Enhanced ISPP/PE slope in Ferroelectric NAND through Laminated $HfZrO_2$ Film

Hyun Jae Lee[1]*, Minji Sohn[1], Asif I. Khan[1], Shimeng Yu[1], and Suman Datta[1]

[1]*Department of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA, USA*

Ferroelectric NAND (FENAND) based on the MIFIS (Metal-Insulator-FE-I-Silicon) structure has gained attention due to its potential to lower operating voltage via FE polarization, thereby enabling aggressive spacer scaling [1-3]. A steep Incremental Step Pulse Programming/Erase (ISPP/PE) slope is crucial in this context [4], as it directly reduces the required program voltage (V_{PGM}), facilitating high-density 3D vertical FENAND.

In this work, we demonstrate that introducing a laminated FE structure improves the ISPP/PE slope compared to a conventional single-layer FE. The laminated FE consists of two 7.5 nm $HfZrO_2$ (HZO) layers separated by a 3 Å Al_2O_3 interlayer (Fig. 1(a)), while the reference device uses a single 15 nm HZO layer.

Polarization-Voltage (P-V) characteristics on MFM devices (Fig. 1(b)) reveal a 25 % increase in coercive voltage (V_C) and a 19 % reduction in remnant polarization (P_r) with lamination. These changes lead to a steeper ISPP/PE slope (Fig. 2(a-b)), with ISPP and ISPE increasing by 13 % and 6 %, respectively. The improvement arises from two mechanisms:

1. Before switching: The increased V_C delays FE switching, allowing higher V_{PGM} to drop across the gate insulator, enhancing the gate injection rate.
2. After switching: The reduced P_r lowers the required compensation charge, lowering the channel-side injection rate.

Meanwhile, the maximum memory window (MW) remained larger by 16 % in the laminate structure, despite its smaller P_r. This is attributed to the higher V_C of the laminate, which requires less compensation charge. As a result, the laminate simultaneously enables an increased MW and a steeper ISPP/PE slope. This work highlights design strategy for FE engineering and offers a pathway toward further FENAND scaling for future memory applications.

References

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* Corresponding author: email: hlee3132@gatech.edu

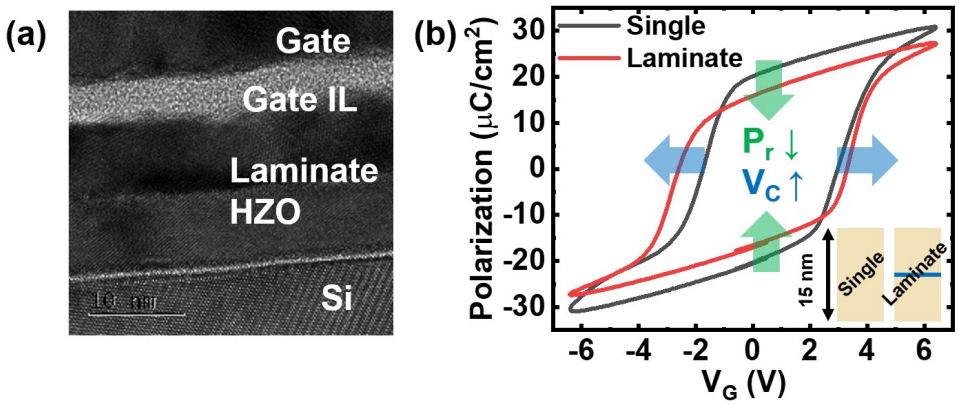

Figure 1. (a) Cross-sectional TEM image of the MIFIS structure incorporating a 2-layer laminated HZO as the FE. (b) P-V characteristics of single and laminated HZO measured on MFM devices, showing increased V_C and reduced P_r in the laminate.

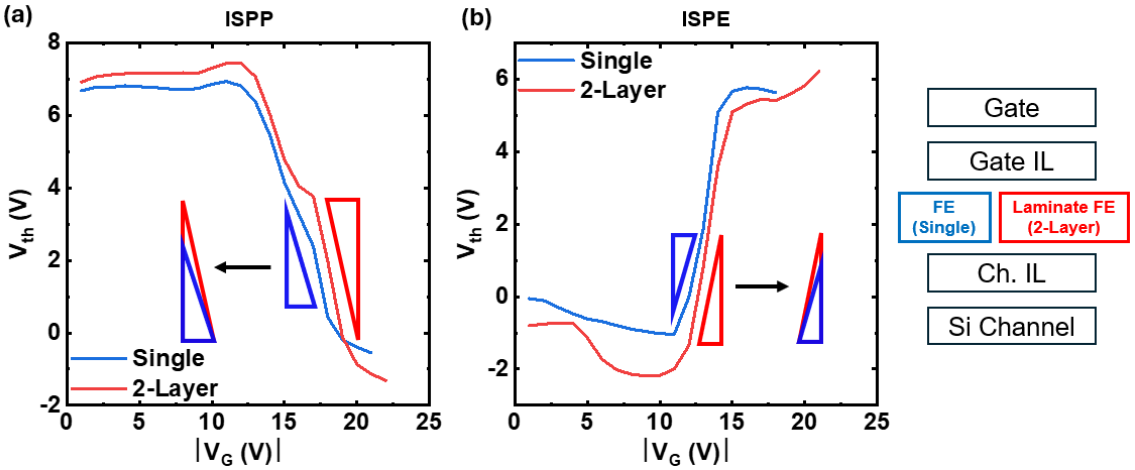

Figure 2. (a) ISPP and (b) ISPE curves for single and laminated FE devices. The slopes are indicated by triangles, clearly showing an increase for both ISPP and ISPE in the laminate.