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Utilizing SiO_2 Reflow for Corner Rounding to Prevent Cracking in Passivation Layers above 500 °C

Julien Körfer, Alexander May, Mathias Rommel, Oleg Rusch, and Michael Jank

julien.koerfer@iisb.fraunhofer.de

Fraunhofer Institute for Integrated Systems and Device Technology IISB, Schottkystrasse 10, 91058 Erlangen, Germany

Motivation

- High-temperature 4H-SiC electronics (500 – 600 °C) demand robust, crack-resistant passivation [1-2].
- Angular field oxide corners act as stress concentrators, triggering cracks and premature failure.

➔ SiO_2 reflow enables CMOS-compatible corner rounding to reduce stress without redesign.

Background

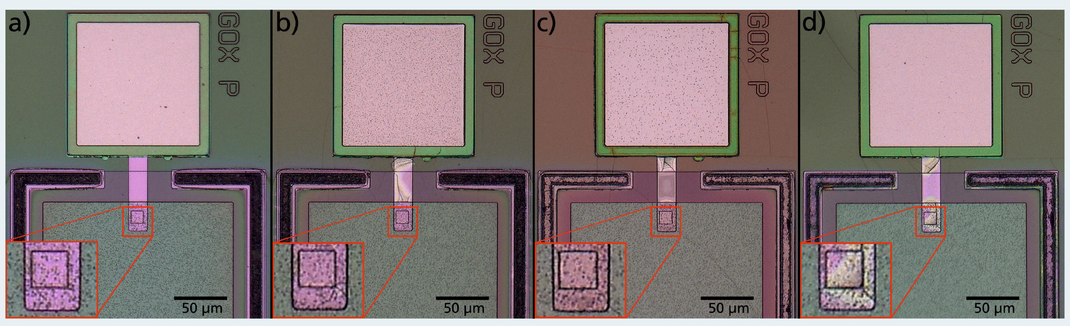

Fig. 1. Optical micrographs of samples annealed for 10 h a) at 400 °C , b) 500 °C, c) 600 °C in air and d) 600 °C in vacuum. Cracks appear above 400 °C in both atmospheres.

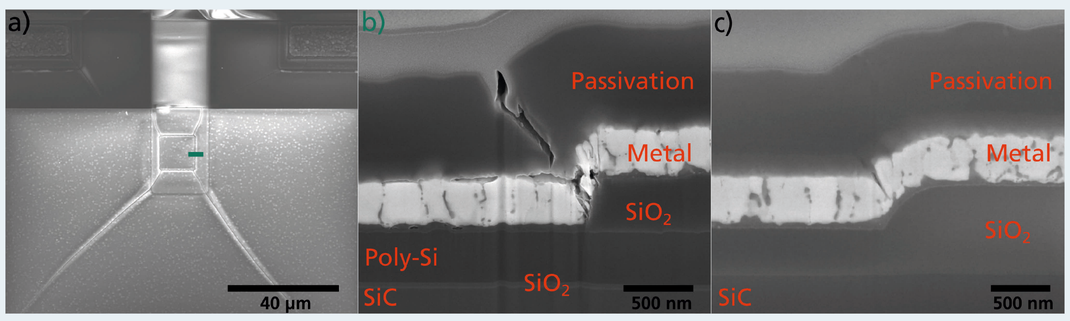

Fig. 2. SEM images of sample shown in Fig.1 c): a) top view with visible cracks, the green marker indicates the FIB cross-section position shown in b). b) FIB cross-sectional view of Gate structure with crack in passivation layer initiated due to steep SiO_2 edge; c) FIB cross-sectional view (position not shown in a) of crack-free passivation due to rounded SiO_2 edge.

SiO_2-Reflow

- Glass transition temperature of SiO_2: T_g = 1200 °C [3].

