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Investigation on Channel Mobility of SiC Trench MOSFET

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Introduction

The complex channel interface states in SiC trench MOSFET pose significant challenges to the continuous improvement of channel mobility. This work experimentally investigates the impact of phonon scattering, coulomb scattering, and surface roughness scattering on channel mobility, providing critical insights for further mobility enhancement.

Field mobility extraction structure

A 0.6-μm epitaxial SiC trench MOSFET structure was designed on the SiC (11-20) face (Fig. 1), eliminating parasitic epitaxial layer resistance inherent in conventional designs. Critical processes were rigorously controlled to maintain manufacturing compatibility.

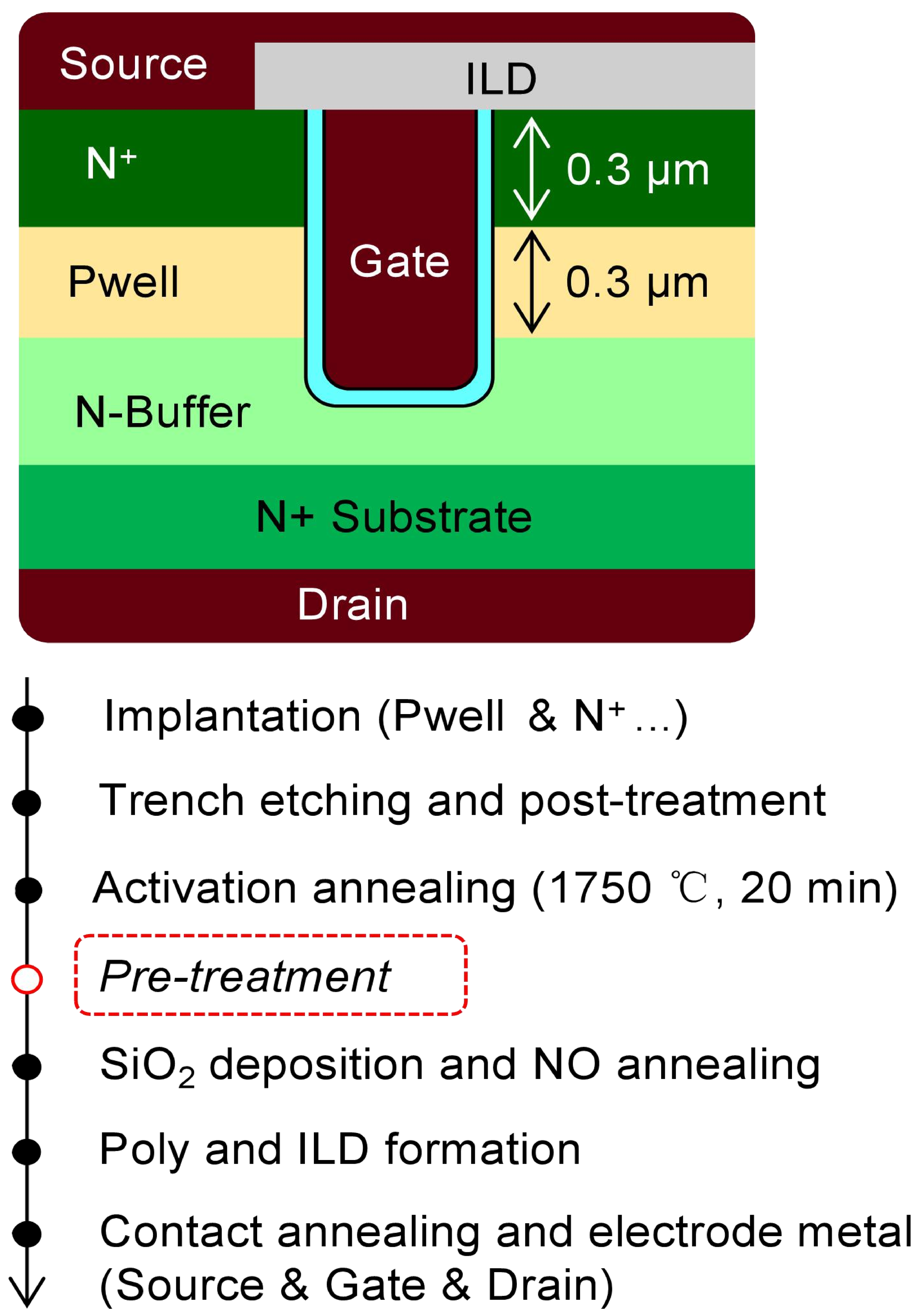

Fig. 1 Field mobility extraction structure and process flow of SiC trench MOSFET

Surface roughness-limited mobility

For trench sidewalls with RMS roughness below 0.4 nm, field mobility variation was uncorrelated with roughness and was primarily governed by lattice damage induced during pre-treatment.

