A Theoretical Study of Multi-Domain Ferroelectric Switching in AOS (Amorphous Oxide Semiconductor) channel based Ferroelectric Field Effect Transistors

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Next-generation workloads in AI, imaging, and edge computing demand embedded memories that offer high density, fast access, and energy efficiency.[1] While HfO_2-based ferroelectric field-effect transistors (FeFETs) with Si channels have shown promise for nonvolatile memory applications, recent advancements in amorphous oxide semiconductor (AOS) channel materials offer new opportunities for low-temperature, back-end-of-line (BEOL) integration. Among these, AOS-based FeFETs exhibit distinct electrical behaviors not observed in conventional counterparts—most notably, asymmetric subthreshold swing (SS) and abrupt steep-slope switching during reverse gate sweeps (off transitions).[2] Despite their significance, the physical mechanisms behind these unique switching characteristics remain poorly understood.

In this work, we present a detailed modeling study to elucidate the origin of steep-slope switching and SS asymmetry in AOS-based FeFETs. Two representative models are compared: a conventional Preisach model (Fig. 1) and a physics-based time-dependent Ginzburg–Landau (TDGL) model (Fig. 2). While both models capture general hysteresis behavior, only the TDGL model—coupled with a drift-diffusion-based channel transport simulation—reproduces the abrupt current drop during the erase transition as shown in Fig. 2. This effect is attributed to localized domain nucleation near the source/drain regions, which triggers a percolation-driven conduction path breakdown and coexists with negative capacitance (NC)-like effects. Furthermore, the TDGL model quantifies how asymmetric screening and incomplete polarization switching affect SS asymmetry.

These findings highlight the necessity of domain-resolved modeling to accurately describe switching in AOS FeFETs and provide new insights toward optimizing device operation for low-power embedded nonvolatile memory applications.

References

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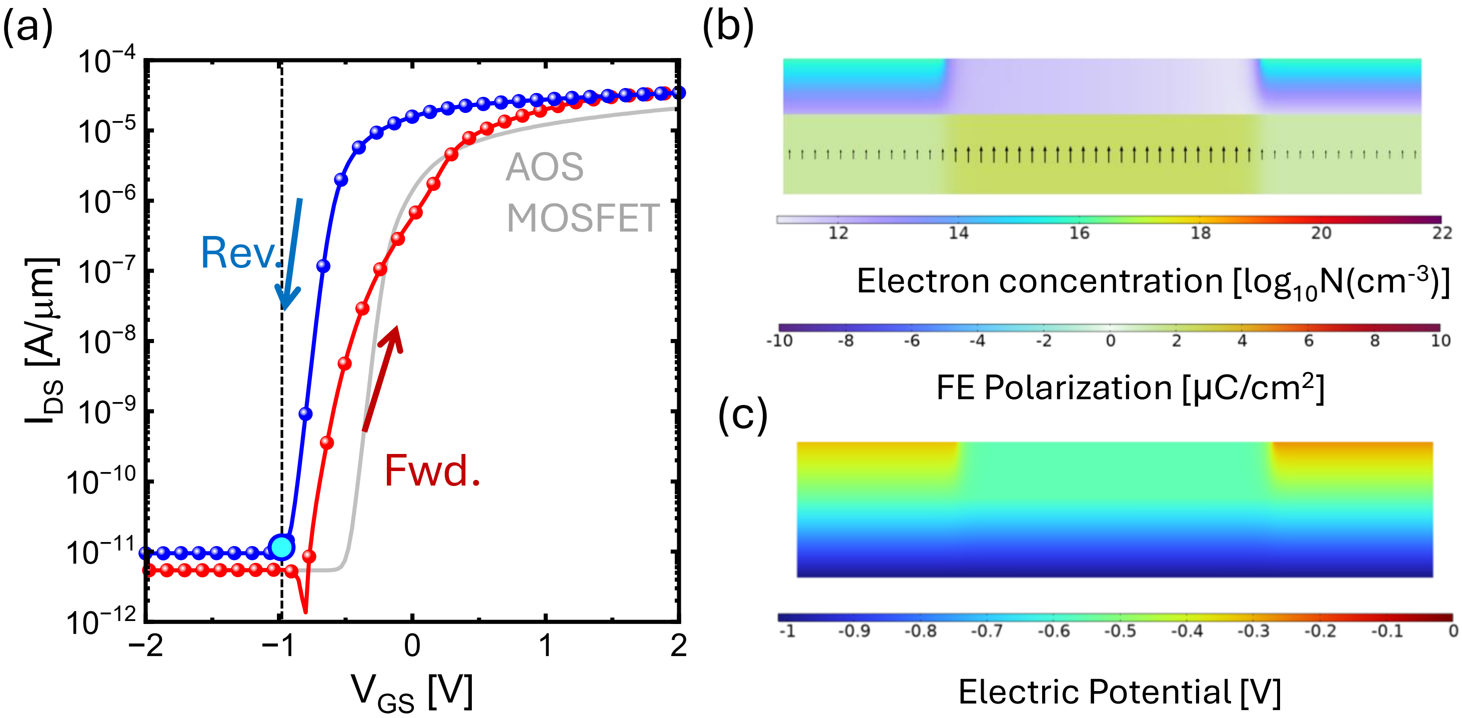

