Nanoscale imaging of buried MOS interface charge states by time-resolved scanning nonlinear dielectric microscopy

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Buried oxide-semiconductor interfaces, such as the SiO_2/SiC interface in SiC power devices, can critically affect the performance of MOS devices based on wide-bandgap semiconductors. In particular, microscopic charge states at these buried interfaces can strongly influence channel mobility, which often limits the on-resistance of power MOSFETs. To observe and analyze charge states at buried interfaces, we employ time-resolved scanning nonlinear dielectric microscopy (tr-SNDM) [1]. SNDM is a near-field, microwave-based scanning probe technique that offers high sensitivity to microscopic variations in tip-sample capacitance. By incorporating temporal resolution into conventional SNDM, tr-SNDM enables local capacitance-voltage (CV) profiling of MOS structures [2].

In this study, we apply tr-SNDM to visualize and quantify spatial fluctuations in local CV profiles on SiC wafers with different interface treatments. These fluctuations reflect potential variations at the buried interface, primarily caused by dominant carriers trapped at interface defects. We examined two types of SiC wafers: one with as-oxidized interfaces, and the other treated by post-oxidation annealing in NO (NO-POA). By extracting characteristic voltages from the local CV profiles, we visualized their spatial fluctuations across different regimes, including depletion, accumulation, and intermediate regions. The fluctuations were found to be more pronounced in the accumulation region, indicating that dominant carriers trapped by acceptor-like defects exacerbate local non-uniformity more significantly than in the depletion region. NO-POA treatment was observed to significantly suppress these fluctuations in all regions, suggesting an improvement in MOS interface quality. However, the remaining potential fluctuations remained larger than the thermal energy at room temperature (~26 meV), even in the depletion region. This implies that fixed charges and deep-level trapped charges can still cause substantial potential variation at the interface.

These interface charges may be underestimated by conventional macroscopic CV profiling, yet they can have a significant impact on carrier transport properties in the MOSFET channel due to Coulomb scattering. From these results, we conclude that tr-SNDM is a powerful tool for investigating buried insulator-semiconductor interfaces, such as those used in wide-bandgap semiconductor devices including SiC, GaN, and diamond.

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References

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