

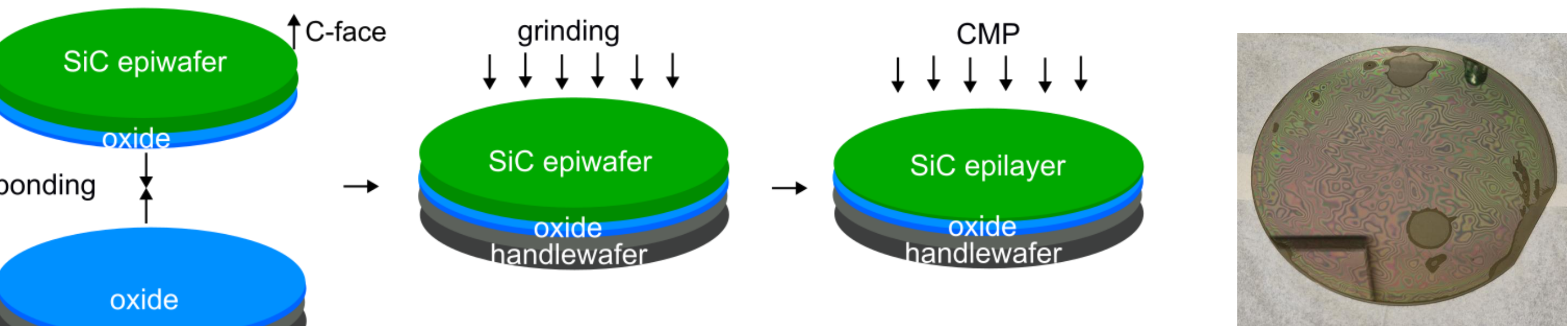
Dopant-selective photo-electrochemical etching of SiC and SiC-on-Insulator

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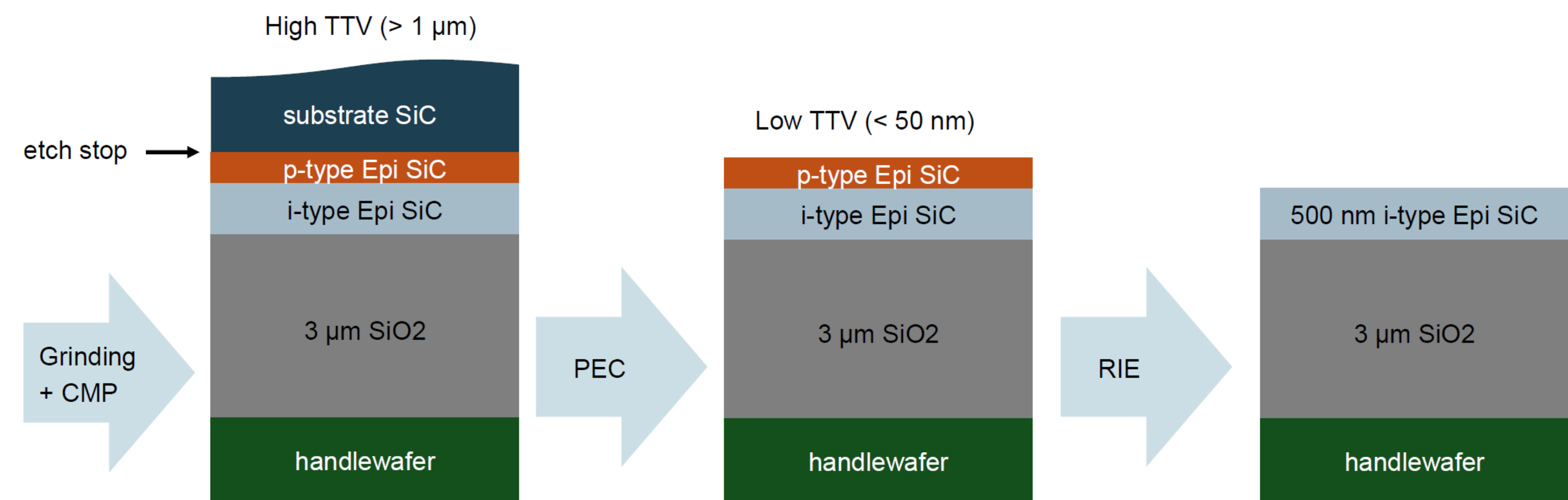
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Motivation: Planarisation of SiC-on-Insulator



