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New Insight into Impacts from Read Cycle Number and Voltage Sweeping Direction on Memory Window of Ferroelectric FET

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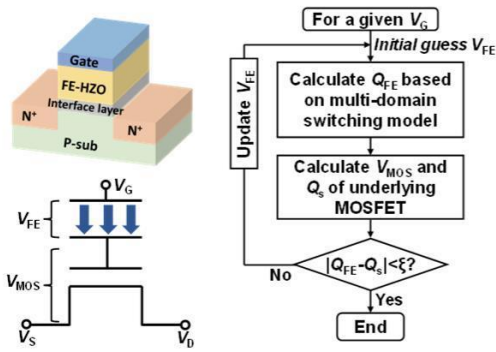[2]Beijing Advanced Innovation Center for Integrated Circuits, Beijing 100871, China
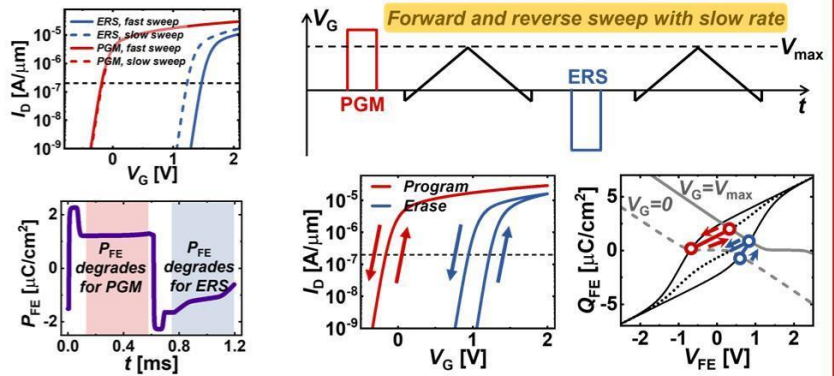[3]Beijing Superstring Academy of Memory Technology, Beijing 100176, China

ABSTRACT

In this work, impacts from cycle number and direction of sweep voltage on electrical characteristics of ferroelectric FET (FeFET) during readout are investigated. Considering polarization switching dynamics, it is found that the memory window (MW) of FeFET shows large dependence on both sweep time and read cycle number. Under continuous sweep voltage cycles for readout, MW will gradually degrade. Furthermore, MW dependence on sweep direction of gate voltage is demonstrated, showing significant V_{TH} shift under reverse sweep for erase state. This work provides theoretical analysis for more accurate MW estimation of FeFET.

SIMULATION METHOD

For a given V_G
Initial guess V_{FE}
Calculate Q_{FE} based on multi-domain switching model
Calculate V_{MOS} and Q_s of underlying MOSFET
$|Q_{FE} - Q_s| < \xi$?
No / Yes
End

MW IMPACTED BY SWEEP RATE
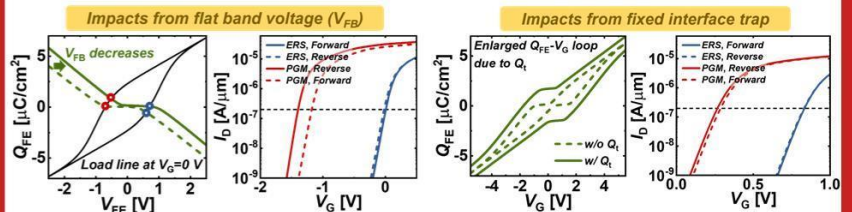

Forward and reverse sweep with slow rate

> MW **decreases** due to P_{FE} switching under **slow rate**.

> P_{FE} degradation and V_{TH} shift under slow IV sweep will be **much larger for erase state** during readout.
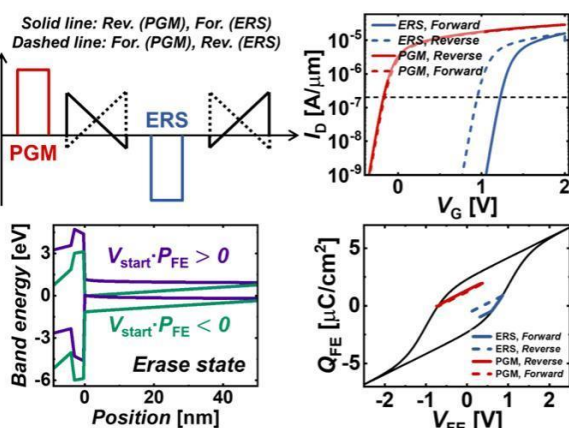
IMPACTS OF CYCLE NUMBER

Continuous read cycles

Read cycle increases
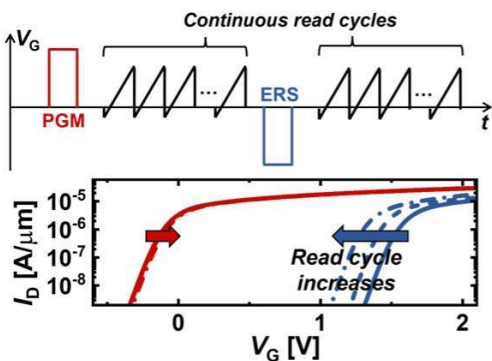
> **Accumulated P_{FE} switching** leads to decreased MW with **increased cycle**.

SUPPLEMENTARY DISCUSSIONS

Impacts from flat band voltage (V_{FB})

V_{FB} decreases
Load line at $V_G = 0$ V

Impacts from fixed interface trap

Enlarged Q_{FE}-V_G loop due to Q_t
w/o Q_t / w/ Q_t

> For **negative V_{FB}** with large value, depolarization effect for **program state** is more evident.

> Impacts from sweep direction will be **weakened by trap** due to inhibited P_{FE} switching.

IMPACTS FROM SWEEP DIRECTION UNDER SLOW RATE

Solid line: Rev. (PGM), For. (ERS)
Dashed line: For. (PGM), Rev. (ERS)

$V_{start} \cdot P_{FE} > 0$
$V_{start} \cdot P_{FE} < 0$
Erase state

> V_{TH} of erase (or program) state will be lower (or higher) under reverse (or forward) sweep compared with that under forward (or reverse) sweep.

> The MW dependence on sweep direction is originated from **depolarization effect** caused by applied voltage on FE layer and P_{FE} at the **beginning of sweep**.

SUMMARY

- MW will **degrade with sweep time and sweep cycle number** of read voltage.
- It is suggested that **forward and reverse sweep should be applied with fast read sweeping rate** for erase and program state respectively to evaluate MW more accurately.