

4H-SiC Deep Trench Development for Superjunction Devices

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Motivation

- Minimizing power losses via novel SiC device concepts like superjunction (SJ) [1-4]
 - alternating n- and p-pillars for full charge compensation in the drift region
 - implementation of pillars by deep-trench and epitaxial filling approach
- Process development to increase trench depth by improving SiC/SiO₂ selectivity

Recipe	Process Parameter				Selectivity SiC/SiO ₂ [-]	Micro-trench [nm]	Trench profile [°]
	ICP [W]	Bias [W]	SF ₆ [sccm]	O ₂ [sccm]			
V4.1	↑	→	→	→	8.2	0	84
V4.3	↑	→	→	↑	28.1	0	83 – 86
V4.4	↑	↑	→	↑	17.5	0	85 – 86
V4.5	↑	→	↑↑	↑	4.3	93	86 – 88
V4.6	↑	↑	→	↑↑	-14.2*	0	85 – 86
V4.7	↑	↑	↑	↑↑	11.3	125	83 – 87
V4.10	↑	↑↑	→	↑↑	-29*	0	84 – 88

* increase in hard mask thickness, leading to a negative calculated SiC/SiO₂ selectivity

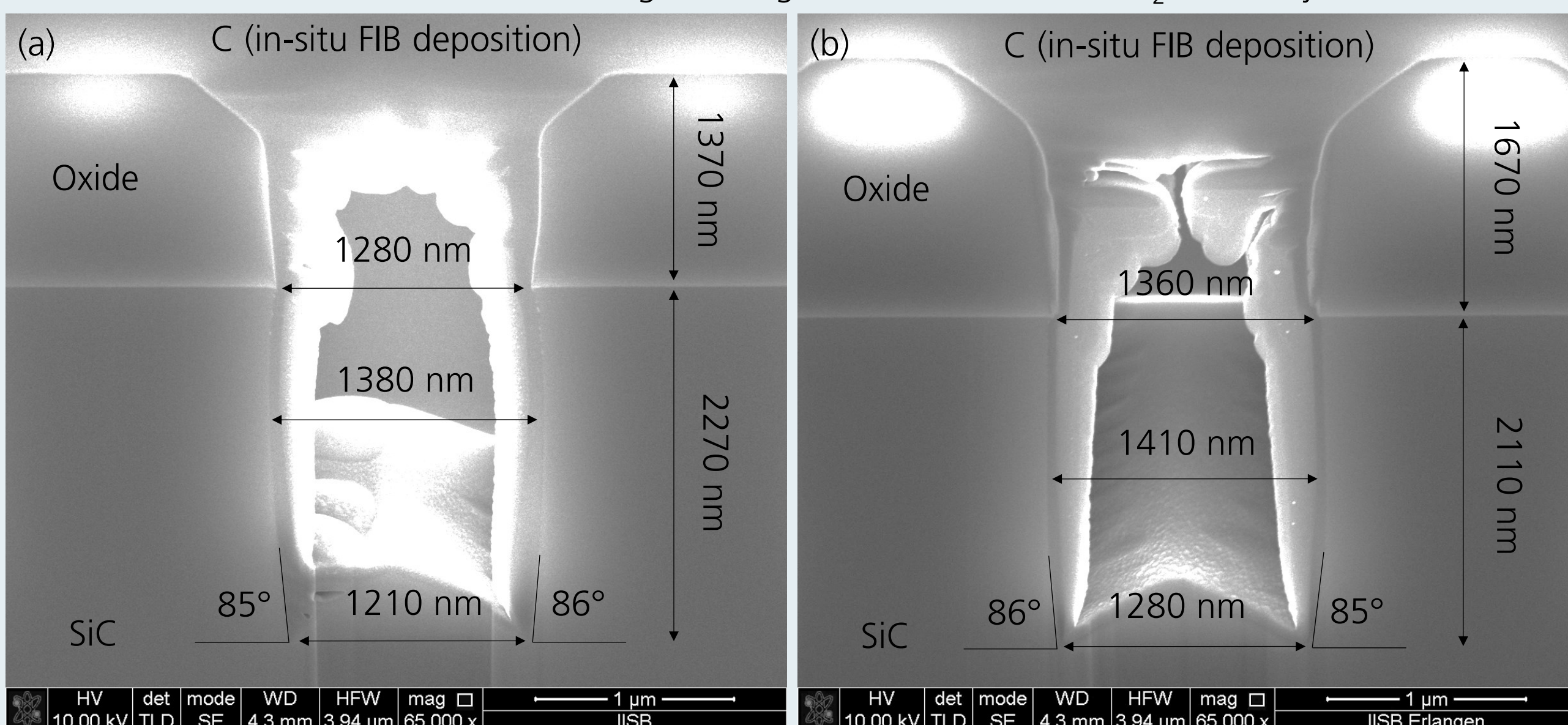


Fig. 1: SEM cross-section images of SiC profiles with nominal feature size of 1.5 μm after trench etching with different recipes (a) V4.4, and (d) V4.6, each for 240 s and utilizing a 1.5 μm thick LPCVD oxide hard mask; prepared via FIB and covered by in-situ deposited C layer.