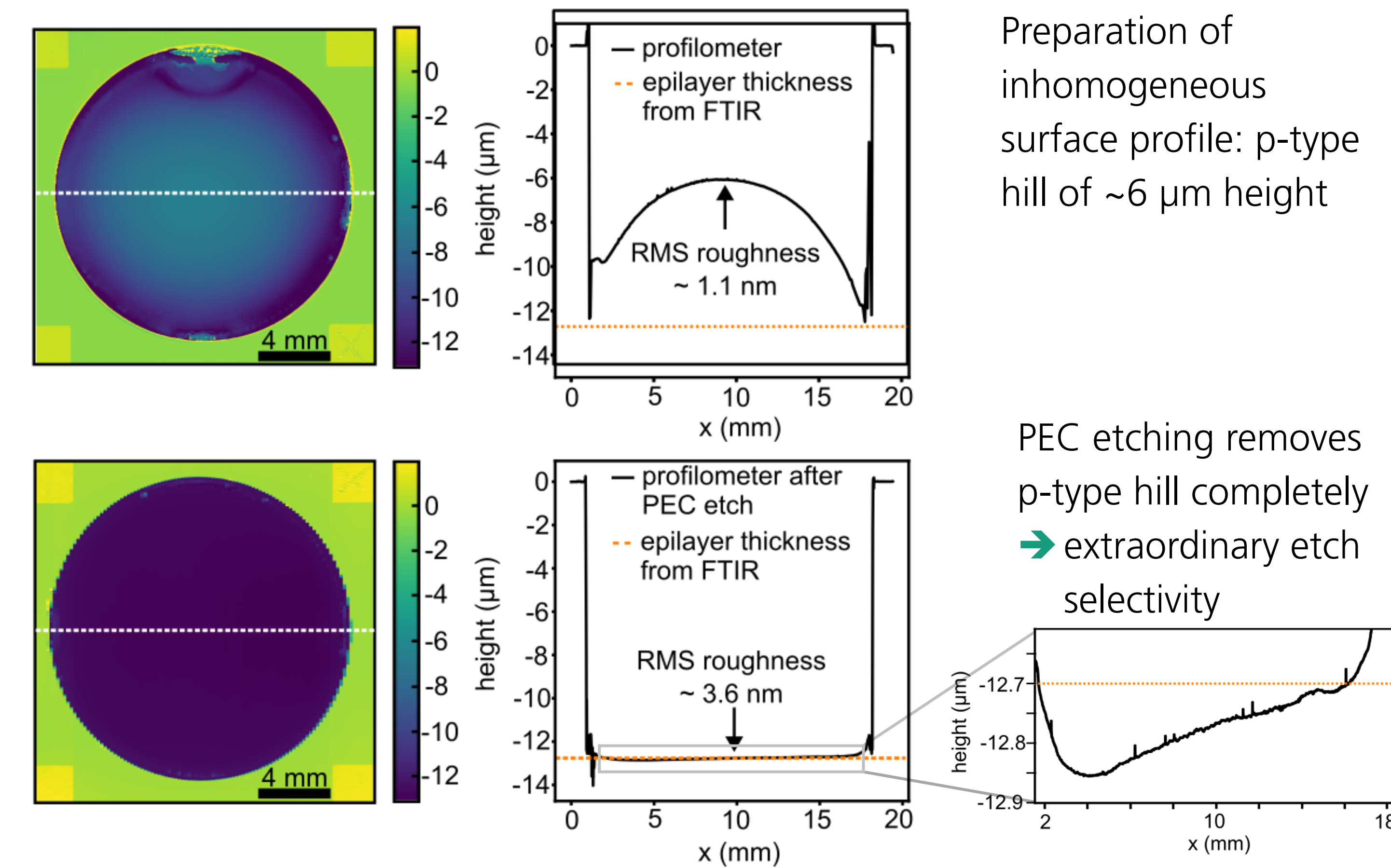
- Bond-Grind-Polish approach is considered to preserve quality of 4H-SiC bulk epilayers on the SiCOI platform [1]
- However, grinding of the SiC substrate leaves TTV of several μm [2], while subsequent CMP still leaves TTV $\approx 1 \mu\text{m}$
- Reproducibility and yield of photonic elements (waveguides, splitters, etc.) is drastically deteriorated
- ➔ Major obstacle for scaling SiCOI as a (quantum-)photonic platform