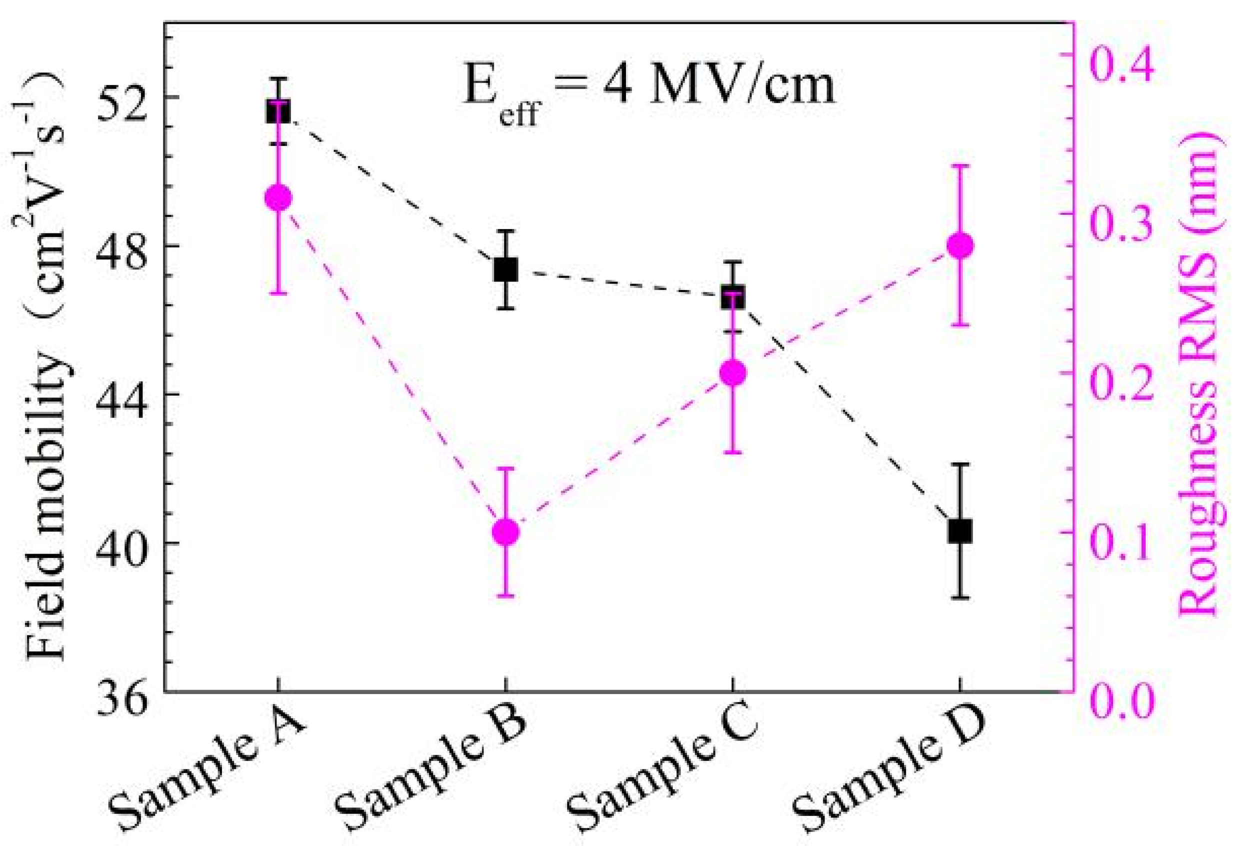

Fig. 2 The field mobility varies with changes in the RMS roughness of the trench sidewall

