

Technology Development of Implantation Masks for a Multi Epitaxy, Multi Implant Approach for 4H-SiC Superjunction Drift Zones



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Motivation

- Superjunction devices allow for substantial improvement in device performance by enabling simultaneous lateral and vertical depletion through charge compensation [1-3]
- Crucial for creating n- and p-pillars with multi epitaxy, multi implant (MIME) approach [4]: high-energy implantation with compatible implantation masks and epitaxial overgrowth
→ Implantation depth determines epitaxial overgrowth thickness

Epitaxial overgrowth

- Epitaxial overgrowth with etching of wafer surface due to hydrogen (H₂)-induced surface reactions during initial heating under H₂ ambient
→ Loss of thickness of previously prepared drift layer
- Planetary epitaxy reactors from Aixtron SE: Back-etching of original surface by 50 to 150 nm → Relevant for designing MIME process

Implantation mask design

- TRIM simulations [5] of 5.5 MeV aluminum (Al) implantation for determination of projected Al ion range

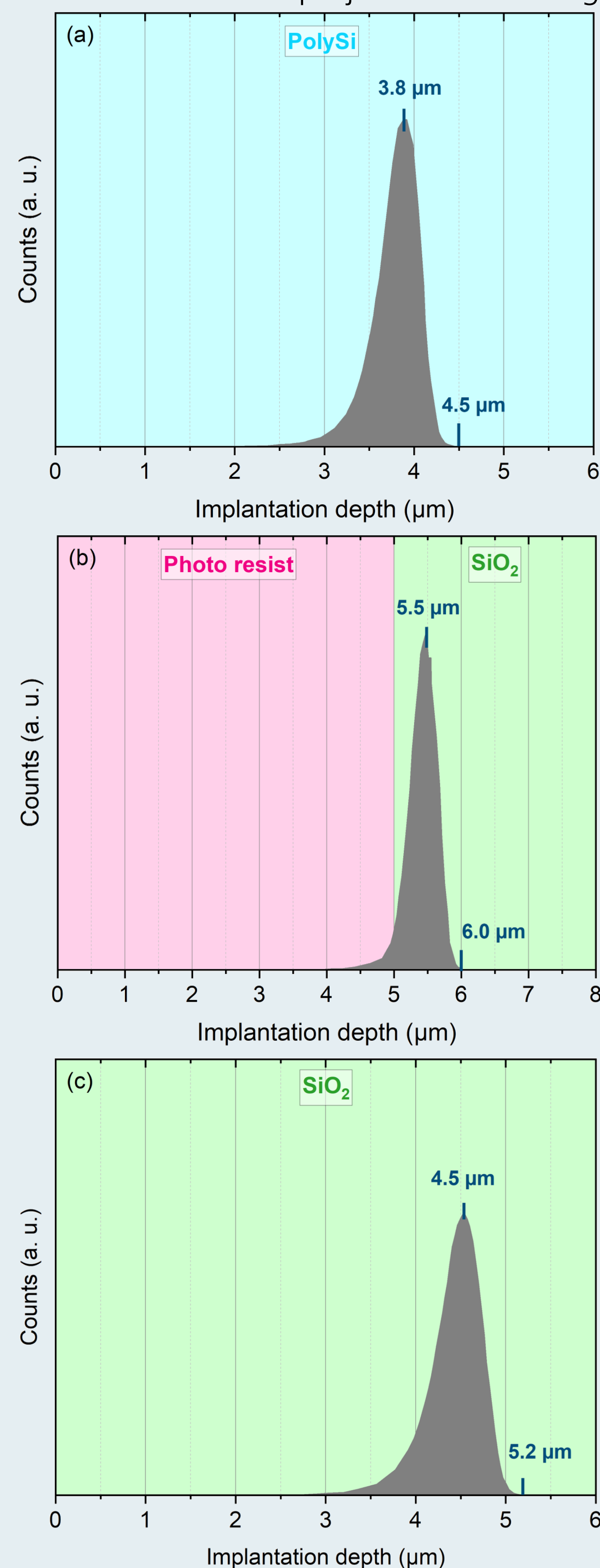


Fig. 1. TRIM simulation of Al ion ranges in (a) a 6.0 μm PolySi mask, (b) a two-component mask consisting of 5 μm photo resist on top of 3 μm SiO₂ and (c) a 6.0 μm SiO₂ hard mask.

