Towards affordable flexible and light weight multi-junction solar cells

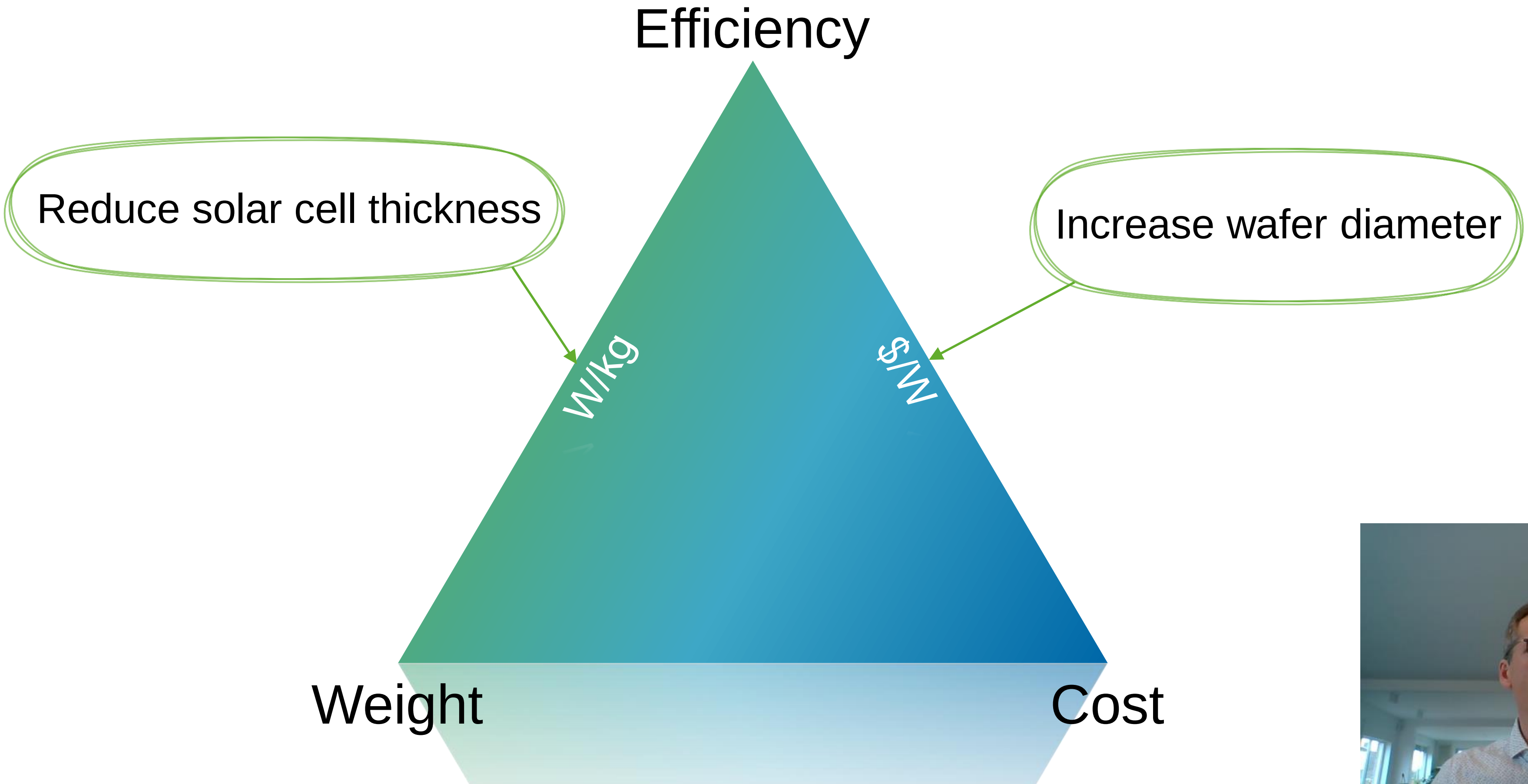
K. Dessein, J. Cho, G. Courtois, R. Kurstjens

SPW 2021

umicore
materials for a better life

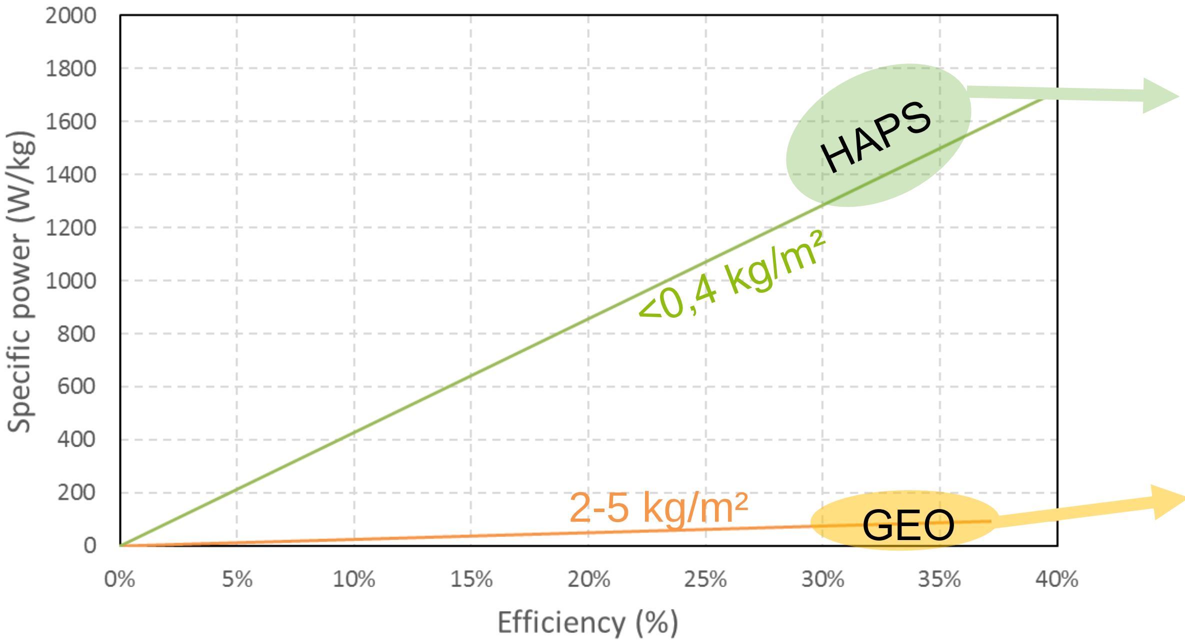
Introduction

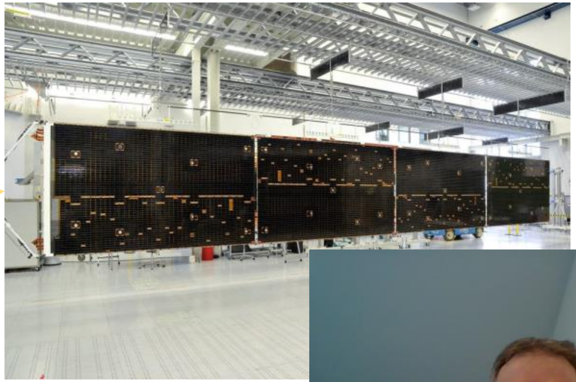
Key metrics are driving substrate diameter and solar cell thickness trends