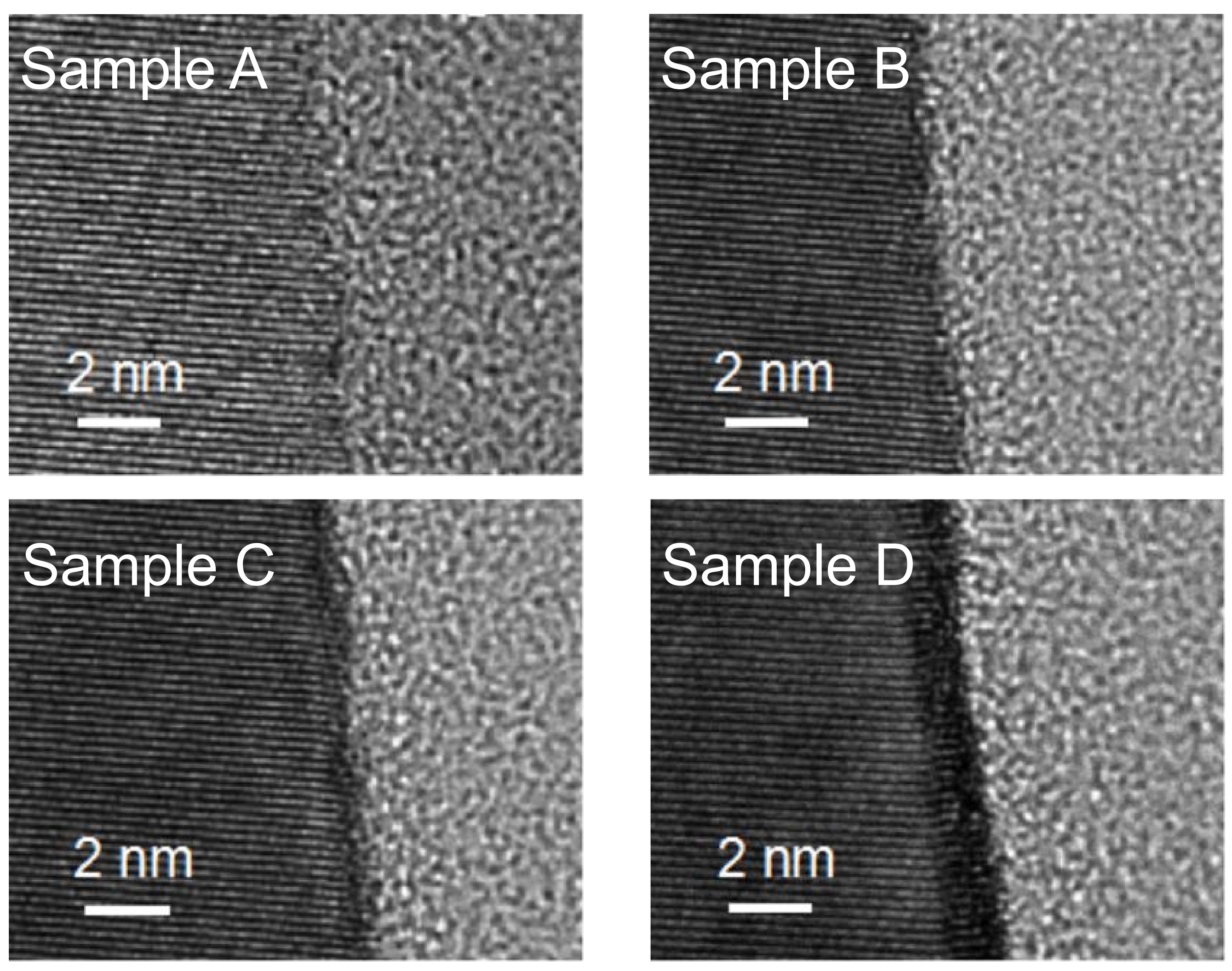

Fig. 3 Cross-sectional TEM results on SiC trench sidewall

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Phonon-limited mobility

The peak field mobility increased linearly from 25°C to 125°C, followed by a gradual rise and saturation at 200°C, implying that phonon scattering does not dominate channel mobility characteristics.