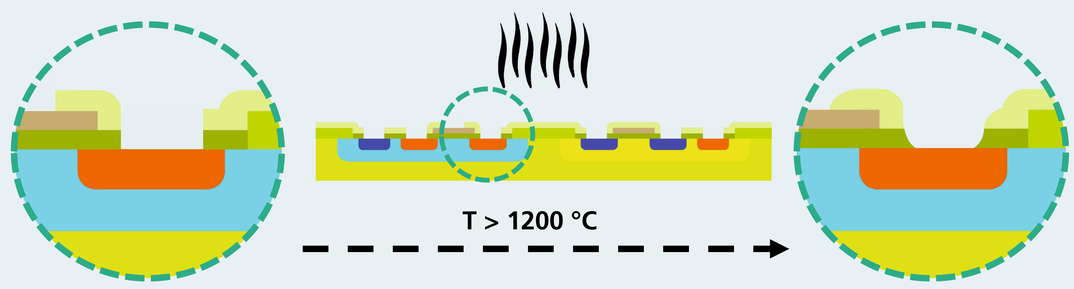

Fig. 3. SiO_2 reflow process schematic and effects, based on [4,5].

Reflow conditions and oxide edge metrics (+ good; ○ neutral; - bad)

Recipe	Process Parameter				Pattern fidelity	Corner rounding	SiC Surface
	Gas	Temperature (°C)	Time (min)	Pressure (mbar)			
V1	Ar	1300	60	20	-	+	-
V2	Ar	1250	30	20	+	○	-
V3	N	1400	45	890	-	+	-
V4	NO	1300	60	890	+	+	-
V5	N + NO	1300	60	890	+	+	○
V6	Ar	1300	60	20	+	-	○

Results

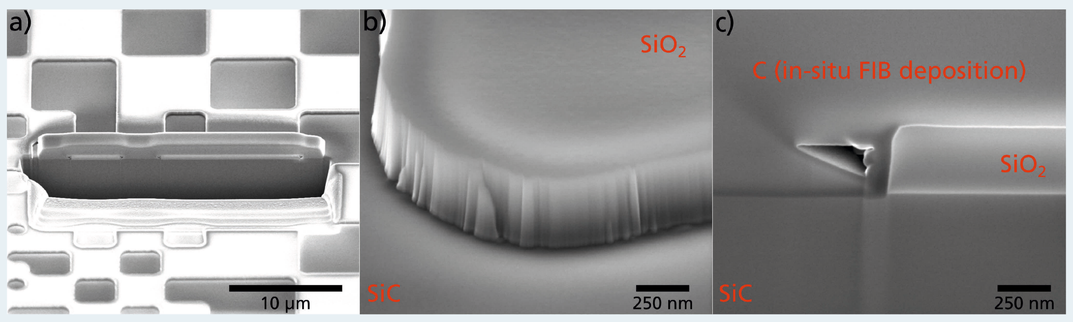

Fig. 4. SEM images of reference SiC oxide edge sample after dry etching before Reflow: a) plan view with in-panel FIB cross-section; b) oblique top view showing a SiO_2 sidewall profile; c) cross-sectional view showing ~89° corner angle and 400 nm SiO_2 thickness.

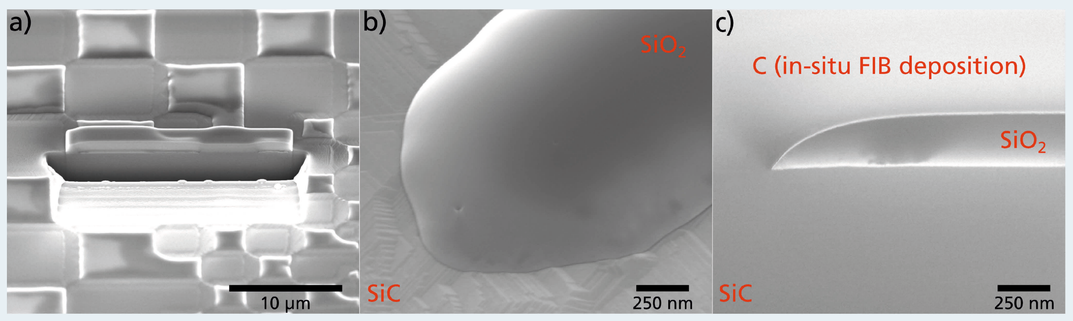

Fig. 5. SEM images after SiO_2 reflow (Recipe V1: 1300 °C, 60 min, 20 mbar, Ar): a) plan view with in-panel FIB cross-section; b) oblique top view showing step bunching; c) cross-sectional view of the oxide edge showing a corner angle of ~60° and 325 nm SiO_2 thickness.

