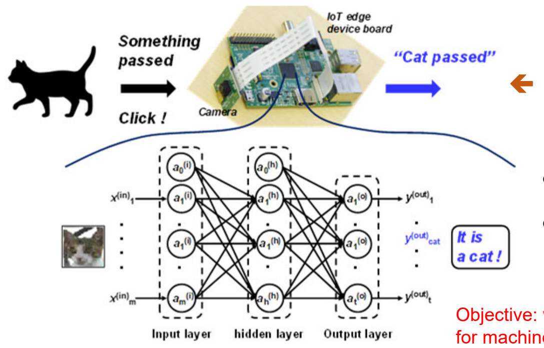
HfO_2-Based Ferroelectric Tunnel Junction Memory with Large Tunneling Electroresistance Ratio and Multi-level Cell

高トンネル抵抗比と多値記憶が可能な強誘電体HfO_2トンネル接合メモリの実現

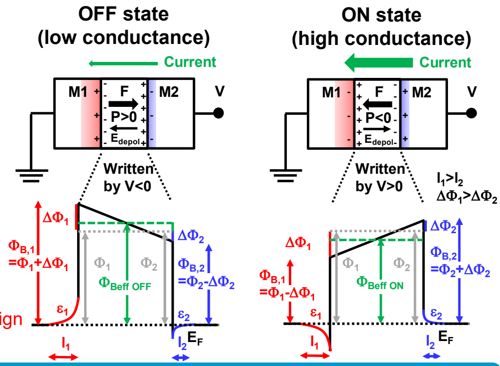
Background



- Machine learning will require energy-efficient massive parallel computing. Therefore Non von-Neumann architecture is needed.
- Synaptic weight should be stored in nonvolatile memory that can store analog or multi-level value.
- FTJ memory is a novel two-terminal resistive change memory.
- By flipping the spontaneous polarization, tunneling barrier height and thus tunneling resistance can be modulated.

Objective: we explore FE-HfO_2 FTJ memory device design for machine learning applications.

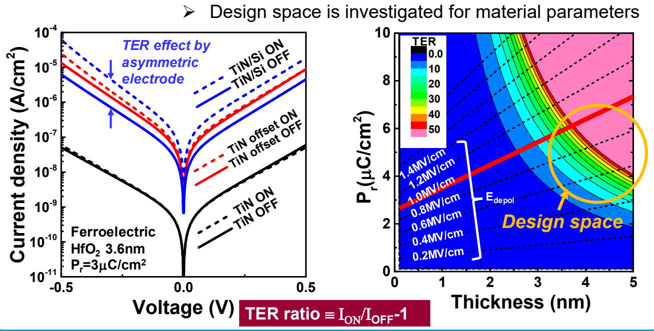
The principle of FTJ



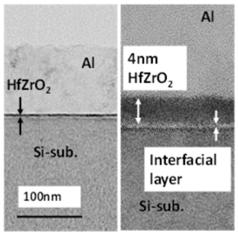
Process development and FTJ evaluation

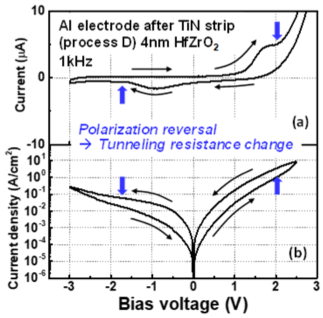
FTJ design

- Asymmetric dielectric property of top and bottom electrodes is a key for high TER ratio.
- Design space is investigated for material parameters



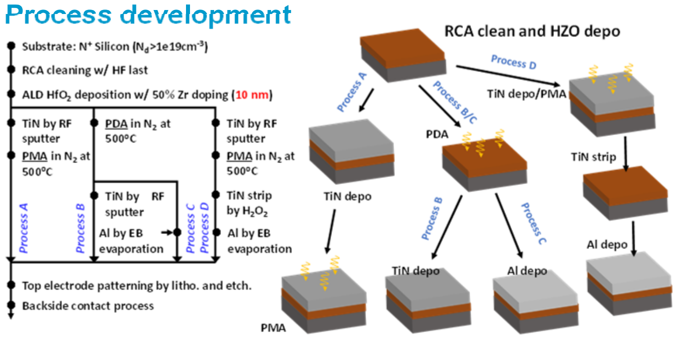
FTJ DC/low frequency Characteristic

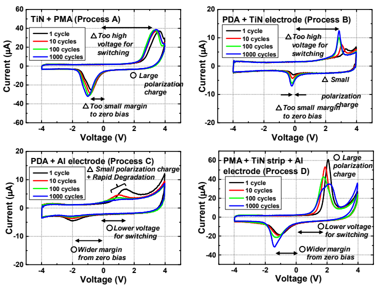


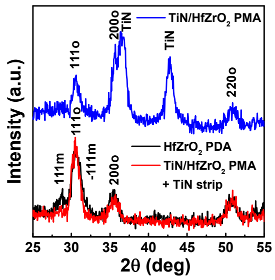


- 4nm-thick $HfZrO_2$ shows clear ferroelectric property by our process.
- Ferroelectric hysteresis is observed in I-V characteristics.

Process development

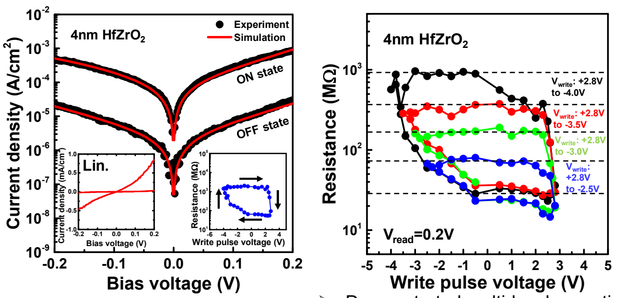




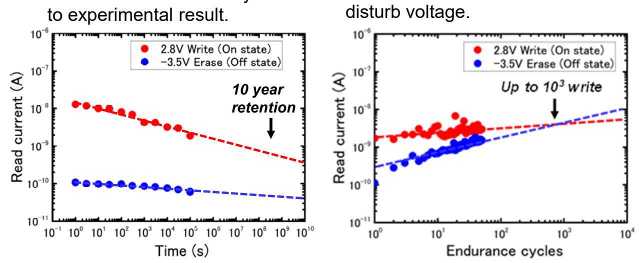


- We developed a process featuring metal replacement process. This process realizes large polarization switching current (charge) and symmetric switching voltage.

FTJ memory characteristics



- 30 TER ratio are obtained.
- Simulation result fits very well to experimental result.
- Demonstrated multi-level operations.
- Each level is flat and immune to disturb voltage.



- Data retention characteristics is good for 1~10year.
- Endurance reliability needs to be improved.

Conclusions

1)Explored FTJ device design space with regard to material parameters.
2)Developed fabrication process that controls crystalline phase of FE-HfO_2 and workfunction of metal electrodes, simultaneously.
3)Achieved TER~30, which is one of the highest at low write voltage among previously reported.
4)Demonstrated multi-level cell operation with disturb immunity.

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