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Nanoscale

SUPPLEMENTARY INFORMATION

First demonstration of 2T0C-FeDRAM: a-ITZO FET and double gate a-ITZO/a-IGZO FeFET with record-long multibit retention time of > 4-bit and > 2000 s

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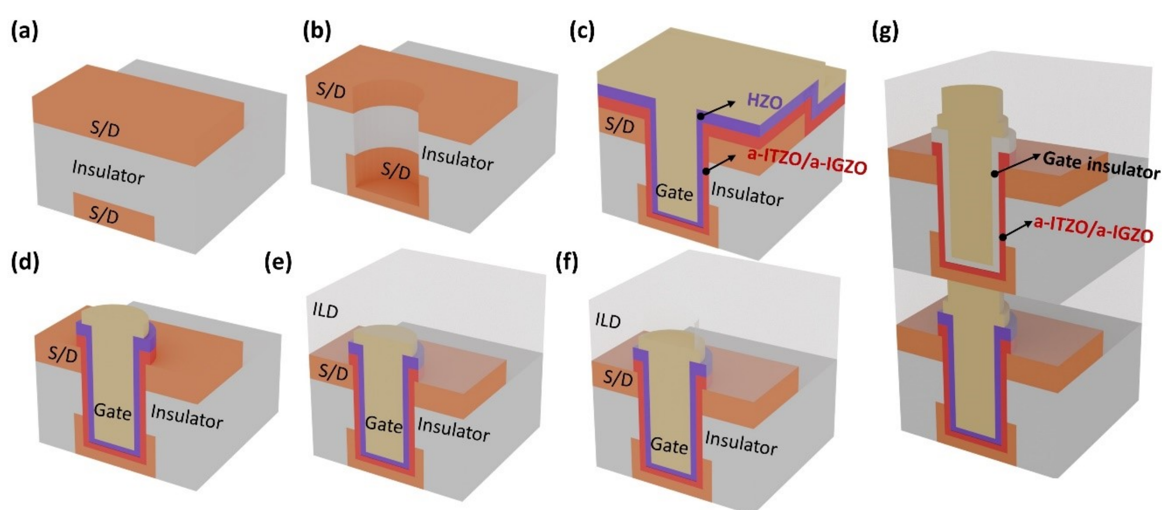

Fig. S1. Process flow of one channel all around (CAA) structure 3D 2T0C-FeDRAM cell (The 3D 2T0C-DRAM process was proposed by Duan *et al.*[1] Here, the main differentiation is the introduction of the ferroelectrics of HZO after channel formation as a gate insulator.) (a) MIM structure deposited by S/D spacer and top electrode in sequence after bottom electrode formation, (b) channel region etching, (c) gate stack deposition by ALD in sequence (R_{tr} gate stack: a-ITZO/a-IGZO/HZO/gate electrode, W_{tr} gate stack: a-ITZO/gate insulator/gate electrode), (d) active region isolation (e) Inter-Layer dielectric (ILD) deposition, (f) ILD etching, (g) After the lower R_{tr} is completed, the upper W_{tr} repeats the same process.

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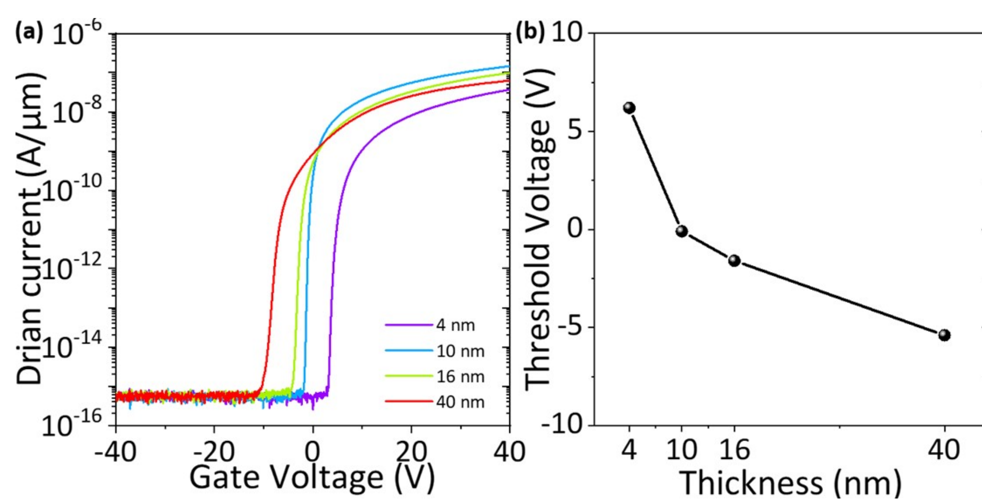

Fig. S2. (a) Transfer characteristics of a-ITZO (4, 10, 16, and 40 nm-thickness) FETs. (b) Thickness dependence of threshold voltage for a-ITZO TFTs.