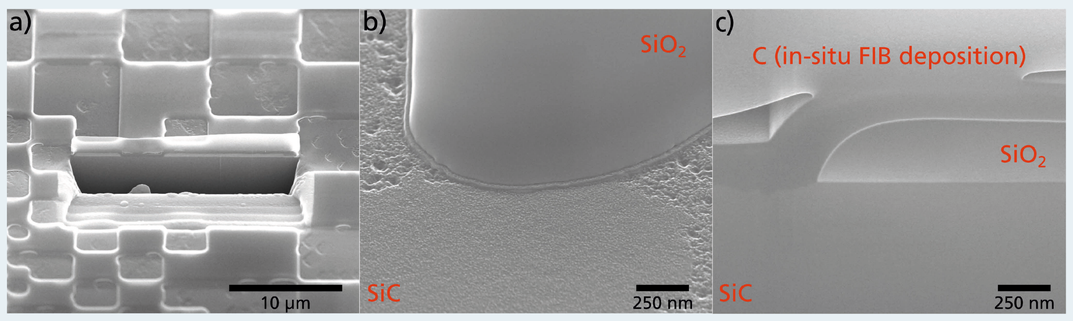

Fig. 6. SEM images after SiO_2 reflow (Recipe V3: 1400 °C, 45 min, 890 mbar, N_2): a) plan view with in-panel FIB cross-section; b) oblique top view showing SiC surface recession due to evaporation; c) cross-sectional view of the oxide edge showing a corner angle of ~70° and 380 nm SiO_2 thickness .

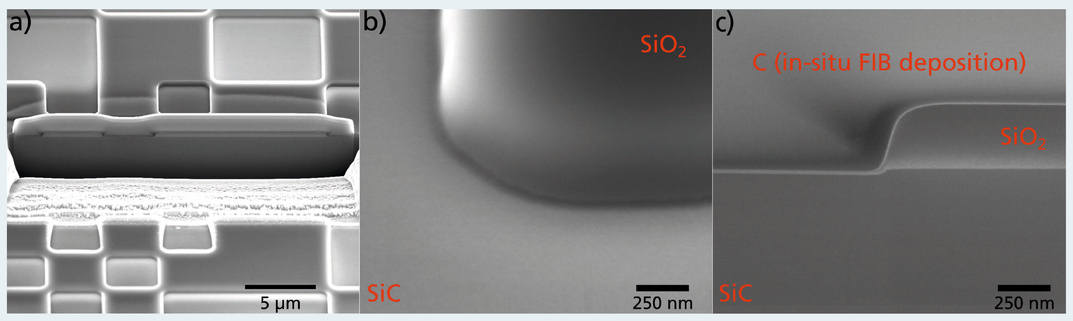

Fig. 7. SEM images after SiO_2 reflow (Recipe V4: 1300 °C, 60 min, 890 mbar, NO): a) plan view with in-panel FIB cross-section; b) oblique top view of the patterned feature; c) cross-sectional view of the oxide edge showing a corner angle of ~78° and 380 nm SiO_2 thickness.

Summary

- Thermal-stress cracks in passivation above metal-covered, angular oxide steps after > 500 °C processing have been linked to angular oxide corners (~70°, 400 nm).
- SiO_2 reflow rounds angular oxide corners (to ~60–78°) and is expected to reduce crack initiation.
- Standard Ar / N_2 reflow attacks the SiC-surface leading to step bunching / SiC evaporation.

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[2] D. Spry et al. Micro- and Nanotechnology Sensors, Systems, and Applications VIII, edited by George T, Dutta AK, Islam MS, 98360N, Micro- and Nanotechnology Sensors, Systems, and Applications VIII, SPIE (2016).
[3] M. Ojovan: Entropy Vol. 10 (2008), p. 334.
[4] A. May et al. 2024 Smart Systems Integration Conference and Exhibition (SSI), pp. 1–5, 2024 Smart Systems Integration Conference and Exhibition (SSI), IEEE (2024).
[5] M.H.P. Pfeiffer et al. IEEE J. Select. Topics Quantum Electron. Vol. 24 (2018), p. 1.