Implantation mask processing

- PolySi: LPCVD PolySi deposition on Si wafers with SiO₂ → Lithography → PolySi dry etch → Photo resist removal
 - SiO₂ as etch stop for PolySi dry etch process
 - Challenge: Structural fidelity (mask and mask opening widths)
- TEOS SiO₂ + photo resist: LPCVD TEOS SiO₂ deposition → Lithography → TEOS SiO₂ dry etch without photo resist removal
 - Challenge: Structural fidelity (mask and mask opening widths, SiO₂ side-wall angles), photo resist thickness
- SiO₂ + PolySi as process development towards a 6.0 μm PECVD SiO₂ hard mask: LPCVD TEOS SiO₂ deposition → LPCVD PolySi deposition → Lithography → LPCVD PolySi dry etch → TEOS SiO₂ dry etch
 - Challenge: Structural fidelity (mask and mask opening widths, SiO₂ side-wall angles)

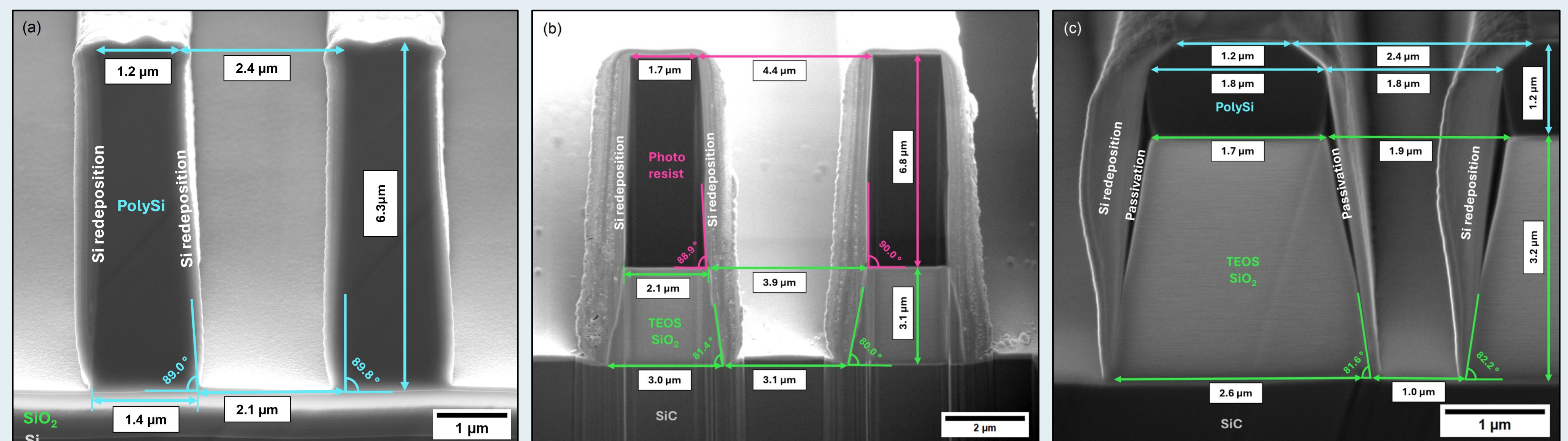


Fig. 2. FIB-SEM cross section images of (a) a 6.3 μm thick PolySi mask, (b) a two-component mask system consisting of 6.8 μm photo resist on top of 3.1 μm TEOS SiO₂ and (c) 3 μm TEOS SiO₂ structured by dry etching utilizing a 1.5 μm thick PolySi mask.

Implantation simulation

- TCAD simulations for visualization of Al concentration in the processed masks after implantation with box profile with maximum energy of 5.5 MeV Maximum Al implantation depth: approx. 2.5 μm
→ Four cycles for 10 μm depth for 1.2 kV device
- Implantation effectively blocked by mask
 - Al concentration < 1E16 cm⁻³ at interface mask/substrate surface)
 - Al concentration < 1E16 cm⁻³ at approx. 5.0 μm depth in PolySi mask
 - Al concentration < 1E16 cm⁻³ at approx. 5.2 μm depth in photo resist