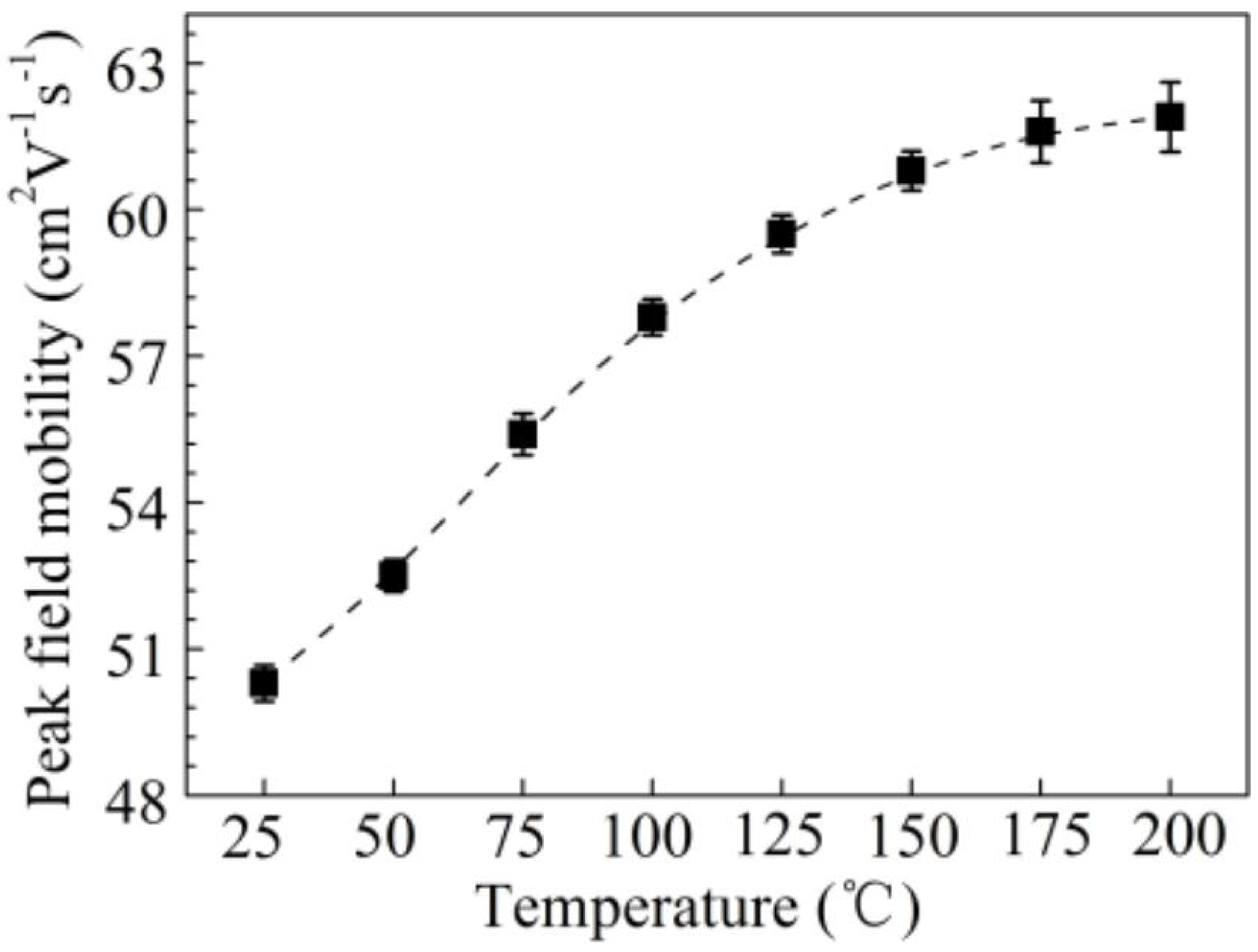

Fig. 4 The peak field mobility varies within the temperature range of 25°C to 200°C

Coulomb-limited mobility

Coulomb scattering dominates channel mobility variations. The observed mobility dependence on Pwell concentration confirms that interface and bulk charge centers critically dictate carrier transport characteristics.

