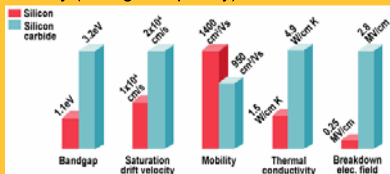
MERIT 2004

Characterization of Interface Traps in SiC MOS Devices

M. Bolen, D. Habersat, A. Lelis

I. Why is this important?

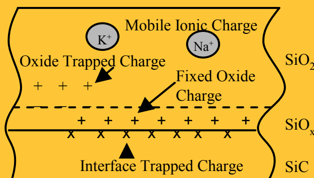
Silicon carbide (SiC) has many material benefits over silicon for high temperature and high power devices. These benefits include a wider bandgap (for high temperature), a greater critical field (for high voltage), a larger thermal conductivity (for high power), and a higher drift velocity (for high frequency).



Benefits of SiC over silicon

II. What is charge trapping?

Charge trapping at and near the semiconductor / gate insulator interface is a critical issue in SiC metal oxide semiconductor field effect transistors (MOSFETs). These charges at and near the interface shift the threshold voltage, lower the inversion channel mobility, and create concerns regarding the integrity of the insulating film.



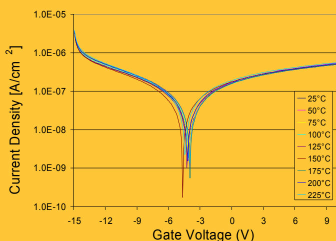
Cross-section of SiC/SiO_2 Interface

III. Measuring Insulating Film Integrity

- Current Density – Voltage

Sweep the gate voltage bias and measure leakage through the substrate. Increase the device temperature and repeat the measurement.

Typical Current Density – Voltage Leakage Results :



Capacitor Gate Area = 3.98E-04

Leakage appears invariant to temperature changes.

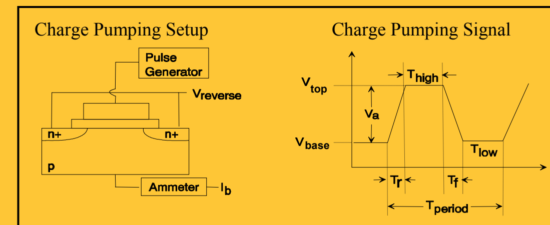
This device has a comparatively good insulating film integrity. Thus, it is a good candidate for continued testing.

IV. Techniques for Measuring the Interface Trap Density

- Capacitance – Voltage Sweep the gate voltage bias with a high frequency sinusoid and measure capacitance of MOS capacitors.

- Conductance – Frequency Sweep the AC signal frequency at a fixed gate bias in depletion and measure the conductance. Step the gate bias towards inversion and repeat the measurement.

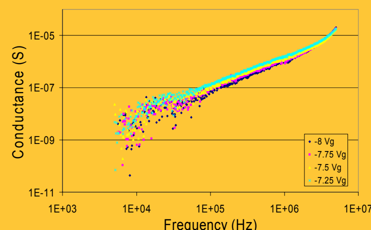
- Charge Pumping (Base Level & Spectroscopic) Apply a periodic signal with known rise and fall times while keeping source and drain of the MOSFET reverse biased. Then, measure the net DC current at the device substrate. Increase the device temperature and repeat the measurement.



Charge Pumping Technique

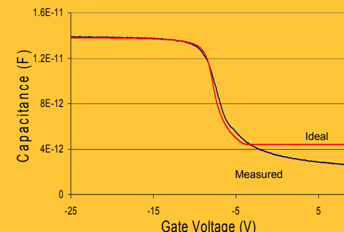
V. Data Results

Typical Conductance - Frequency Results :



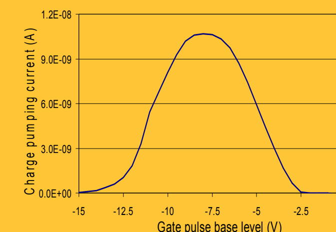
Varying the gate bias controls the surface potential, to which interface traps contribute. The response of these traps can then be extracted from analysis.

Typical Capacitance – Voltage Results :



The measured capacitance is compared with a calculated ideal capacitance curve. The stretch-out along the voltage axis is due to interface traps.

Typical Base Level Charge Pumping Results :



The height of this peak is directly proportional to the average interface trap density. The width is related to the threshold and flat-band voltages.

VI. Data Analysis

By performing multiple measurements on SiC devices, it is possible to gather a more complete picture of the interface trap density (D_{it}) across the bandgap. Each method has its pros and cons. Some are quick and easy measurements, while others require lengthy measurements and detailed analysis.

Capacitance - Voltage details a broad energy range but is limited to one side of the bandgap.

Conductance - Frequency has a limited measuring range in the bandgap, but is very accurate for low D_{it} devices.

Base Level Charge Pumping provides an average of D_{it} across the bandgap.

Spectroscopic Charge Pumping measures D_{it} on both sides of the bandgap in a small energy window which can be shifted by altering the signal rise and fall times.