Introduction

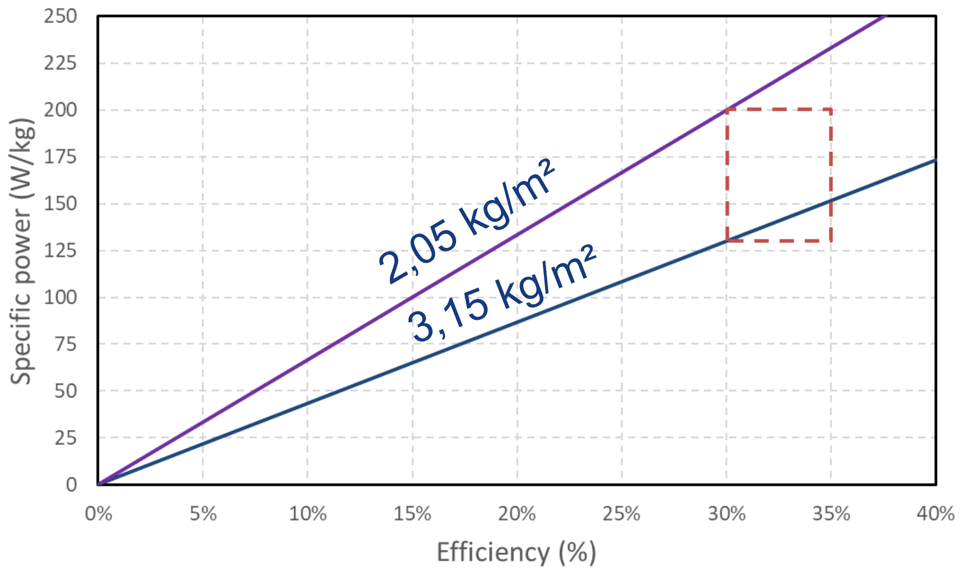
Application needs are driving solar cell assembly design

