ALD HfO_2 and Al_2O_3 as MIM Capacitor Dielectric for GaAs HBT Technology

Jiro Yota

Skyworks Solutions, Inc.
2427 W. Hillcrest Dr.
Newbury Park, CA 91320, USA

In order to reduce die size and increase capacity, the metal-insulator-metal (MIM) capacitor area in circuit designs fabricated using GaAs hetero-junction bipolar transistor (HBT) technology has to be reduced. This can be achieved by using a capacitor dielectric material that has a high dielectric constant or high capacitance density. In GaAs HBT technology, the MIM capacitor dielectric film is typically also required to have a high breakdown voltage (>20 V) and low leakage current. Furthermore, the deposited dielectric film has to be compatible with GaAs processing and has to be deposited at a temperature of $\leq$ 300°C, due to the limited process thermal budget in the HBT technology. As a result of these requirements, there are only a few materials available for MIM capacitor dielectric application in GaAs HBT technology. The most widely used MIM capacitor dielectric film in GaAs technology is silicon nitride (Si_3N_4) film, which is typically deposited using plasma-enhanced chemical vapor deposition (PECVD) method, and which has relatively good mechanical, chemical, and electrical characteristics, including high breakdown voltage and low leakage current. However, PECVD Si_3N_4 has a relatively low dielectric constant of 6 to 7.

In this study, high dielectric constant materials hafnium dioxide (HfO_2) and aluminum oxide (Al_2O_3) films deposited using atomic layer deposition (ALD) method were characterized and evaluated as MIM capacitor dielectric for GaAs HBT technology to fabricate capacitors with high capacitance density, high breakdown voltage, and low leakage current. Figure 1 shows the calculated dielectric constant and measured breakdown voltage obtained from MIM capacitors fabricated on GaAs HBT wafers, with 62 nm of ALD HfO_2 and 59 nm of ALD Al_2O_3 as capacitor dielectric. As can be seen, the dielectric constant obtained in this study is 18.7 for HfO_2 and 10.3 for Al_2O_3, which is significantly higher than that typically obtained with PECVD Si_3N_4. The breakdown voltage is measured to be 34 V and 41 V for HfO_2 and Al_2O_3, respectively. Figure 2 shows the I-V characteristics of MIM capacitors with 4055 μm^2 area and with 62 nm of ALD HfO_2 and 59 nm of ALD Al_2O_3 capacitor dielectric obtained at 2 different temperatures. As can be seen, the leakage current increased and breakdown voltage decreased as the temperature was increased from 25°C to 150°C. Figures 3 and 4 show the C-V characteristics of the ALD Al_2O_3 and HfO_2 films, respectively, as a function of applied voltage and temperature. The figures show that the capacitance density of both films only slightly increased, when the temperature was increased from 25°C to 150°C. No significant change was observed when the applied voltage was varied from -5 V to +5 V. Furthermore, the data also show that when the frequency was varied from 1 kHz to 1 MHz, the capacitance density does not change significantly. These results show that the ALD films of Al_2O_3 and HfO_2 are suitable and are good candidates for MIM capacitor dielectric in GaAs HBT technology, depending on the circuit design, application, and requirements.

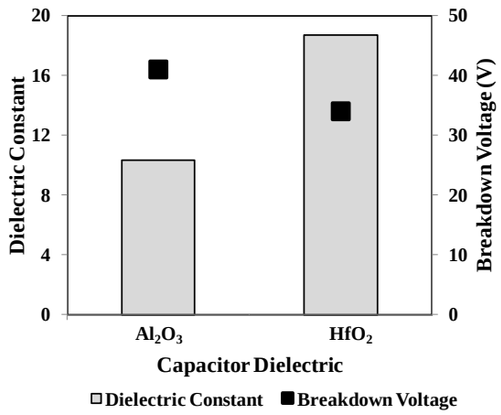

Figure 1. Dielectric constant and breakdown voltage of MIM capacitor with 59 nm of ALD Al_2O_3 and 62 nm of ALD HfO_2 as capacitor dielectric on GaAs HBT wafers.

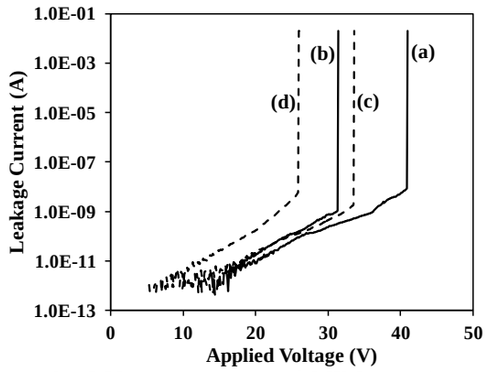

Figure 2. I-V characteristics of MIM capacitor with 59 nm ALD Al_2O_3 at (a) 25°C, (b) 150°C, and 62 nm ALD HfO_2 at (c) 25°C and (d) 150°C.

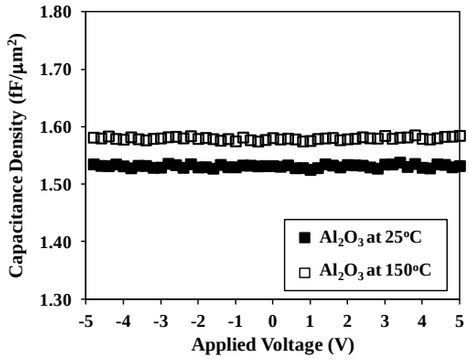

Figure 3. C-V characteristics of MIM capacitor with 59 nm ALD Al_2O_3 at 25°C and 125°C.

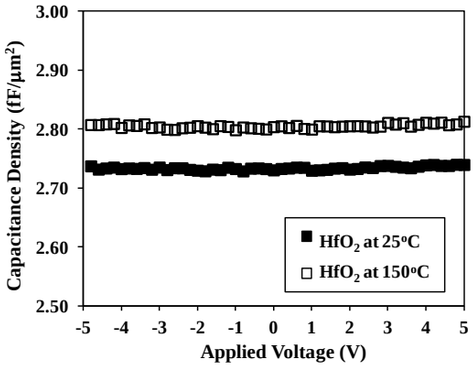

Figure 4. C-V characteristics of MIM capacitor with 62 nm ALD HfO_2 at 25°C and 125°C.