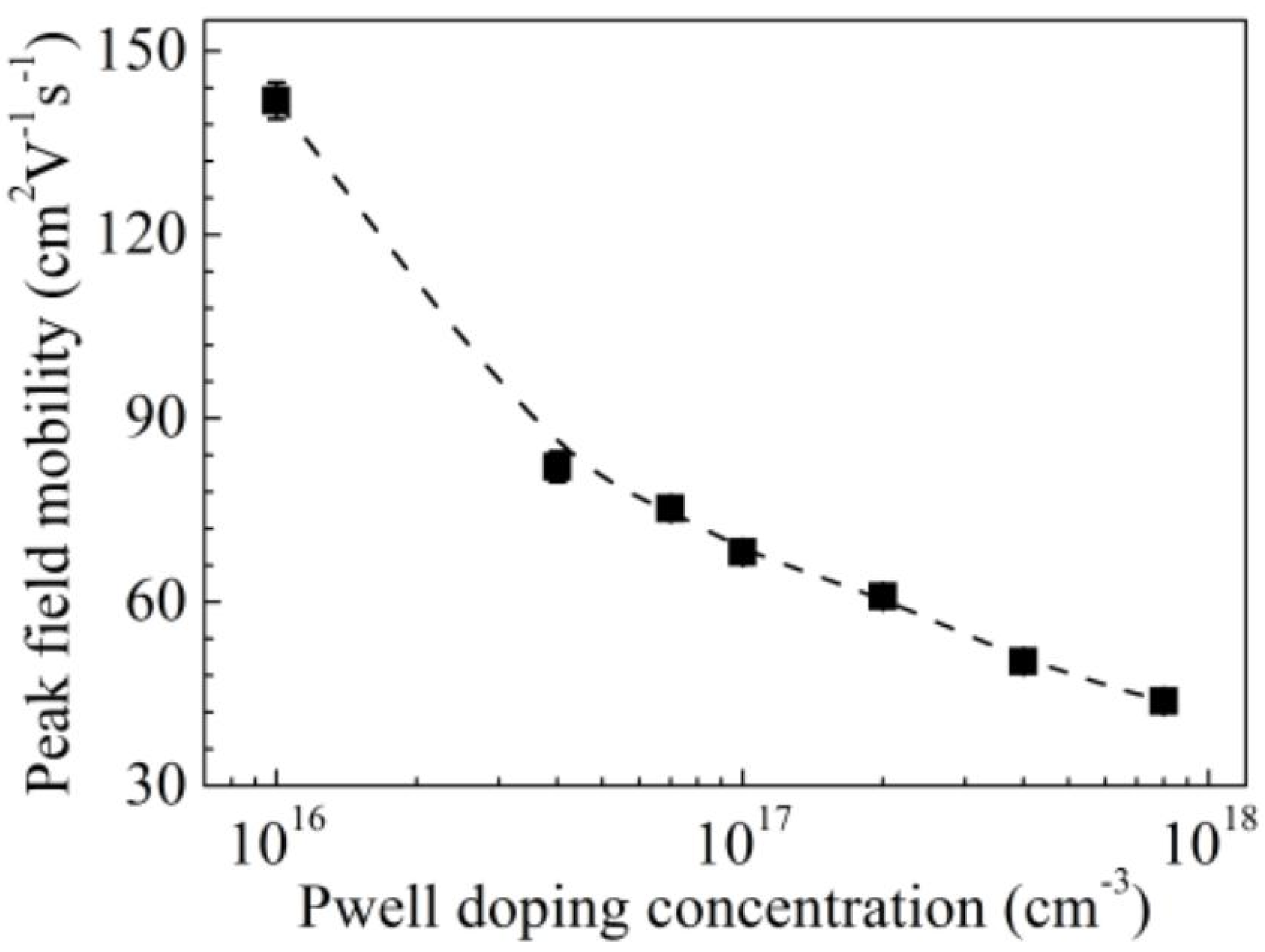

Fig. 5 The variation of peak field mobility with Pwell doping concentration

Channel mobility enhancement

A three-step process substantially reduced coulomb scattering probability: (Step1) novel gate oxide technology minimized interface scattering at the SiC gate oxide interface, (Step2) elimination of conventional pre-treatment further decreased SiC interface scattering, (Step3) ion tunneling injection technology for Pwell formation minimized scattering within the SiC inversion layer.