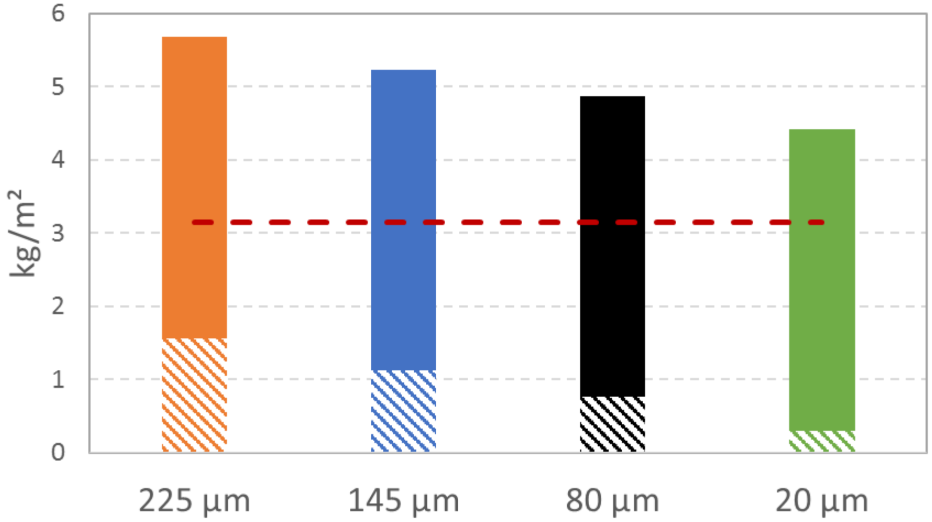




Introduction

GEO target 130-200 W/kg



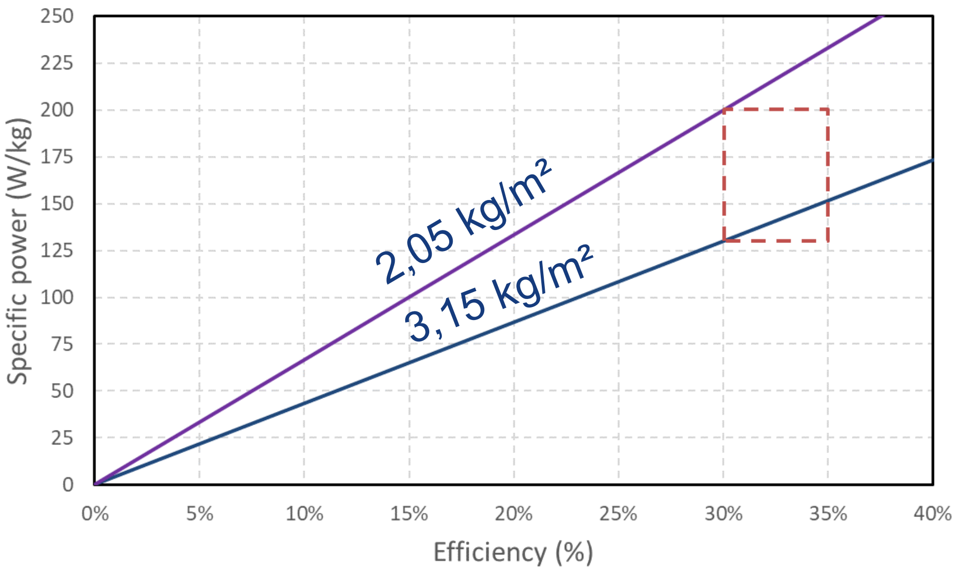


Reduction in Ge thickness isn't enough by itself

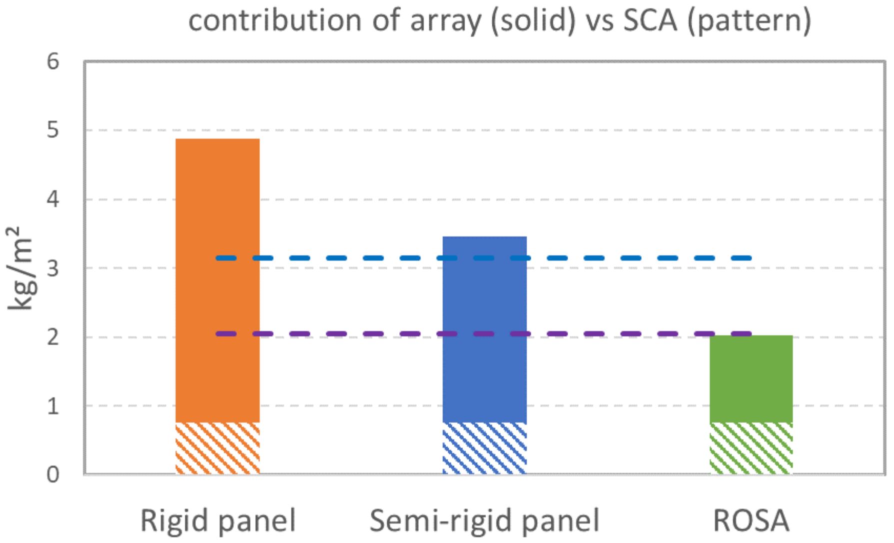
Development of a New, High-Power Solar Array for Telecommunication Satellites, C.G. Zimmermann, E3S Web Conf. 16 01006 (2017)

Introduction

GEO target 130-200 W/kg ➔ thin SCA is enabler



80µm thick SCA + various arrays



Reduction in Ge thickness isn't enough by itself

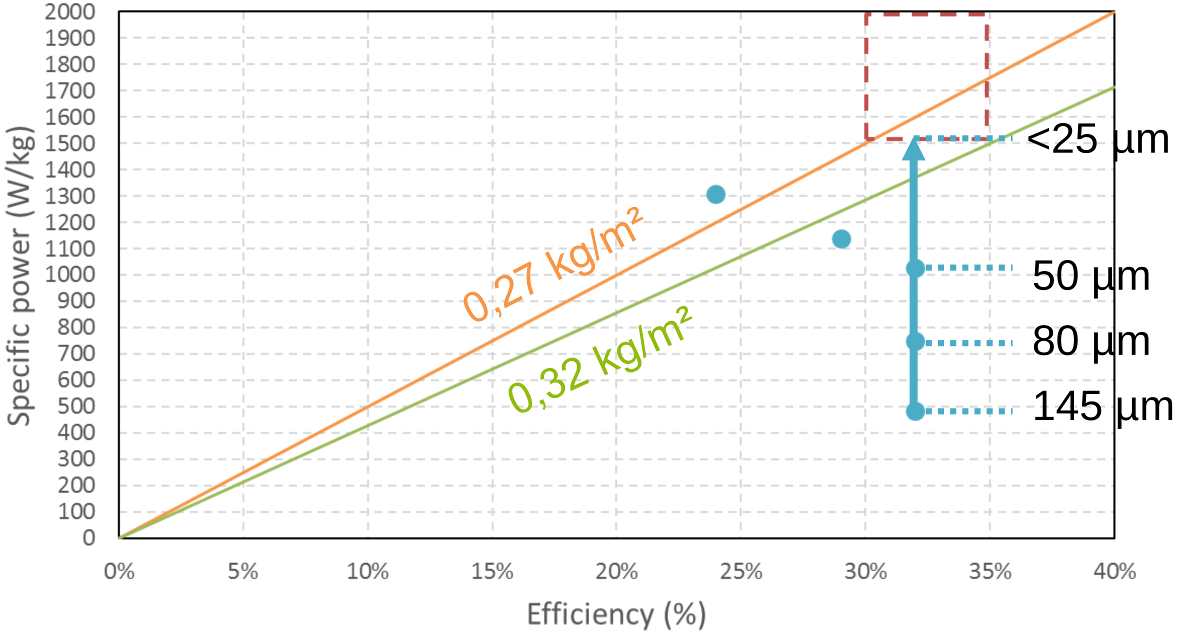
➔

combine with transition from rigid to semi-rigid array or ROSA

Development of a New, High-Power Solar Array for Telecommunication Satellites, C.G. Zimmermann, E3S Web Conf. 16 01006 (2017)

Introduction

HAPS targets ~1500 W/kg ➔ thin SCA mandatory!



https://solaerotech.com/wp-content/uploads/2018/03/UAV-Spec-Sheet-April-2017.pdf

http://mldevices.com/index.php/product-services/photovoltaics

https://www.altadevices.com/technology/

How thick should a Ge substrate be?

Ge substrate has 2 functions

Choice of thickness impacts 2 of the jobs that the Ge wafer must perform:

solar cell functionality

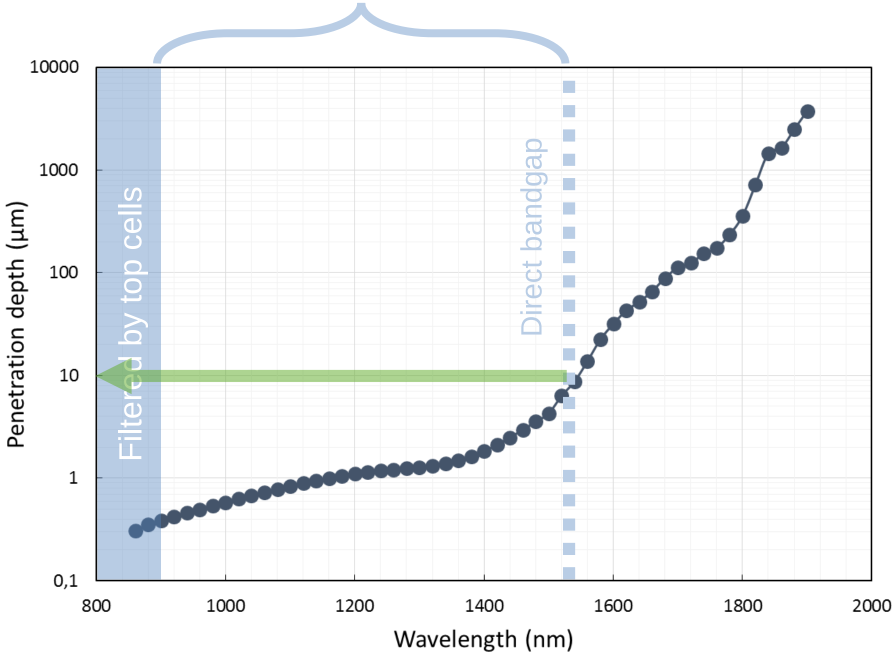
mechanical support

How much Ge is needed for each?

