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Observation of Charge Carrier Manipulation with Nanometer Depth Resolution at Semiconductor-Oxide Interfaces

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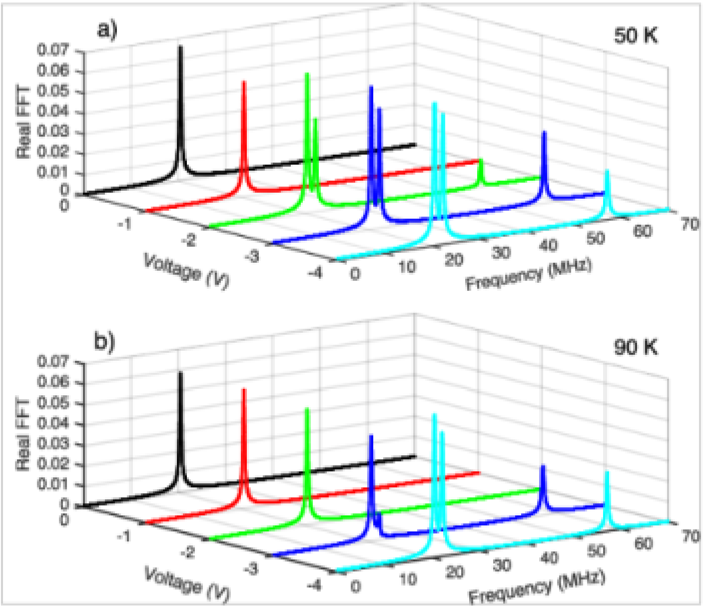
The manipulation and observation of charge carrier distributions at the interfaces of semiconductor device structures is a fundamental problem in semiconductor physics. Standard electrical characterization techniques, such as deep level transient spectroscopy (DLTS) or capacitance-voltage (CV) measurements, have limited depth resolution and are unsuitable to probe the nanometer scale regions at semiconductor interfaces, where electron and hole transport is directly influenced by changes in applied bias/band bending. We have recently developed an extension to the LE-μSR setup at PSI that allows us to apply an external electric field across a thin-film sample, while the sample can be floated to ±10 kV to adjust the implantation energy of the muons for performing depths scans. With this "Electric-field-LE-μSR"(EF-LEM), we were able to observe for the first time the change in electron concentration in Si/SiO_2 and 4H-SiC/SiO_2 structures with nanometer depth resolution, which can be controlled by the EF. We use the muonium state in the semiconductors as a sensitive probe for the presence of free charge carriers and extract their depth distribution \[1\].



FFT spectra from transverse field (150 mT) asymmetry spectra in Si close to the SiO2 interface at various applied sample biases at a) 50 K and b) 90 K. The appearance of the bond-centered Mu lines in Si at applied biases of < -2V indicates the depletion of electrons from the probed region. A higher reverse bias is required to deplete the charge carriers at 90 K, reflecting the higher concentration of electrons at this temperature.

Figure 1: enter image description here

\[1\] M. Martins et al., arXiv:2405.18211

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