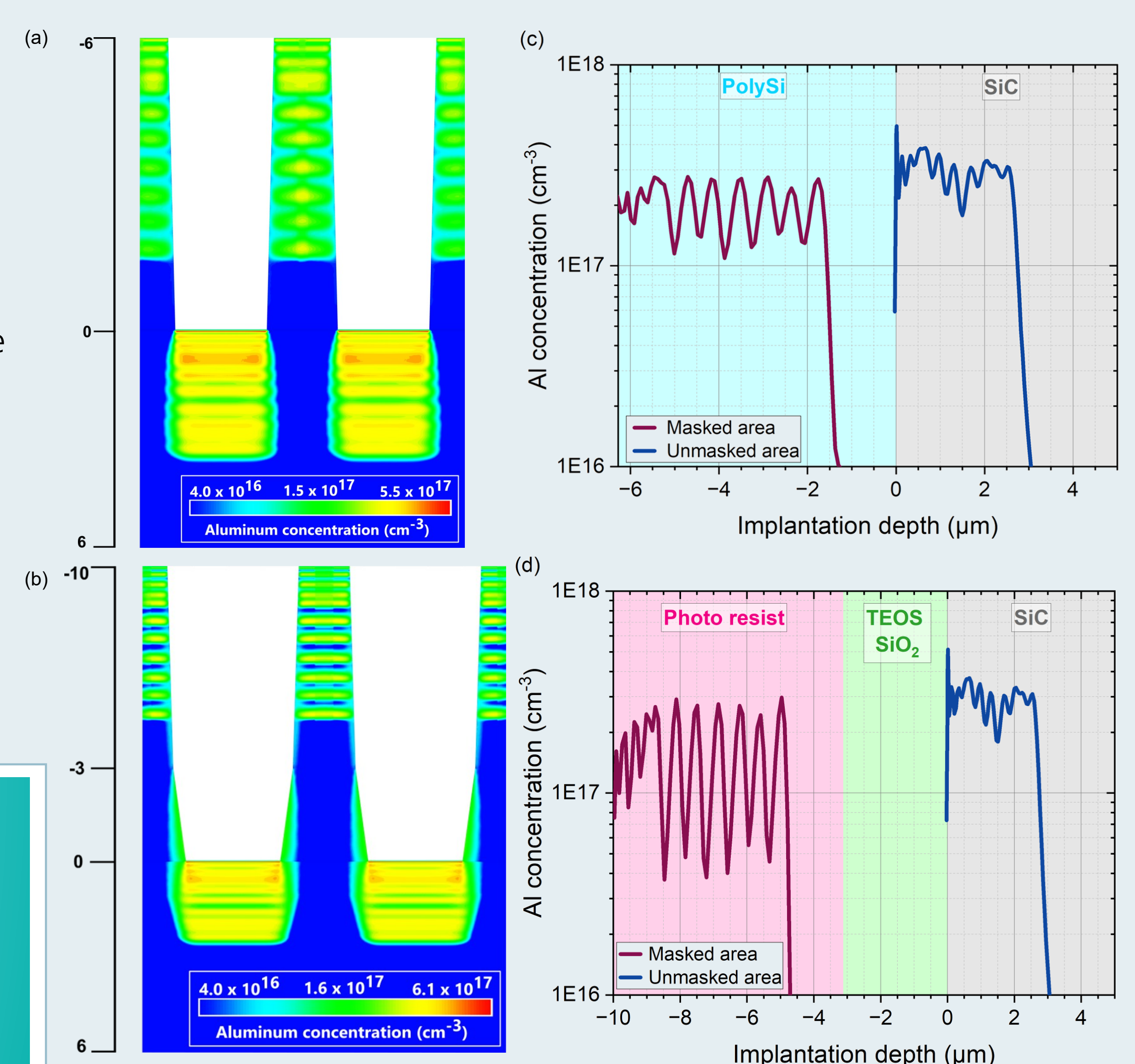


Fig. 3. Visualizations of TCAD simulations of Al implantations (a) using the processed PolySi hard mask and (b) the two-component mask system consisting of photo resist on top of TEOS SiO₂ and (c) and (d) corresponding Al implantation depths Al concentration in the masked and unmasked regions.

Summary & Outlook

- Development of mask systems suitable for high-energy (up to 5.5 MeV) Al implantations
 - PolySi hard masks most promising mask system
 - Implantation depths confirmed by TRIM and TCAD simulations
- PolySi masks also beneficial for structuring (PECVD) SiO₂ with thicknesses > 3 μm
- Outlook: Experimental verification of implantation mask systems for high-energy Al implantation via SIMS and FIB followed by superjunction device fabrication

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