How thick should a Ge substrate be?

How much Ge is needed for the bottom cell in a TJ cell?

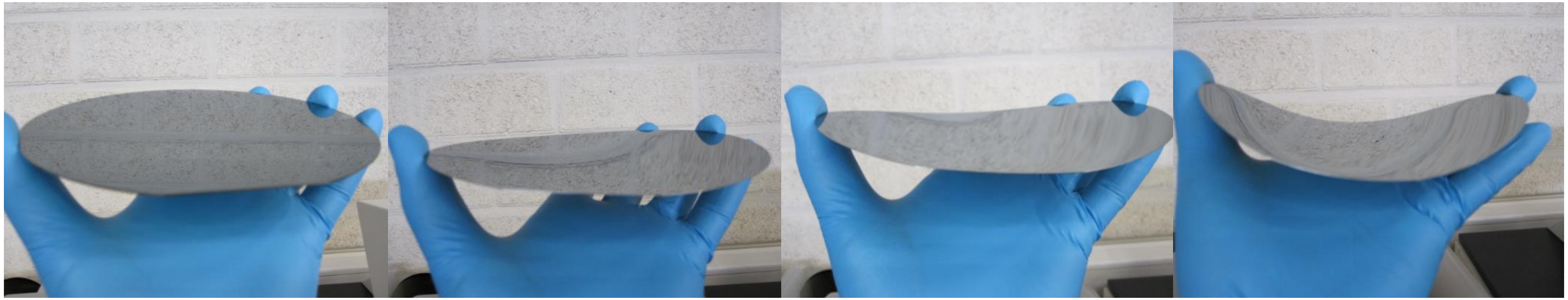
available current ~30 mA/cm²



5-10 µm of Ge is sufficient for the device… but what about mechanical support?

How thick should a Ge substrate be?

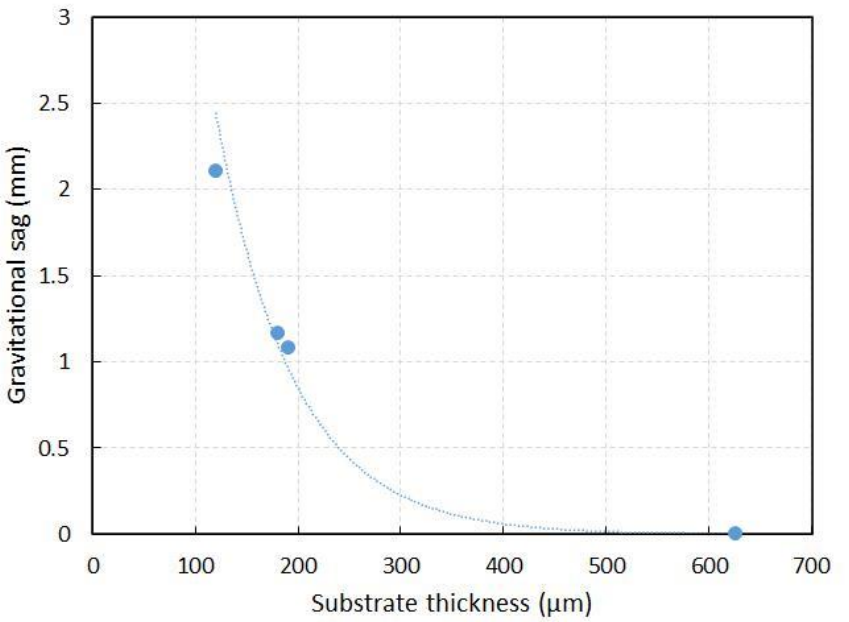
Substrate bow due to gravitation ~ r^2/t^3



625 µm | 190 µm | 180 µm | 120 µm

How thick should a Ge substrate be?

Substrate bow due to gravitation ~ r^2/t^3



4” wafer	6” wafer
135 µm	225 µm

Thinning options

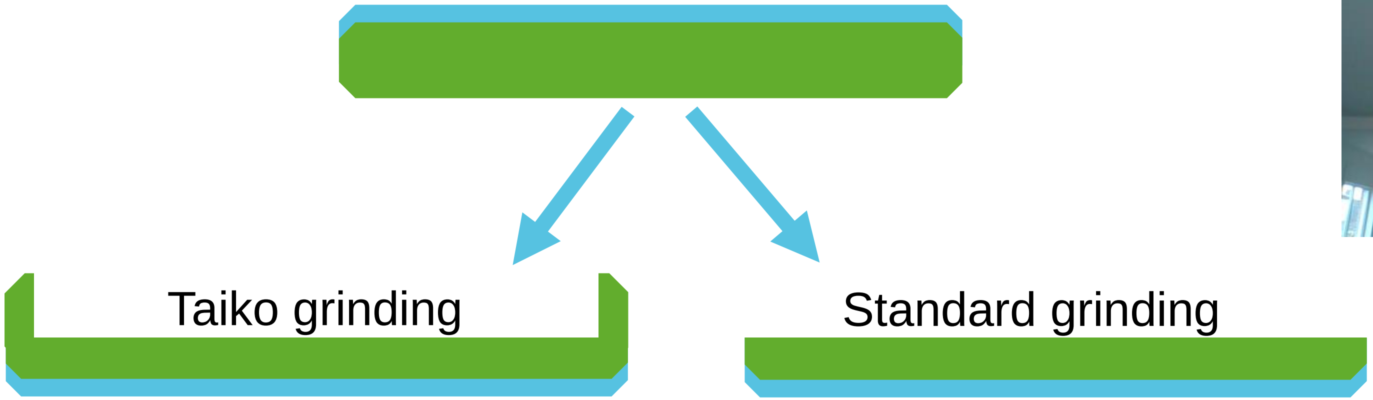
Substraction

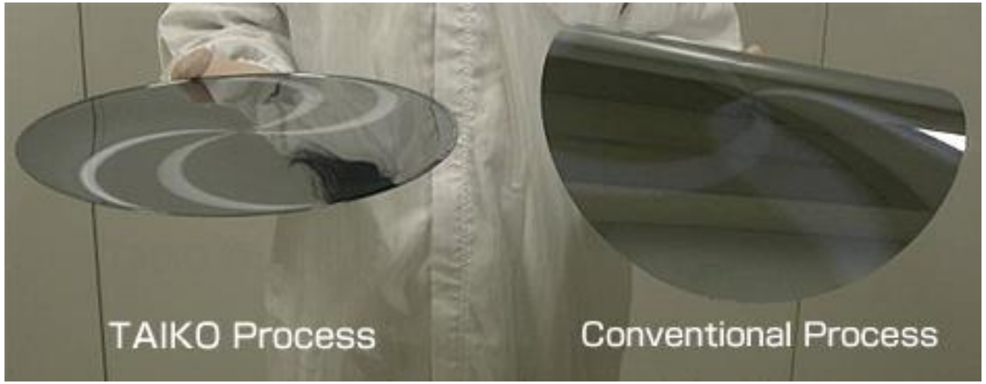
- End-of-line thinning by (Taiko) grinding