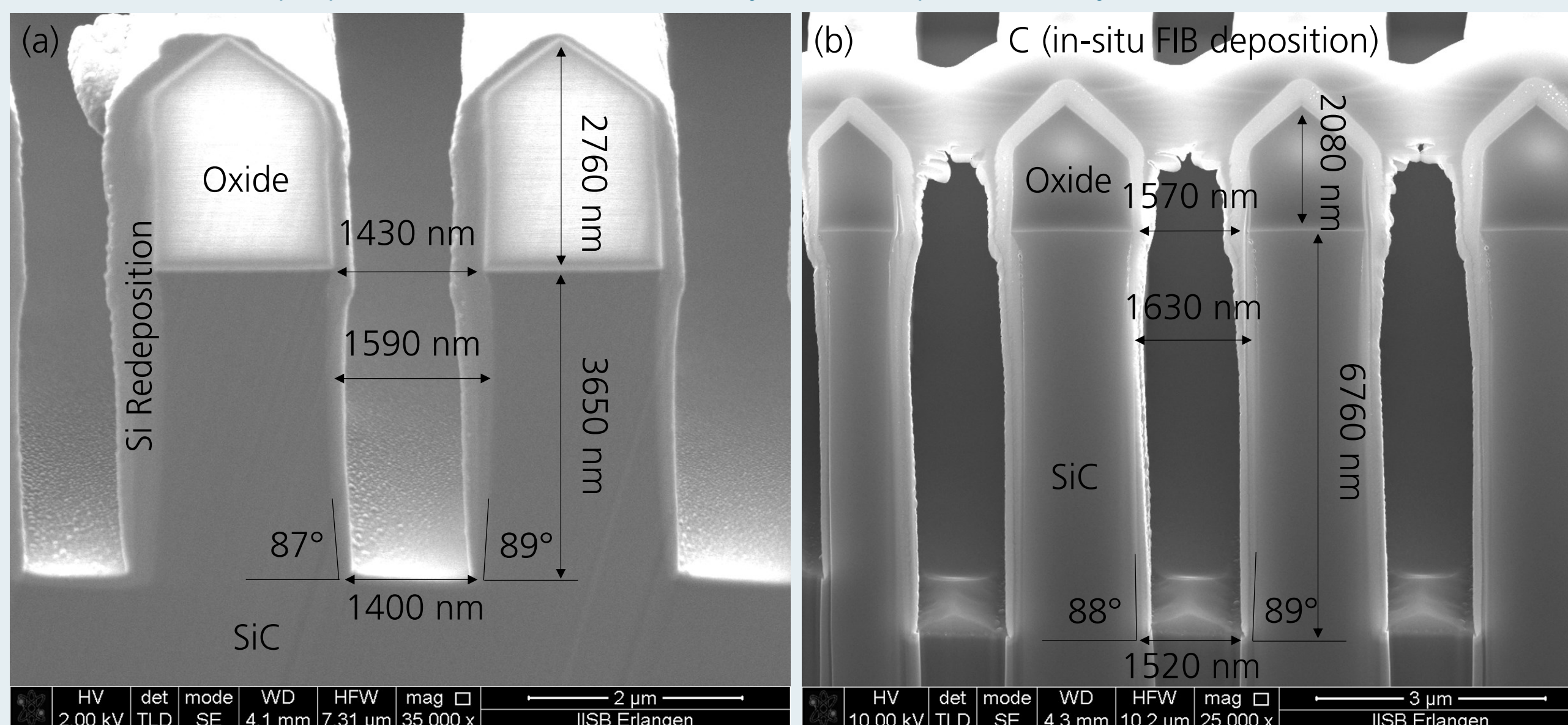


Fig. 2: SEM cross-section images of SiC profiles with nominal feature size of 1.5 μm after trench etching with (a) one and (b) two cycles of recipes V4.10 and V4.4, each for 240 s, utilizing a 3 μm thick LPCVD oxide hard mask; prepared via FIB and covered by (a) Si-redeposition due to an advanced cross-sectional technique and (b) in-situ deposited C layer.