Photo-electrochemical etch stop

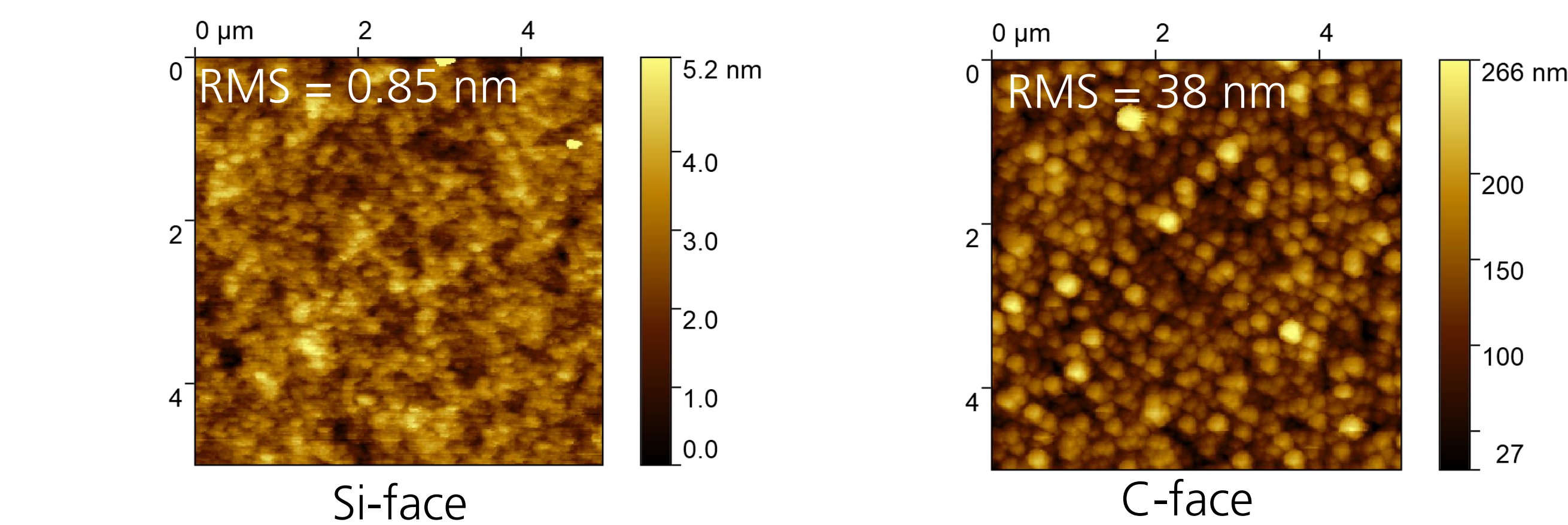


- Dopant selective etch stop via photo-electrochemical (PEC) etching reduces the TTV drastically [3]
- SiCOI thickness variation is determined by epilayer growth inhomogeneity
- ➔ TTV on the order of $\sim 10 \text{ nm}$ is feasible [5]

Etch stop for p-type epilayer



Influence of crystal orientation: Si-face vs. C-face



- 4H-SiC substrate after 2 h of PEC etching at identical parameters:
- Increased etch rate on C-face ($\sim 50 \%$ compared to Si-face)
 - Increased roughness (up to $\times 50$) and/or porous etching on C-face

Summary and Outlook

Milestones achieved:

- Etch stop on bulk SiC: selective removal of p+ epilayer
- SiCOI: partial etch stop