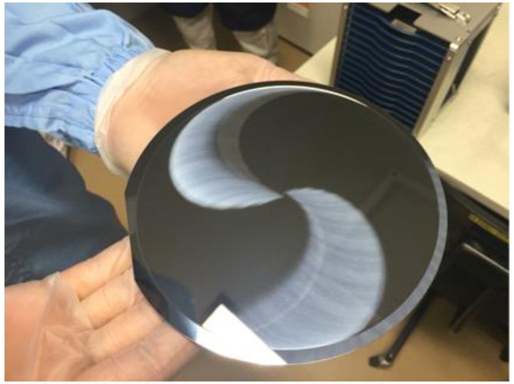
Addition

- ELO
- Weak layer

End of line thinning: (Taiko) grinding







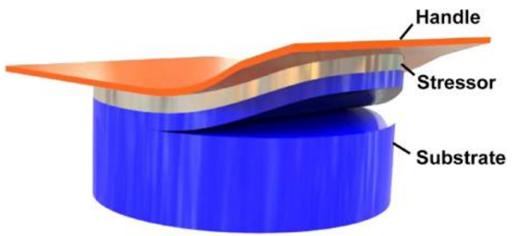
End-of-line wafer thinning

Ge mass balance: 100.000 wafers, 150 mm, 225 µm → 145 µm

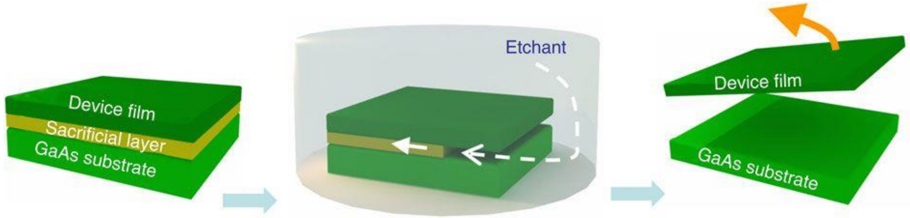
Lift-off techniques

Transfer mechanical support function to other material + substrate re-use

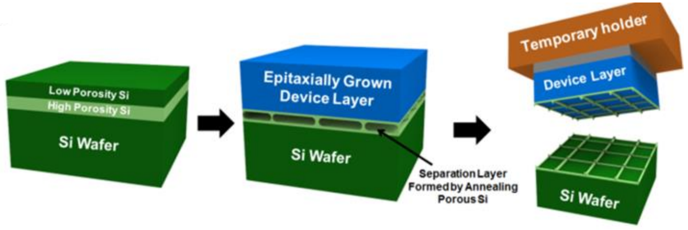
Spalling



Epitaxial Lift Off



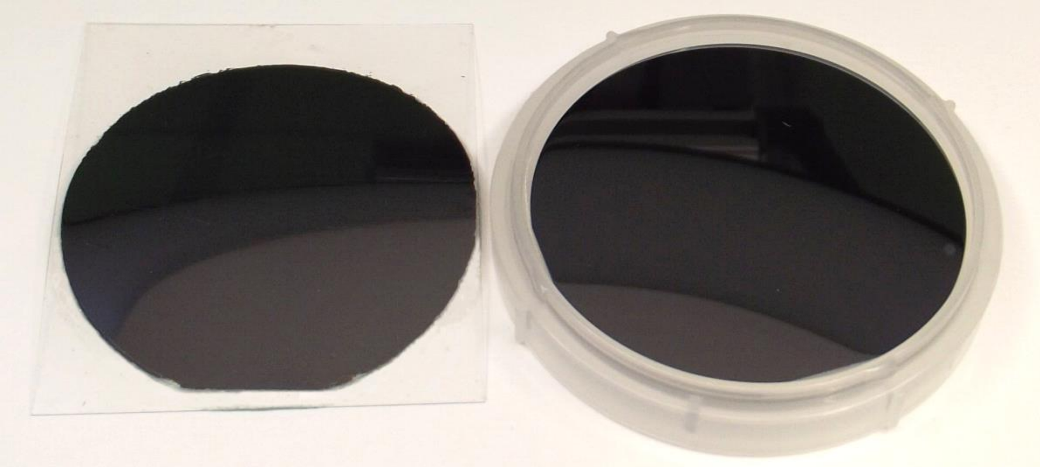
Weak layer

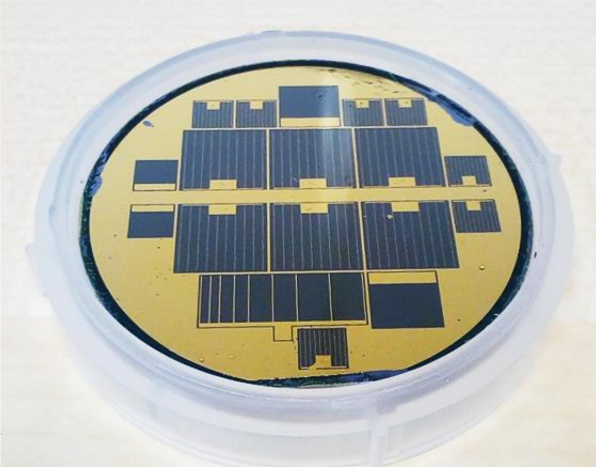


umicore

Lift-off techniques

Epitaxial Lift Off: lifting GaAs layers of from Ge substrates





Demonstration of ELO thin-film (left) from a Ge wafer (right)

