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Profiling defect and charge carrier density in the SiO_2/4H-SiC interface with Low-Energy Muons

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Silicon carbide (4H-SiC) is a wide-bandgap semiconductor with promising applications in high-power and high-frequency devices. An advantage of SiC is that it is the only compound semiconductor that has the ability to form native silicon dioxide (SiO_2). The performance of SiC-based devices relies heavily on interface effects. However, characterization of oxidation-induced defects - both in the oxide and the semiconductor - is still challenging.
Low-energy muon spin spectroscopy (LE-μSR) can probe regions very close to the surface and interface up to a depth of 160 nm in SiO_2/SiC structures and is sensitive to charge carrier and defect concentrations.

We have studied SiO_2/SiC interfacial systems with thermally grown and deposited oxides using LE-μSR. The thermal SiO_2 has higher structural order, as indicated by the undisturbed muonium (Mu^0) formation. However, the oxidation process leads to strain in the oxide and to band-bending at the SiC-side of the interface, which affects the SiC faces differently: i) at the (0001) Si-face the results can be explained by the depletion of electrons at the interface and ii) at the $(000\bar{1})$ C-face a carbon-rich n-type region contributes to the increase of the diamagnetic fraction due to Mu^- formation.
Further investigations have been conducted to understand the passivation effects of state-of-the-art post-oxidation annealing (POA) processes on the SiO_2/SiC interface. Particularly, POA in an NO environment leads to an increase in charge carrier concentration near the interface, likely due to N acting as a dopant, which can be quantified based on the measured diamagnetic fraction.

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