Silicon Carbide Device Simulation and Measurement

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Abstract:

Fabricating semiconductor devices is very expensive and time consuming, but most importantly, can be wasted if there is no clear understanding of what to look for. Computer simulations can accurately predict the fabrication process and device behavior, and can show how a device can be improved for better performance. Metal-oxide-semiconductor (MOS) capacitors are the basic components of MOS transistors, which can store or amplify charges and are the building blocks of integrated circuits. Using the simulation of an MOS capacitor, we wanted to develop silicon carbide (SiC) as a profitable semiconductor so that production of higher quality SiC can become a common process. With the simulation software Silvaco, we simulated an MOS capacitor using molybdenum (Mo) for the metal or gate, silicon carbide (4H-SiC) for the semiconductor and silicon dioxide (SiO_2) for the oxide. Then we measured different device parameters, including interface charge, oxide charge, and compared our results to a measured capacitance-voltage (C-V) curve of an MOS capacitor. Our purpose was to introduce SiC for more use in devices by; (a) simulating SiC MOS capacitors, (b) measure the C-V curve of the MOS capacitor with different characteristics, and (c) compare simulated with experimental data.

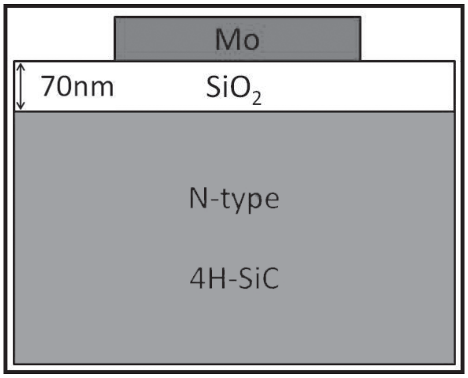

Figure 1: N-SiC MOS capacitor.

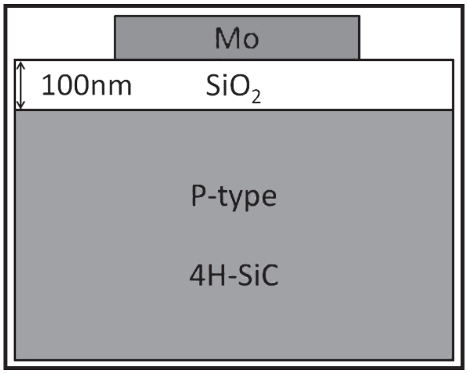

Figure 2: P-SiC MOS capacitor.

Experimental Procedure:

We first set up two MOS capacitors for Silvaco. Each had different oxide thicknesses and were named n-SiC (Figure 1) and p-SiC (Figure 2). We ran different simulations on each capacitor to gather information on their C-V curves. Each simulation was developed using five groups. Structure specification contained the mesh, region, electrode, and doping sections. Material models specification contained material, models, contact, and interface sections. Numerical method selection contained the method section. Solution specification contained log, solve, load, and save sections. Results analysis contained extract and tonyplot sections.

We exported the data from Silvaco (see Table 1, at right) and then; imported the data into Excel, normalized the data, refitted plots using Origin, and finally, compared the shifts and degradation between cases and ideal curve.

Silvaco
i. Run Time Environment
ii. Command File
iii. Structure Files
iv. ATLAS Device Simulator
v. Log Files and/or Solution Files
vi. Tonyplot

Results:

Our simulations of n-SiC and p-SiC devices showed a slight voltage shift and some degradation. In Figure 3, the ideal curve reaches depletion around 2 V. The interface state curve reaches depletion at 0 V, while oxide charges shift the depletion region to -2 V. In Figure 4, the ideal curve reaches depletion around 3.2 V. The interface state curve reaches depletion around 5 V and oxide charges shift the depletion region to 0 V.

Our results show how the SiC MOS capacitor is stable and efficient even with oxide charges and interface states.

Conclusions:

SiC is a potentially important high-temperature semiconductor for power device applications and it can operate at temperatures much higher than Si. Using Silvaco, we simulated the effect of SiC oxide charges and interface traps on the behavior of MOS capacitors. The simulation software uses Poisson's, Carrier Continuity, and many other equations in Atlas to solve and gather data to generate the C-V curves. P-type MOS capacitors were able to retain the shape of the ideal C-V curve with only slight inversion due to the oxide charge. N-type MOS capacitors were also able to retain the CV curve shape, but with degradation due to interface states and lateral curve shift due to the oxide charge.

Future Work:

In the future, we hope to replace Si with SiC or take the technology to another level by building high-power devices using SiC. Even with defects, we have proven that SiC can still provide power and efficiency in devices. We will continue to research and simulate SiC and further prepare it for high-power use.

Acknowledgments:

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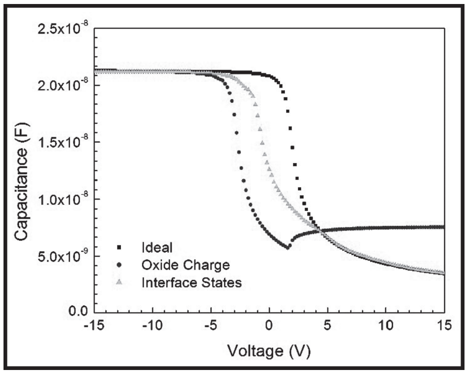

Figure 3: P-SiC results.

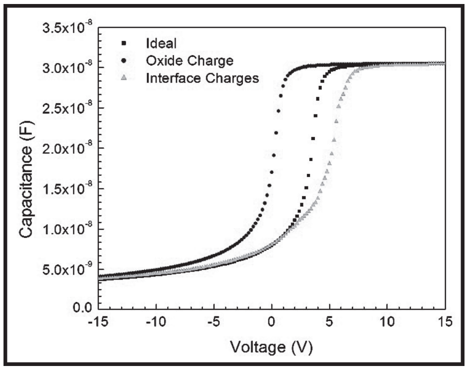

Figure 4: N-SiC results.