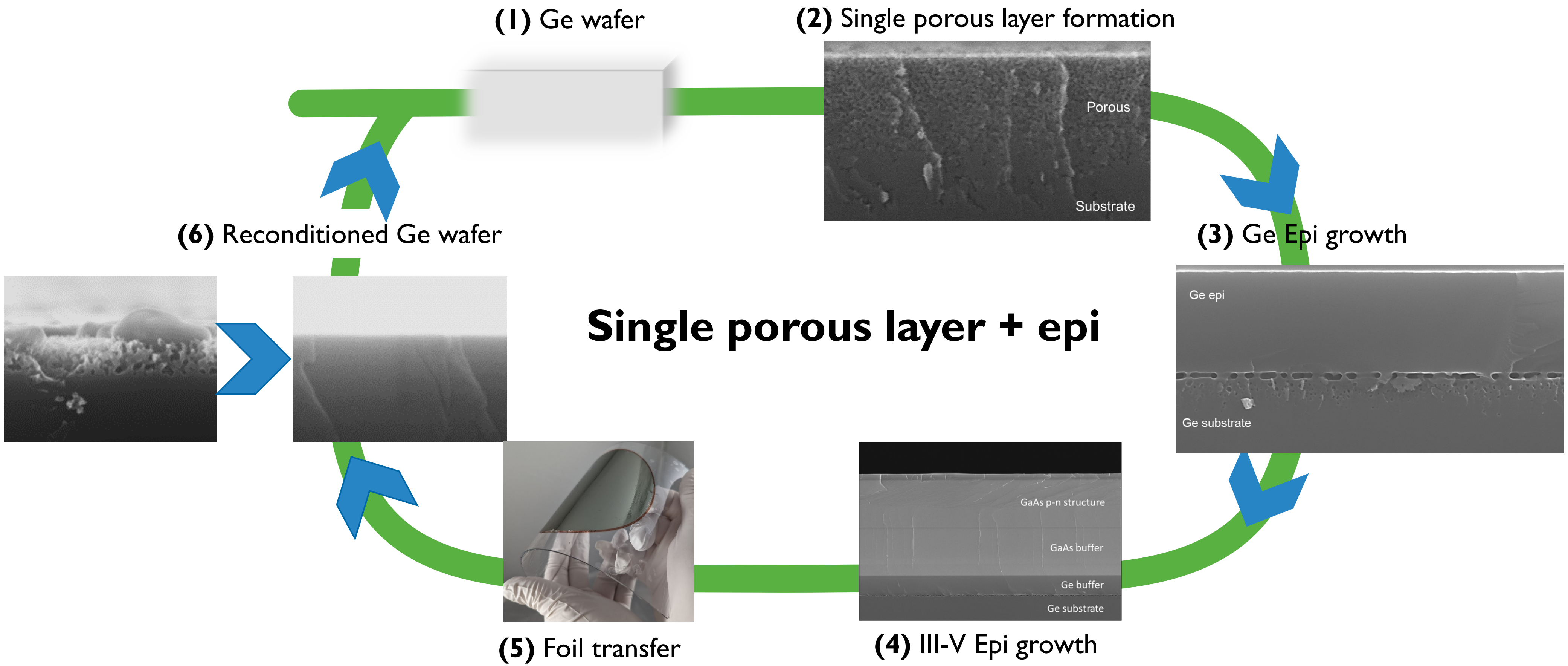
**(6)** Reconditioned Ge wafer

**(5)** Foil transfer

**(4)** III-V Epi growth

# Electrochemical etching

## Two approaches



**(1)** Ge wafer

**(2)** Single porous layer formation

**(3)** Ge Epi growth

**(4)** III-V Epi growth

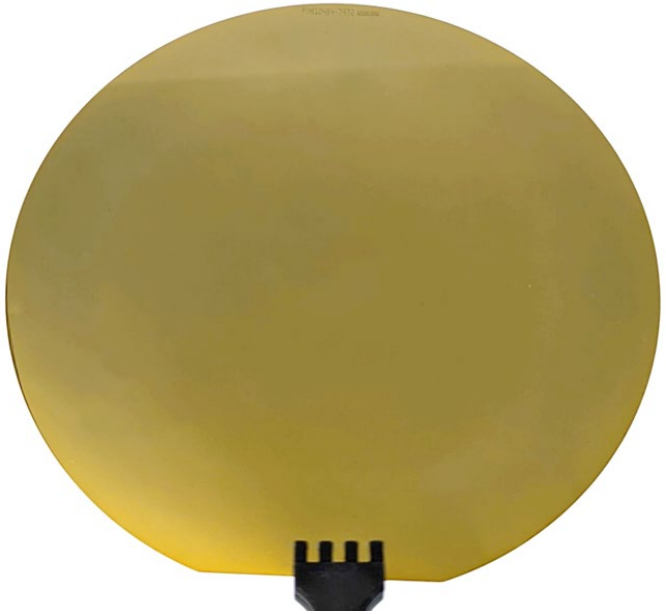
**(5)** Foil transfer

**(6)** Reconditioned Ge wafer

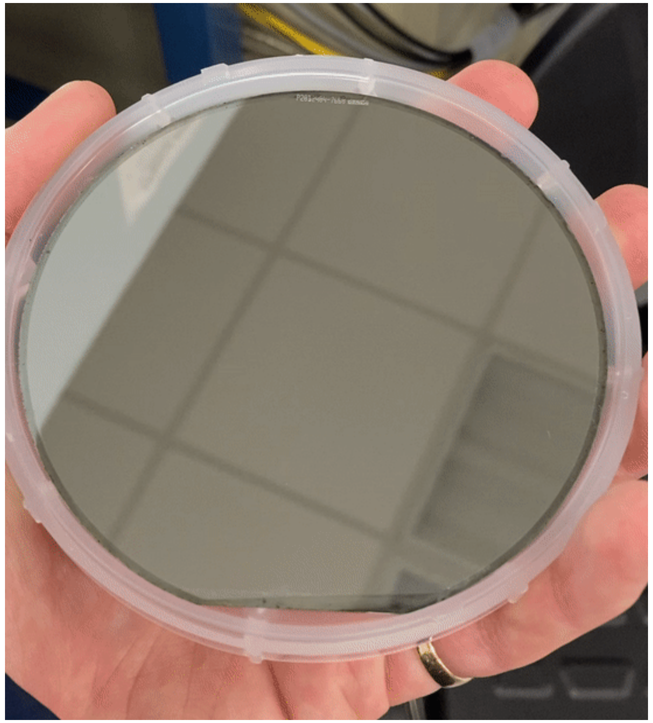
**Single porous layer + epi**

# Electrochemical etching

## Yields epi ready wafers…



porous 4” wafer



Porous 4” wafer after Ge epitaxy

# Engineered substrates – way forward

## Upscaling to 6” and pilot fab @ Umicore Belgium

| Until 2023 | 2023-2025 | 2025-2028 | Beyond 2028 |
|---|---|---|---|
| ***Proof of concept (v1)*** | ***Technical insourcing (v2)*** | ***Master processes, Scale up*** | ***Full production, Capacity expansion*** |
| 10/yr, 4” | $10^2$/yr, 4” | $10^3$/yr, 6” | >$10^4$/yr, 6” |

umicore
Electro-Optic Materials

# Connecting Life