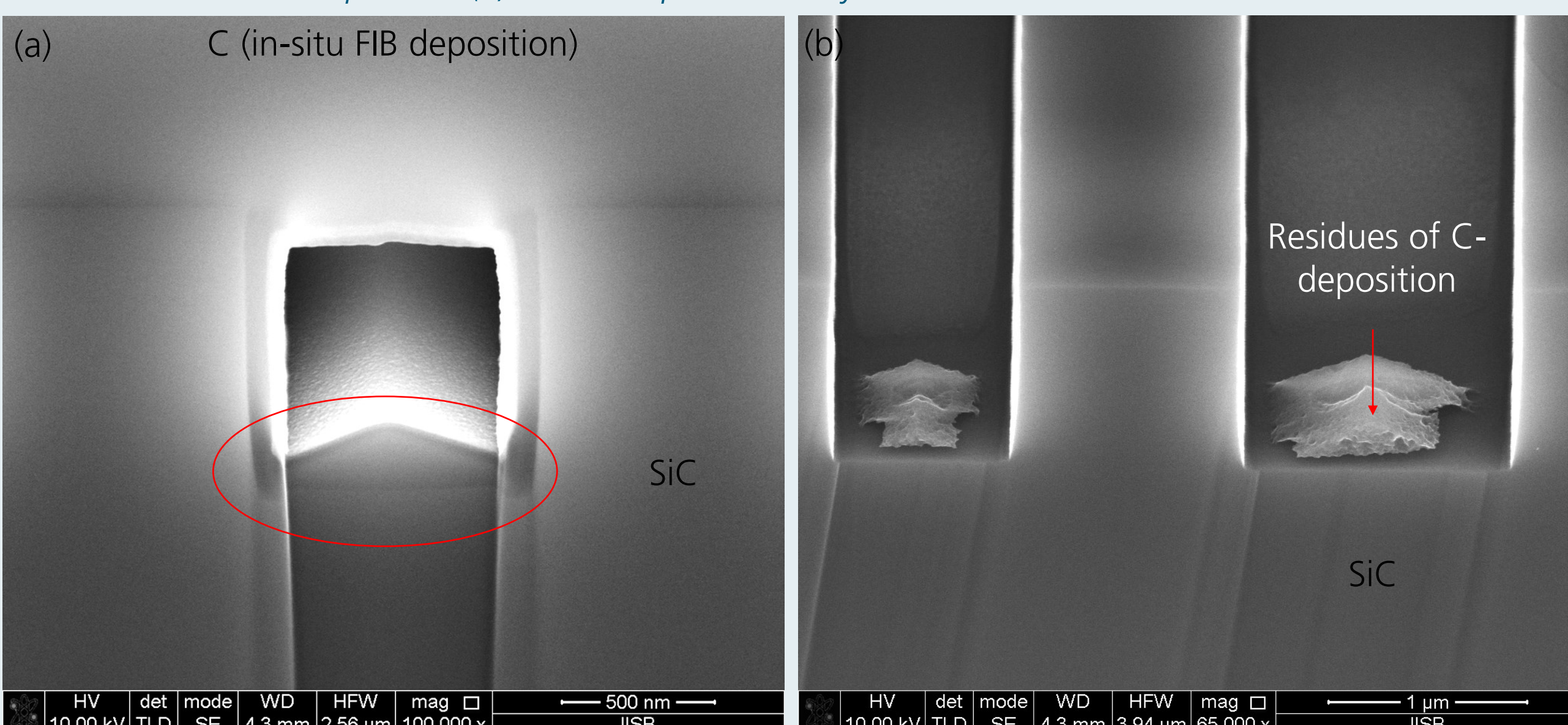


Fig. 3: SEM cross-section images of SiC profiles after removal of oxide mask; (a) covered by in-situ deposited C layer and (b) utilizing advanced cross-sectional technique together with C layer removal.

Deep Trench Formation in SiC via Dry Etching

- Parameters: ICP (plasma density) and bias power (ion energy), SF₆ and O₂ gas flow
- SiC/SiO₂ selectivity** ↑ with ICP-power ↑ [5] + bias power ↓ + O₂ gas flow ↑
 - less oxide hard mask consumption due to O₂ saturation with increased gas flow
 - see recipes V4.1, V4.3 and V4.4 together with Fig. 1 (a)
 - Redeposition on hard mask with increased O₂ gas flow → mask reconstruction
 - see recipes V4.6 and V4.10 together with Fig. 1 (d) and Fig. 2
- Lateral etching** due to differential charges creates curved trench profile (bowing)
 - differential charging → deflection of ions towards trench sidewalls [6-8]
 - with deeper trench depth and higher aspect ratios, bowing is more pronounced
- Micro-trench** ↑ with bias power ↓ [5] + SF₆ gas flow ↑
 - More ions being deflected and reduced ion acceleration energy
 - see recipes V4.5 and V4.7