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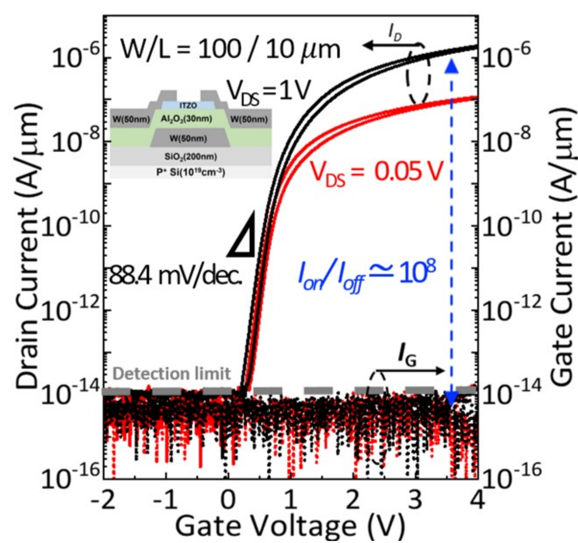

Fig.S3. I_D - V_G characteristics of the write a-ITZO FET. Utilizing high mobility near 25.5 cm^2/V s and low leakage current attributes of a-ITZO, a low *S.S.* value of 88.4 mV/dec. and an off current below 10^{14} A/μm were achieved, making it suitable as a write transistor (W_{tr}) for 2T0C-FeDRAM.

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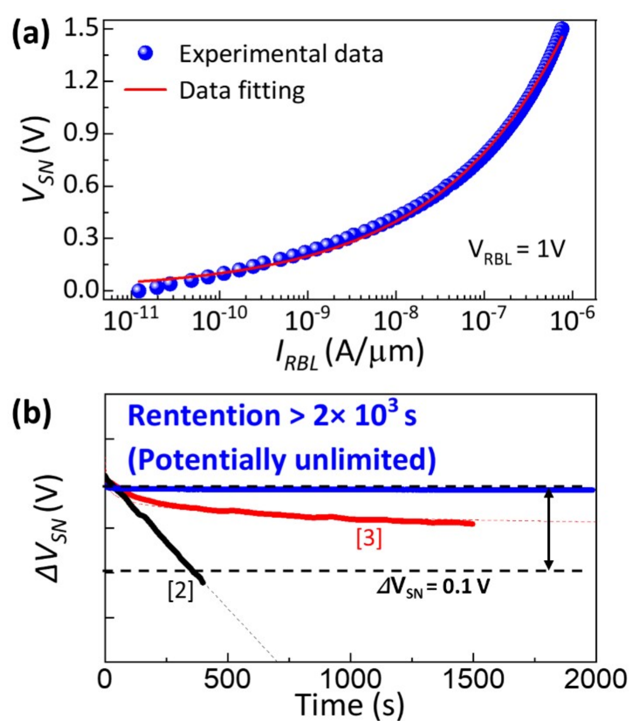

Fig. S4. (a) Data fitting of V_{SN}-I_{RBL}, detected during the 2T0C-FeDRAM read operation, V_{SN} can be extracted. (b) V_{SN} changes vs. time, indicating that the excellent retention time. I_{RBL} was maintained almost without the voltage dropping for a period of 2000 s.[2, 3]

Notes and references

1. X. Duan, K. Huang, J. Feng, J. Niu, H. Qin, S. Yin, G. Jiao, D. Leonelli, X. Zhao and Z. Wang, *IEEE Trans. Electron Devices*, 2022, **69**, 2196-2202, DOI: http://dx.doi.org/10.1109/TED.2022.3154693.
2. A. Belmonte, H. Oh, N. Rassoul, G. Donadio, J. Mitard, H. Dekkers, R. Delhougne, S. Subhechha, A. Chasin and M. Van Setten, presented in part at the 2020 IEEE International Electron Devices Meeting (IEDM), 2020.
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