As a result, The mobility is subsequently enhanced by 9.9 $cm^2V^{-1}s^{-1}$, 6.4 $cm^2V^{-1}s^{-1}$, and 5.3 $cm^2V^{-1}s^{-1}$ through the implementation of Step 1, Step 2, and Step 3 processes, respectively, yielding a final mobility of 71.9 $cm^2V^{-1}s^{-1}$.

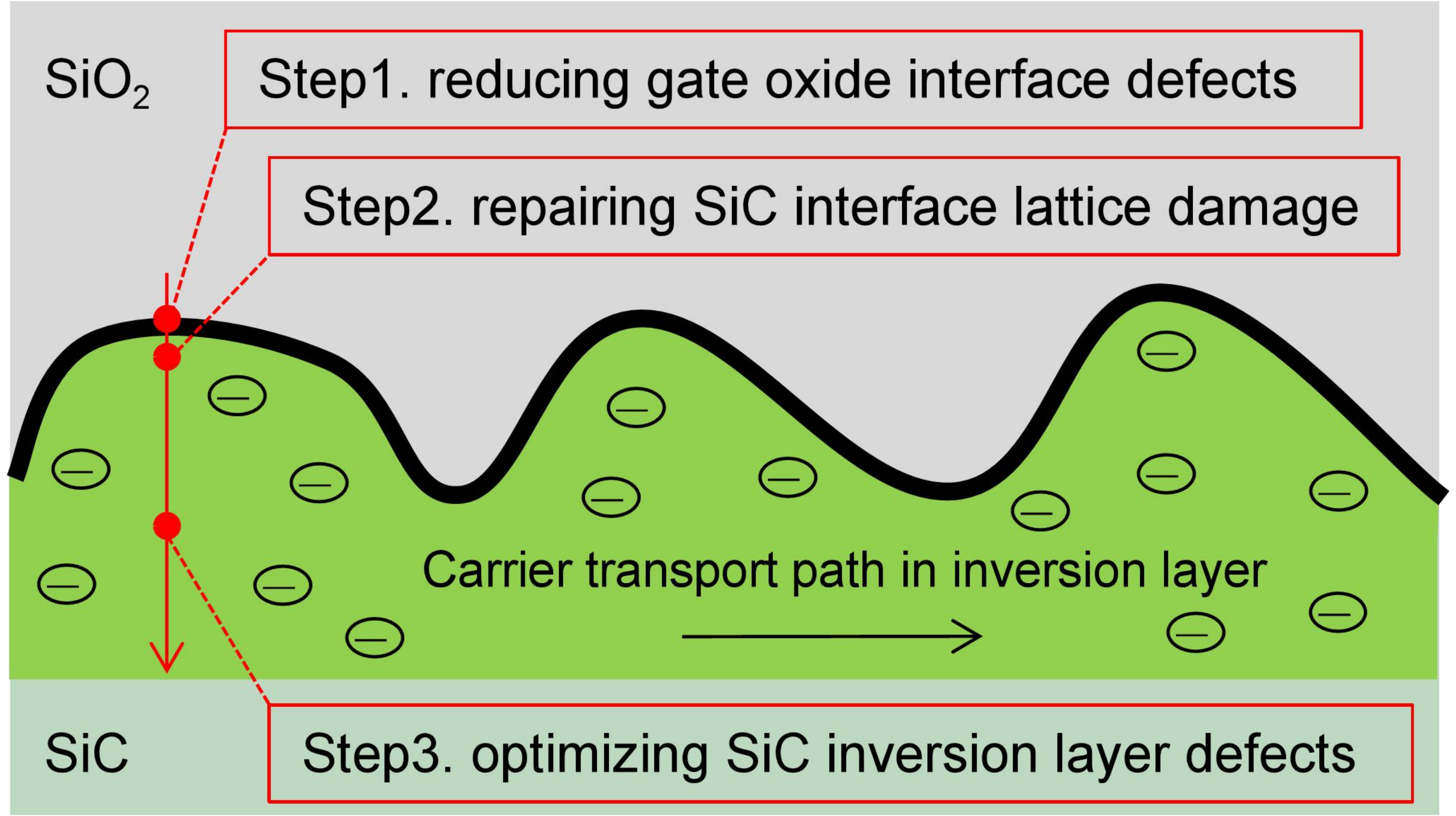

Fig. 6 Mechanism and optimization methods of coulomb scattering based on carrier transport path