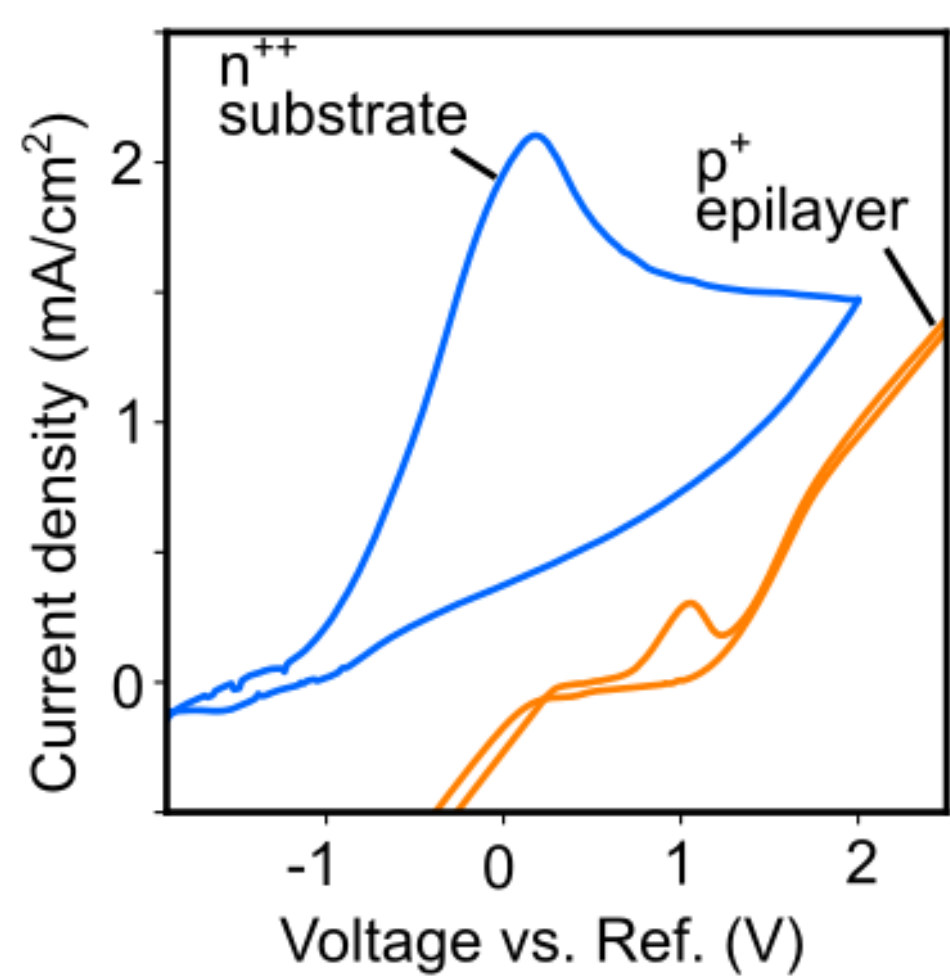
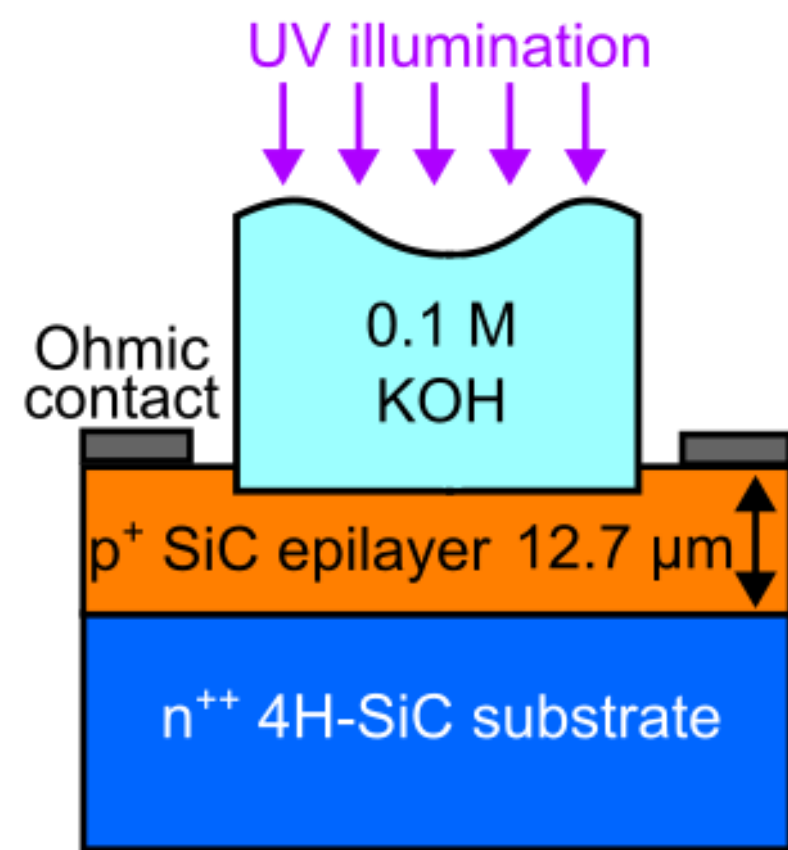
Next steps:

- Adapt PEC etching process to SiCOI
- Scaling to 6-inch platform

Strategy: SiCOI with Si-face or C-face exposed?