Cells processed from the ELO thin-film after replacement of the flexible foil handle with a rigid carrier to facilitate processing

eit RawMaterials Connecting matters

EIT RawMaterials is supported by the EIT, a body of the European Union

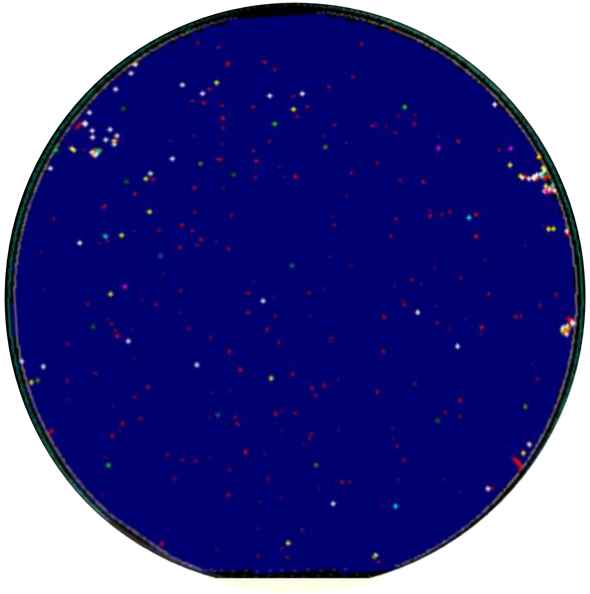
Radboud Universiteit

Fraunhofer ISE

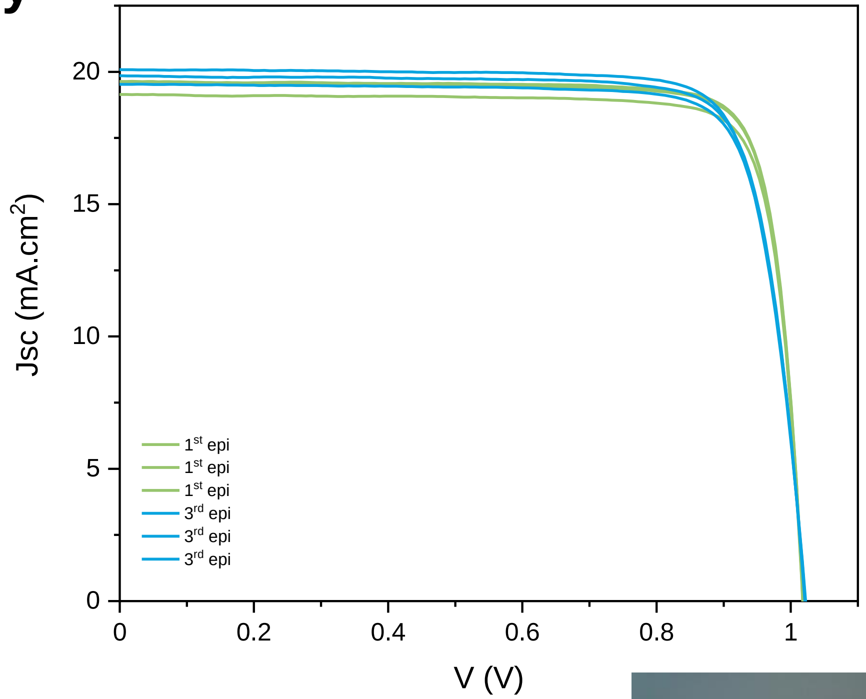
tf2 devices

Lift-off techniques

Epitaxial Lift Off: Proven technology



Surfscan of Ge wafer before 3rd epitaxial growth.

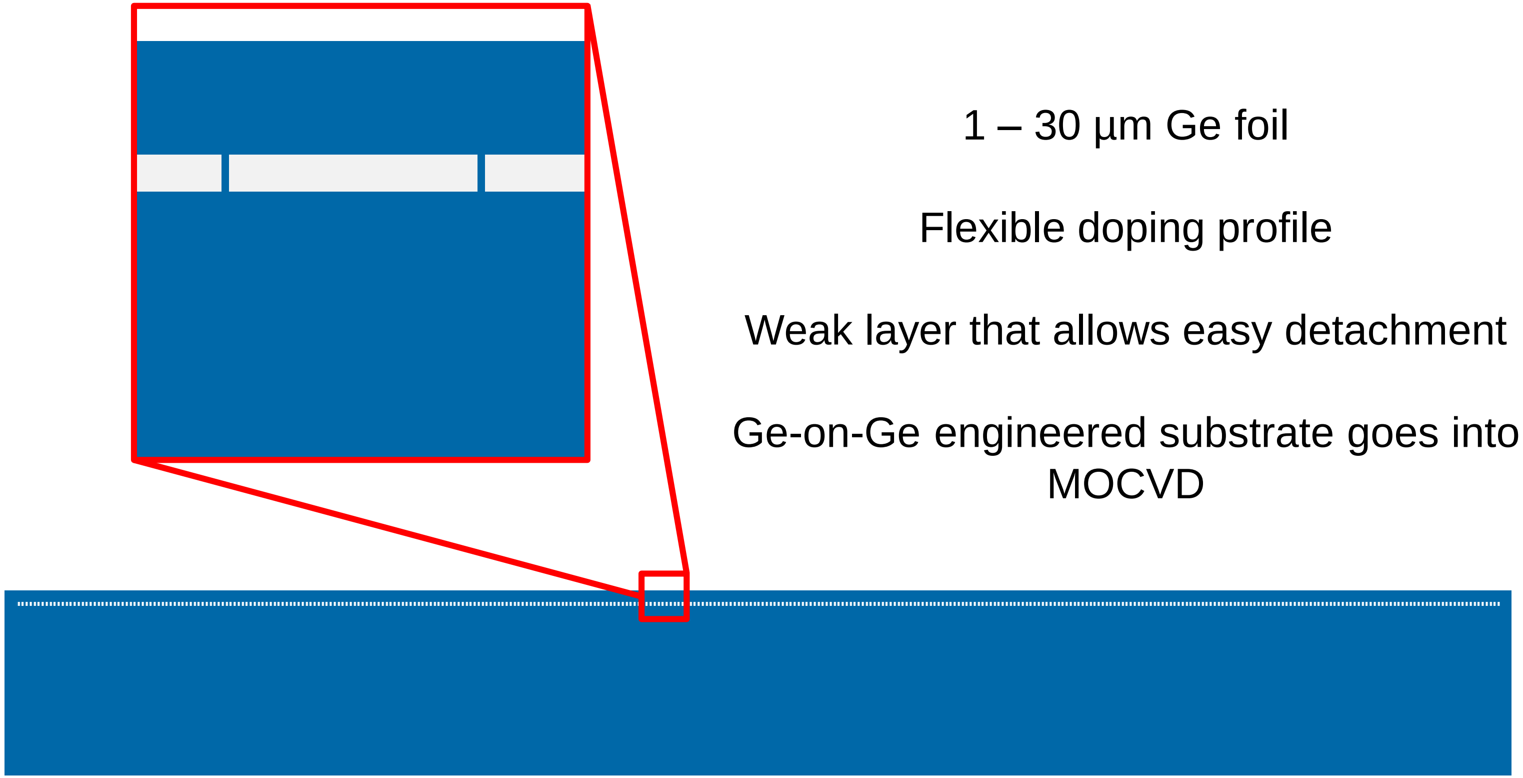


JV-characteristics of thin-film GaAs solar cells grown on a new Ge wafer (1st epi) and on a reused Ge wafer (3rd epi). 1 cm^2 without ARC.