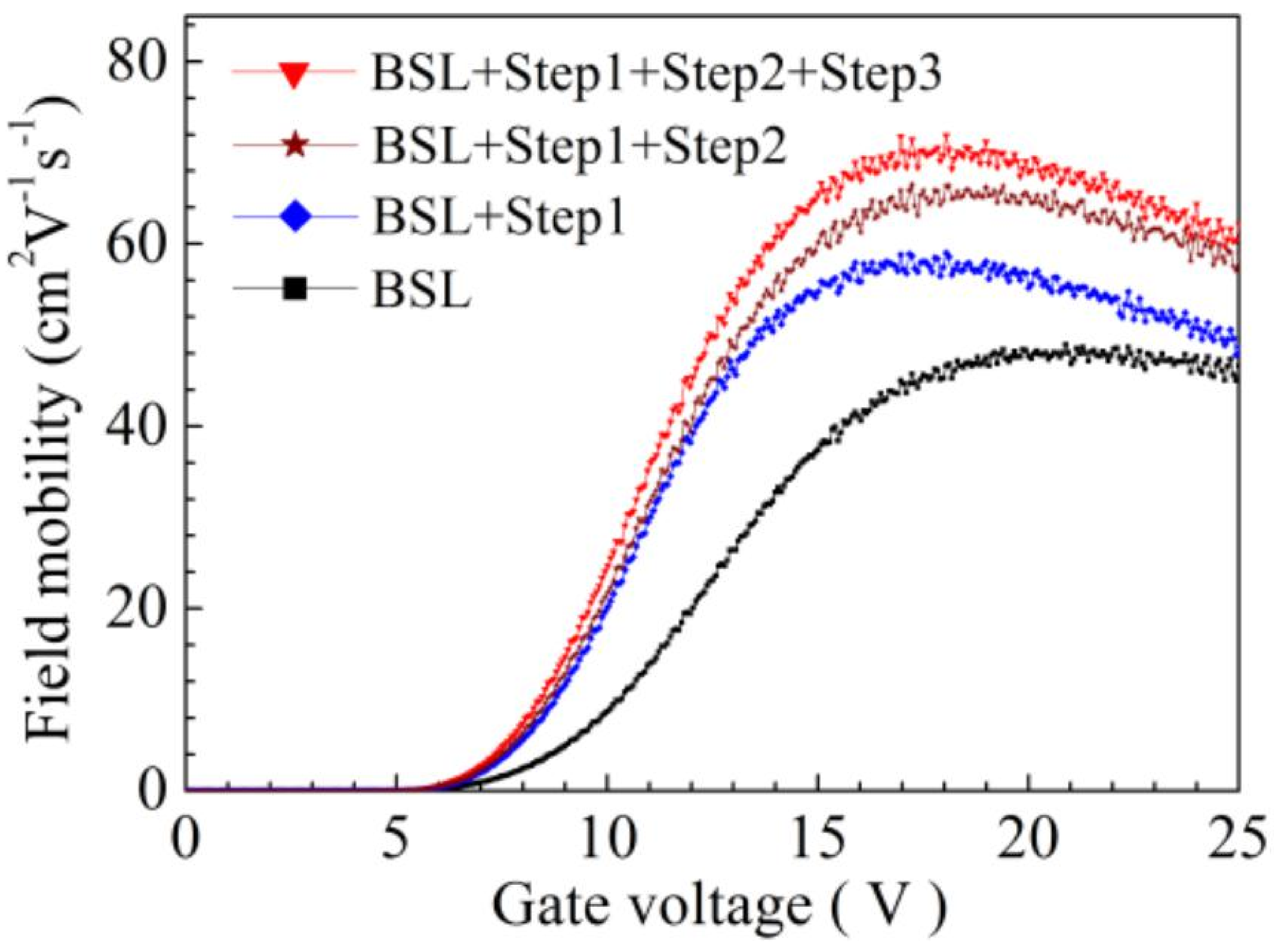

Fig. 7 Comparative reduction in Coulomb scattering probability achieved through Steps 1-3