- Implication on SiCOI fabrication process as well as electronic and photonic integration

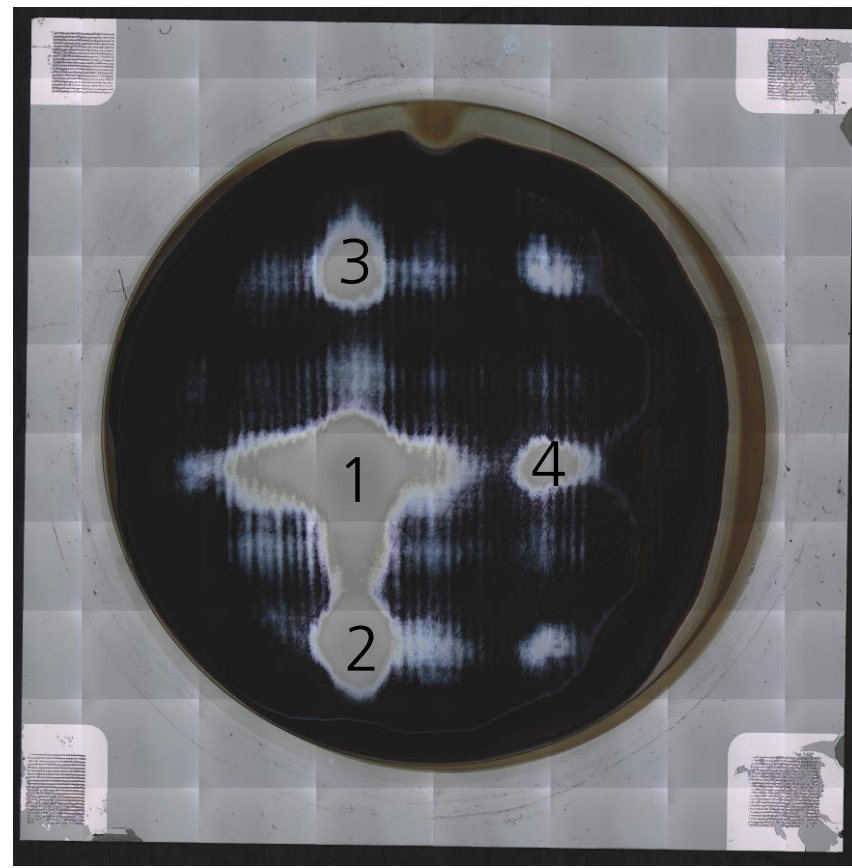
Dopant-selective photo-electrochemical etching (PEC)



Experimental setup:

- 3-electrode electrochemical cell with holder for 20 x 20 mm dies
 - UV illumination unit for homogeneous intensity distribution
 - Ohmic contacts on the frontside ensure applicability to SiCOI
- Cyclic voltammetry exhibits clear passivation peak [4] for n-type SiC at $\sim 0 \text{ V}$, while p-type SiC can only etch for $> 1.3 \text{ V}$
- ➔ Different etching windows for n-type and p-type 4H-SiC facilitate doping selectivity

Preliminary result: PEC of SiCOI



Optical micrograph

SiCOI with exposed substrate (C-face) on top of $5 \mu\text{m}$ i-type epilayer

Findings:

- ➔ Partial etch stop is achieved, according to reflectometry (see Table 1)
- ➔ High roughness at the etch stop ($> 10 \text{ nm RMS}$), elsewhere porous SiC
- ➔ Process parameters need to be optimized for SiCOI (C-face)

Table 1: Reflectometry and AFM after PEC etch

Pos. #	SiCOI thickness (nm)	RMS roughness (nm)
1	5109	18
2	5042	not meas.
3	5004	12
4	5002	13

Acknowledgements:

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1 A. Boretti, Q. Li, S. Castelletto, *Pioneering the future with silicon carbide integrated photonics*, Optics & Laser Technology, Volume **181**, Part B (2025).

2 Wang, C., Fang, Z., Yi, A. et al. *High-Q microresonators on 4H-silicon-carbide-on-insulator platform for nonlinear photonics*. Light Sci Appl **10**, 139 (2021).

3 J. Lipton, B. Yurash, A. Sorensen, et al. *Low-Loss Nanophotonic Devices with Chip-Level Uniformity and Integrated Color Centers in SiC-On-Insulator*. ACS Photonics; **12** (5): 2397–2405 (2025).

4 S. P. Pavunny, R. L. Myers-Ward, K. M. Daniels et al. *On the doping concentration dependence and dopant selectivity of photogenerated carrier assisted etching of 4H-SiC epilayers*, Electrochimica Acta, Volume **323**, 134778 (2019).

5 AIXTRON SE: Product Sheet G10-SiC, <https://www.aixtron.com/de/produkte/verbindungshalbleiter-mocvd/g10-sic>