Fig. 1. (a) Transfer curve ($I_D - V_G$) of an (Hf,Zr)O_2 (or HZO) AOS FeFET simulated using an analytical Preisach model. The blue and red curves represent the reverse and forward sweeps, respectively, while the gray line corresponds to a conventional AOS MOSFET without ferroelectric polarization. (b) Ferroelectric polarization in the HZO layer and electron concentration in the channel at the off state (indicated by cyan circle marker in (a)). (c) Electric potential distribution under the same condition.

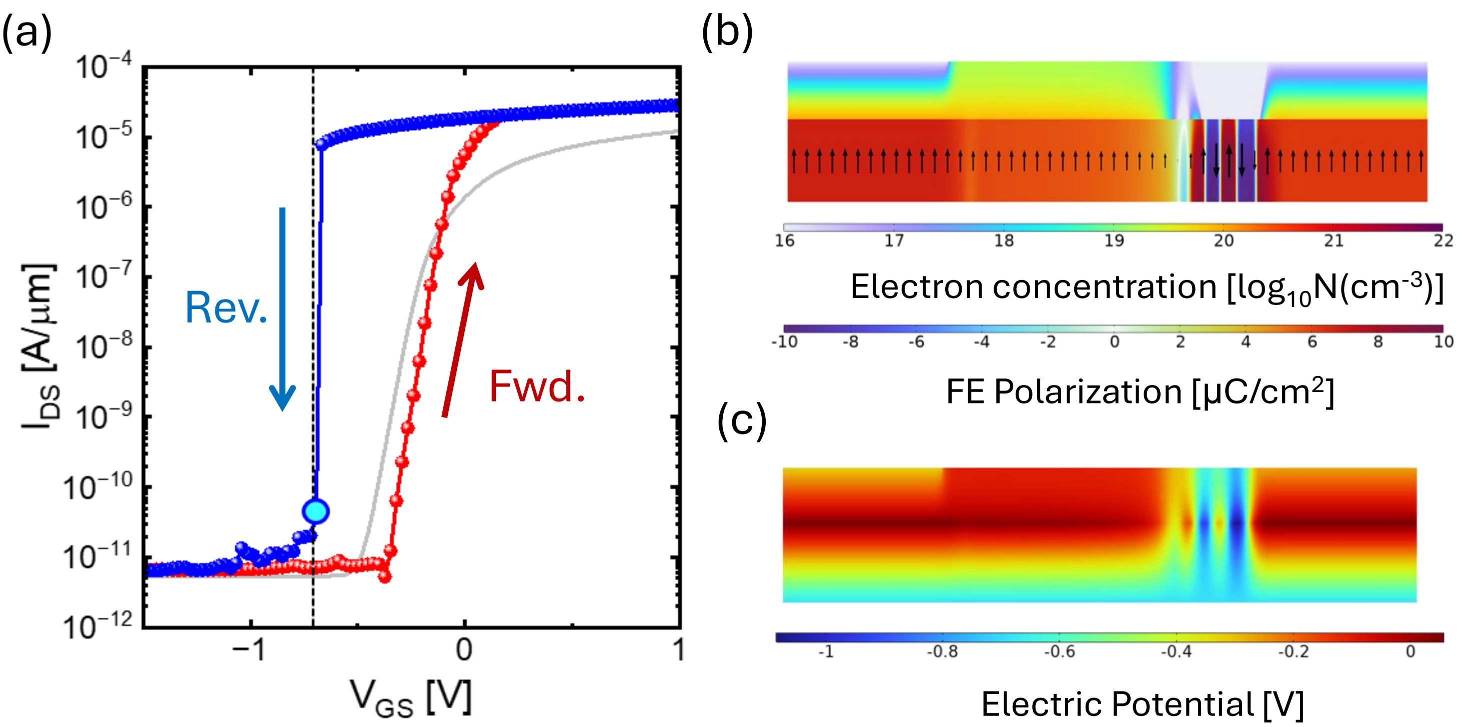

Fig.2. (a) Transfer curve ($I_D - V_G$) of an (Hf,Zr)O_2 (or HZO) AOS FeFET simulated using the Time Dependent Ginzburg Landau (TDGL) model. The blue and red curves represent the reverse and forward sweeps, respectively, while the gray line corresponds to a conventional AOS MOSFET without ferroelectric polarization. (b) Ferroelectric polarization in the HZO layer and electron concentration in the channel at the off state (indicated by cyan circle marker in (a)). (c) Electric potential distribution under the same condition..