Radboud Universiteit
eit RawMaterials Connecting matters
EIT RawMaterials is supported by the EIT, a body of the European Union
Fraunhofer ISE
tf2 devices
umicore

Lift-off techniques

Umicore concept wafer: Ge-on-Ge engineered substrate



1 – 30 µm Ge foil

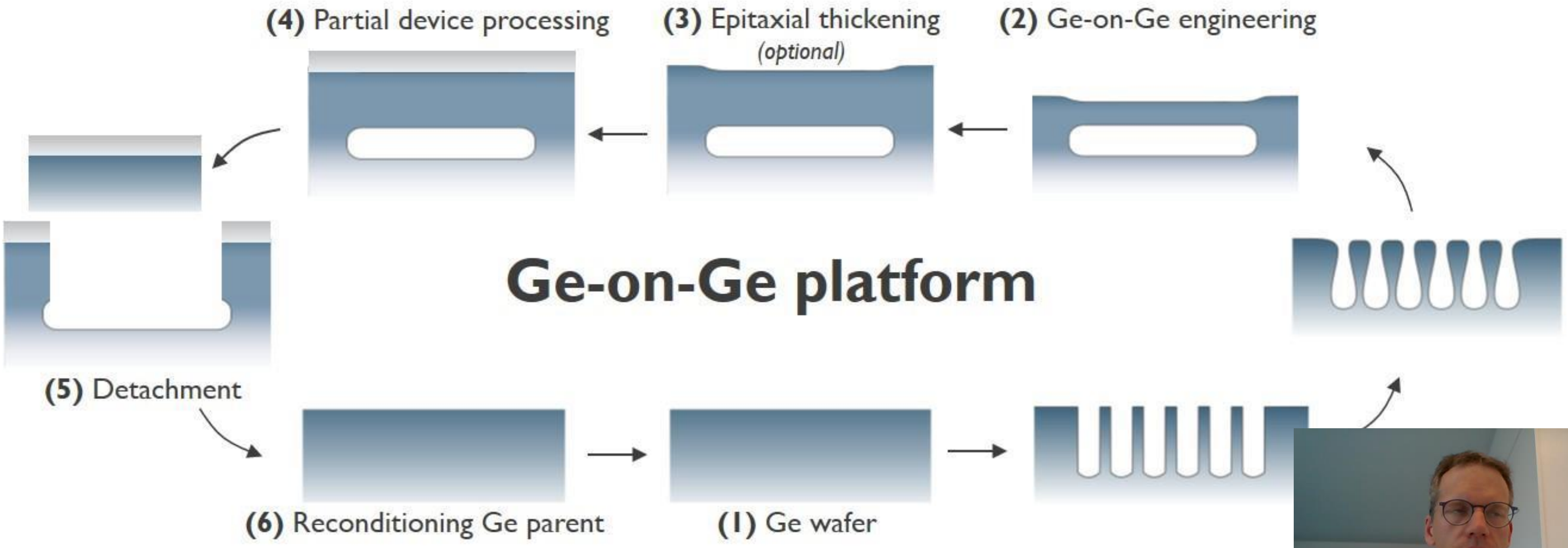
Flexible doping profile

Weak layer that allows easy detachment

Ge-on-Ge engineered substrate goes into MOCVD

Ge-on-Ge engineered substrate

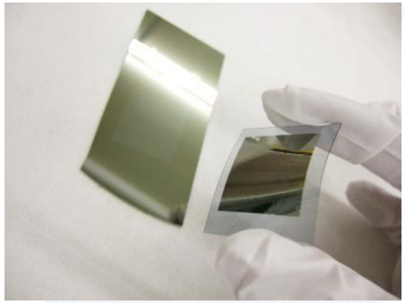
Process flow

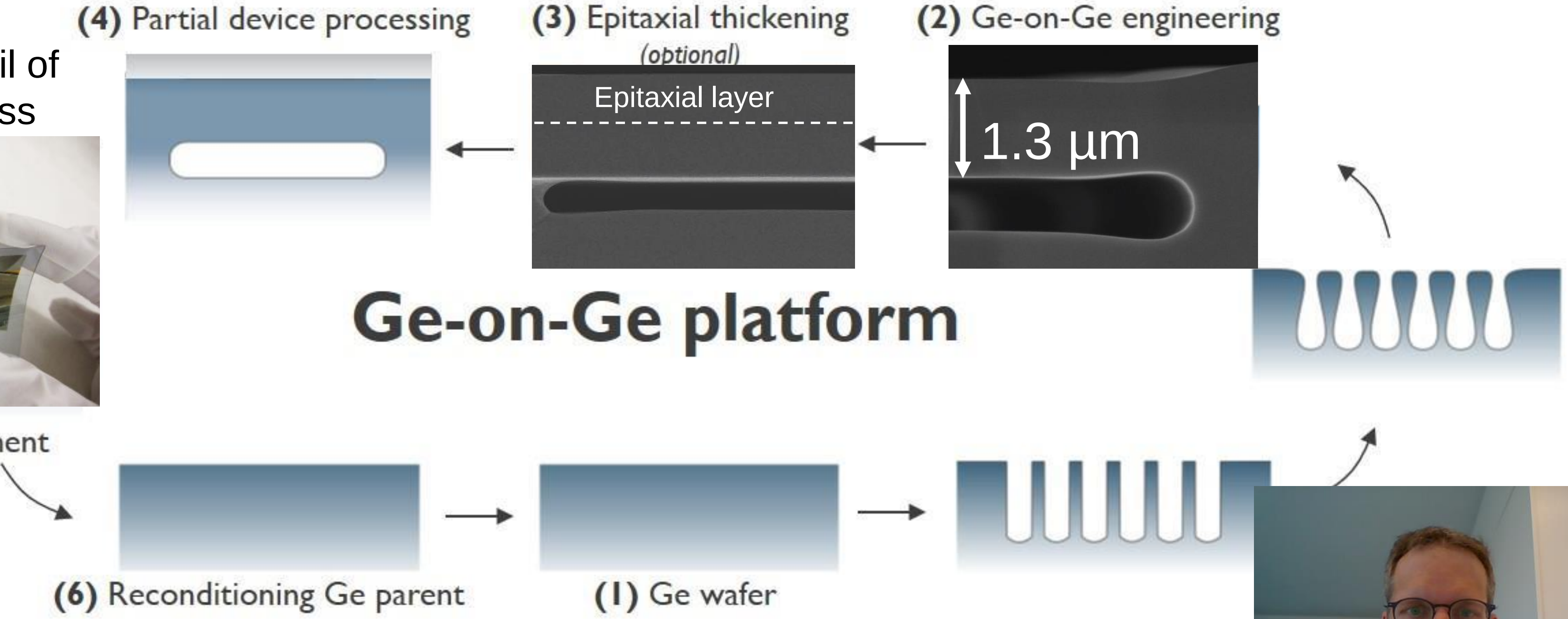


Ge-on-Ge engineered substrate

Process flow

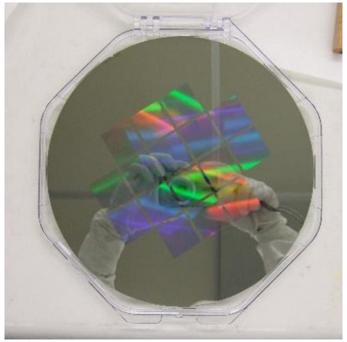
2.5 x 2.5 cm foil of
1.5 µm thickness

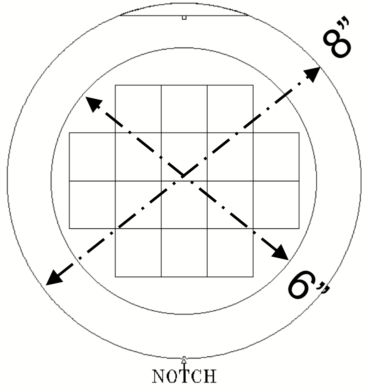


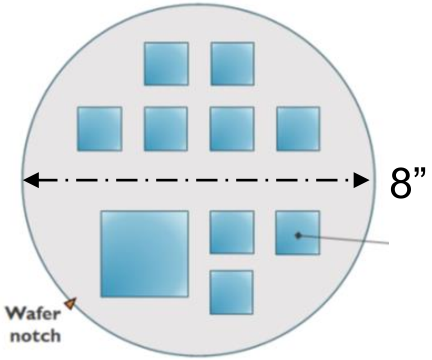


Ge-on-Ge engineered substrate