Highlight: 10 μm deep SiC trenches

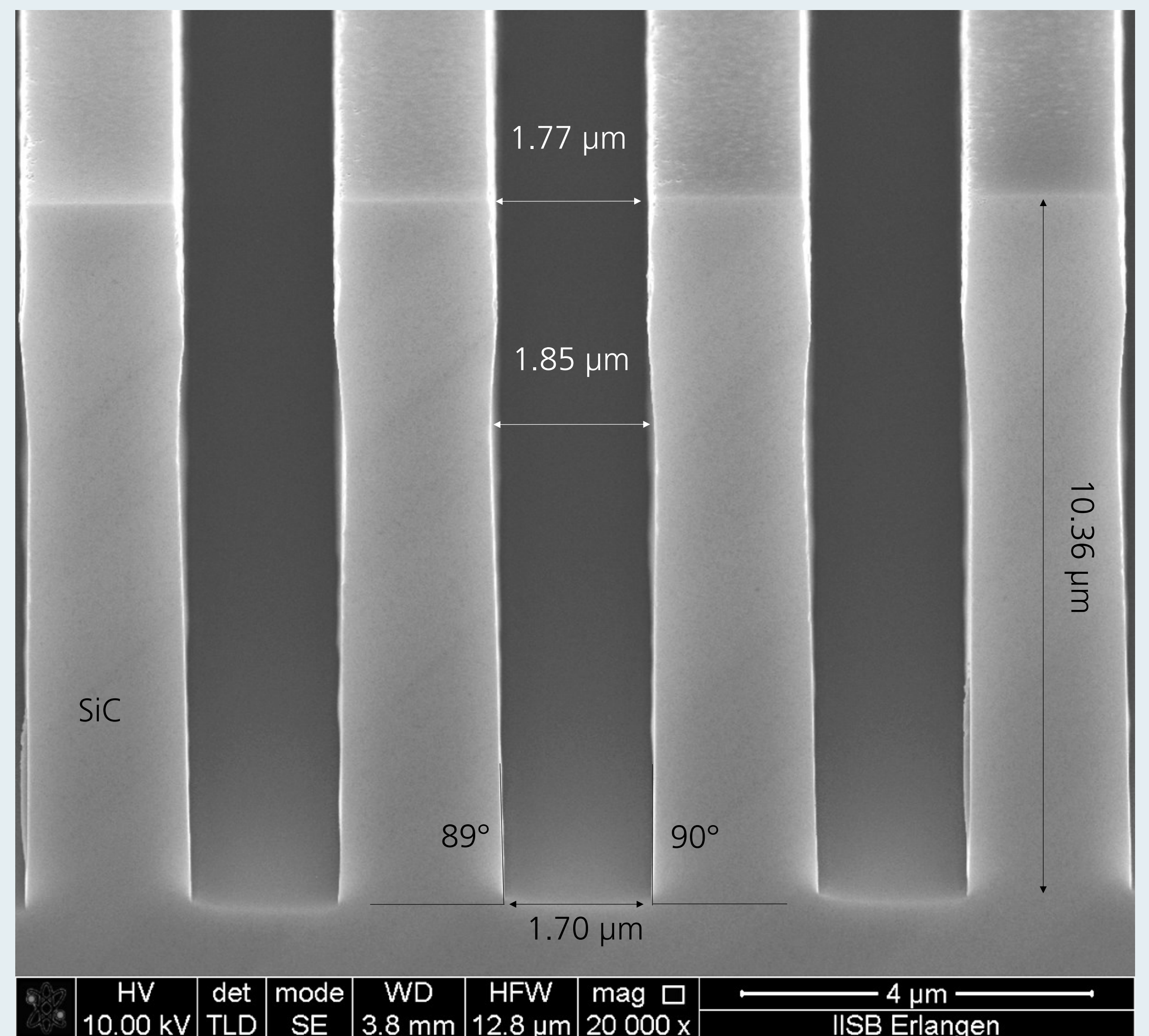


Fig. 4: SEM cross-section image of SiC profiles with nominal feature size of 1.5 μm after trench etching with recipe V4.4 for 1600 s, utilizing a 3 μm thick LPCVD oxide hard mask; prepared via FIB utilizing an advanced cross-sectional technique after removal of oxide hard mask and Si-redeposition.

Summary & Outlook

- SiC/SiO₂ selectivity increase of SiC dry etch process up to 28
 - 10 μm SiC trench depth with approx. 1.8 μm opening width achieved
 - aspect ratio approx. 6
 - structural fidelity to be improved (1.5 μm nominal width)
- Aspect ratio dependencies for trench depth, bowing and micro-trenching
 - Opening width and trench depth crucial for resulting trench profile
- Cycles of alternating recipes, utilizing the effect of hard mask reconstruction
 - Further development to reach aspect ratios of 10
 - 10 μm depth with 1 μm width and 15 μm with 1.5 μm width

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