Polarization switching in highly scaled ferroelectric MOS capacitor

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Sponsorship:

Ferroelectric FETs (FeFET) are promising candidate for low power, scalable and non-volatile memory enabling applications such as in-memory computing, artificial intelligence (e.g. analog synapses, coupled oscillator networks, spiking neurons) and quantum computing (i.e. cryogenic memory). Ultra-thin doped HfO_2 based thin-films have emerged as an attractive option for FeFETs due to precise thickness control through atomic layer deposition and CMOS compatibility. However, the design space of a FeFET-based memory that operates with a low supply voltage, a sufficient memory window and high endurance is not well understood. In this work, we systematically investigate ferroelectric $Hf_{0.5}Zr_{0.5}O_2$ MOS capacitors to study the electrostatics of the device which solidifies the design criteria for low voltage FeFETs.

In this study, MOS capacitors (Figure 1) are fabricated on p-Si wafers using standard CMOS processing with different ferroelectric thickness. The dielectric constant, k, of the annealed $Hf_{0.5}Zr_{0.5}O_2$ film is higher than those of HfO_2 and ZrO_2(k = 25) for all thicknesses as observed from the small signal capacitance-voltage (C-V) characteristics (Figure 2) due to its orthorhombic phase. At low gate biases, the HZO film is hysteresis-free (Figure 2 inset) and shows negligible frequency dispersion indicating a high-quality interface. At high gate bias, the thinner films show rapid increase of the capacitance resembling the peak of butterfly-like behavior of standard ferroelectric capacitors as the net charge exceeds the critical charge required to achieve the coercive field. However, this behavior is absent in the thick HZO film where coercive field is higher than the breakdown field. High dielectric constant and relatively low effective charge of the ferroelectric thin film, in combination with the ultrathin SiO_2 interlayer enables the polarization switching of the thinner dielectrics. This is the *first* observation of polarization switching ferroelectric MOS capacitors using small-signal measurement.

These results indicate that our technology can enable FeFETs operating at 2.5 V with highly scaled dielectrics (t_{FE} =5 nm) that are required for a future transistor topology. This is a significant improvement compared to state-of-the-art flash memory. However, to enable lower switching voltage FeFET, additional materials and device engineering would be required as the switching voltage weakly scales with ferroelectric thickness.

<Figure 1 here>	<Figure 2 here>
Figure 1: Cross section transmission electron micrograph of fabricated MFIS capacitor with 10Å amorphous interfacial SiO_2 deposited through ozone and crystalline $Hf_{0.5}Zr_{0.}5O_2$ (HZO), in this case 7.5 nm, capped with WN deposited by plasma-assisted ALD.	Figure 2: Small-signal C-V characteristics of MFIS capacitor with different ferroelectric layer thickness. Inset shows the frequency dependent bi-directional C-V of 10.5 nm ferroelectric MOS capacitor for low bias range.

Further Reading

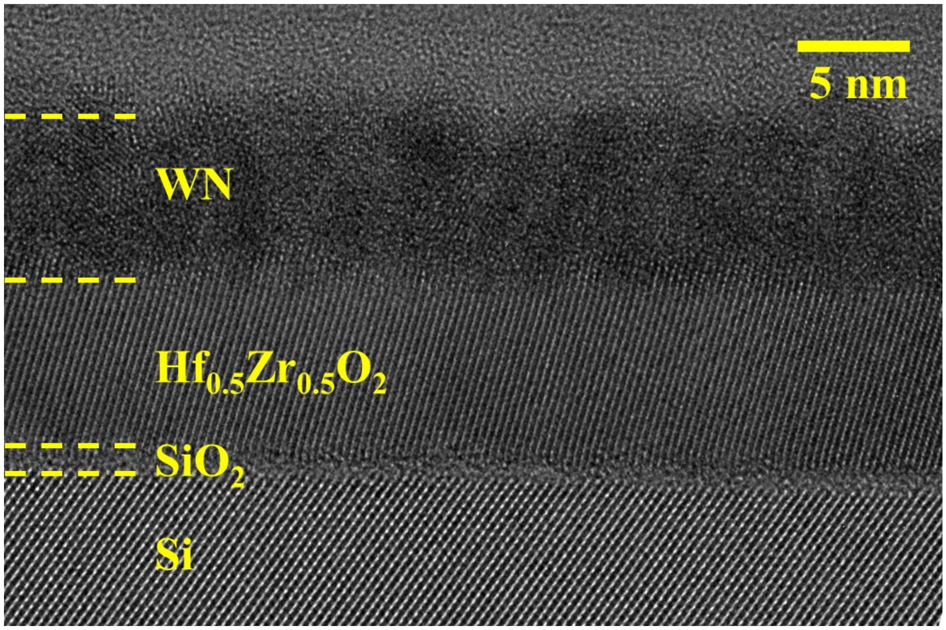

Figure 1

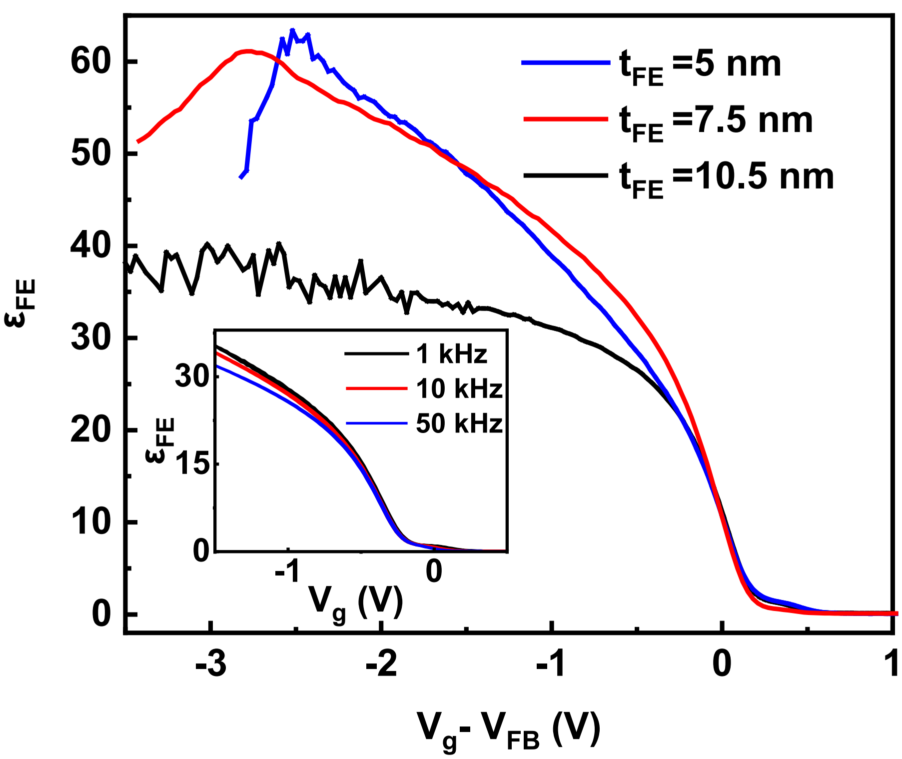

Figure 2