Work done on full wafer substrate size



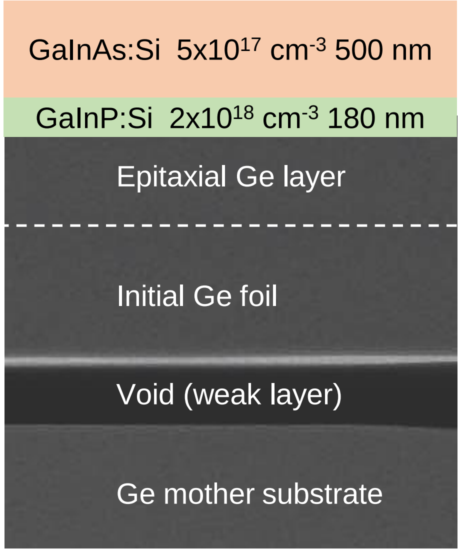




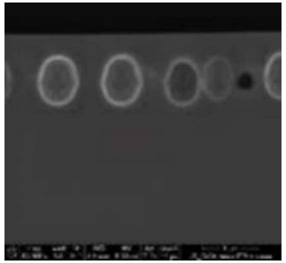
Activity carried out under a program of, and funded by, the European Space Agency.

Ge-on-Ge engineered substrate

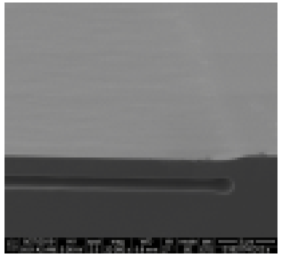
MOCVD growth results



Sample A



Sample B

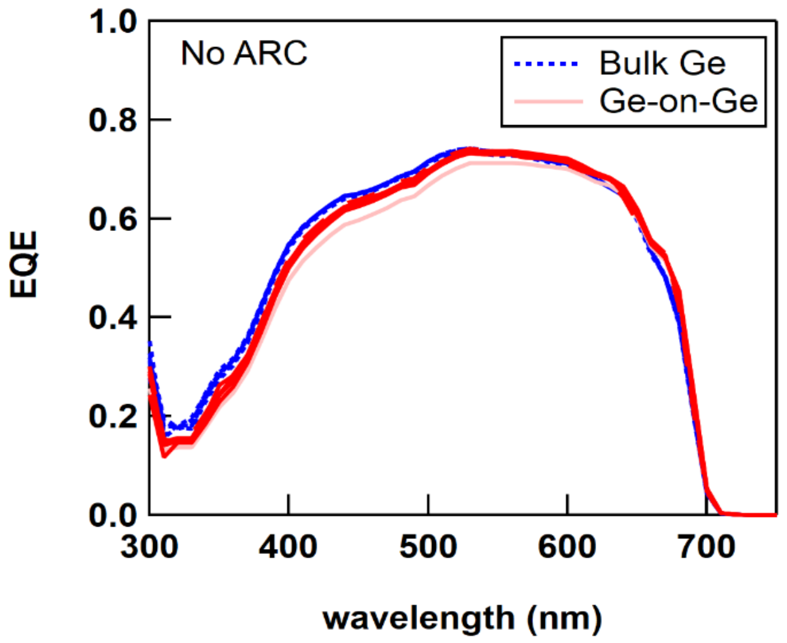


- Process maintains monocrystalline nature
- Process maintains 6 degrees off-cut
- No flaking or collapsing observed during growth

Activity carried out under a program of, and funded by, the European Space Agency.

Ge-on-Ge engineered substrate

MOCVD growth results



Activity carried out under a program of, and funded by, the European Space Agency.


umicore
Electro-Optic Materials
Connecting Life