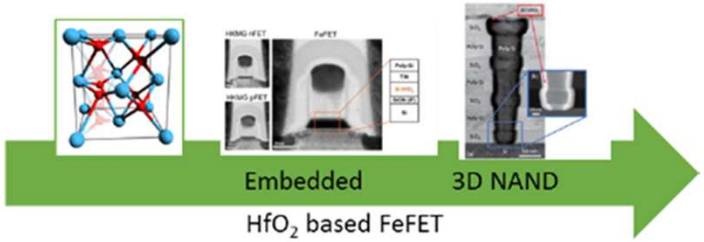
History of FeRAM

- 1st Gen. Early of 1950s,
  Bulk $BaTiO_4$ single crystal
- 2nd Gen. Late of 1980s,
  Perovskite PZT , SBT based Fe-RAM: 1T-1C, 2T-2C
- 3nd Gen. After 2011
  Ferroelectric HfO_2 based Fe-RAM: 1T,1T-1C
  Properties must be revaluated

intel :2000 polymer ferroelectric : PVDF:TFE 70:30 scaling down

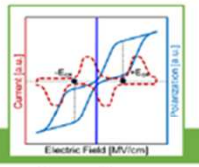
Product in the market Now



HfO_2 based FeFET

Generation 3

Basic research on FeFET using various materials



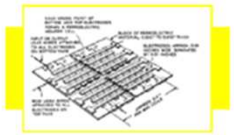
Antiferroelectric RAM

HfO_2 based FeRAM

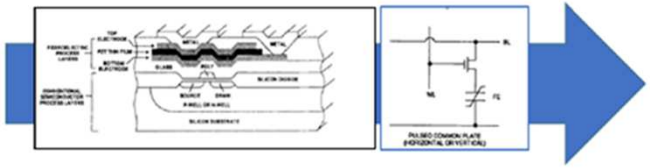
Generation 1

Generation2

Invented by D. A. Buck (MIT) in 1952



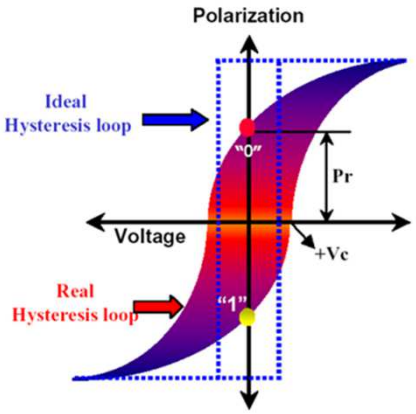
BTO based cross-point memories

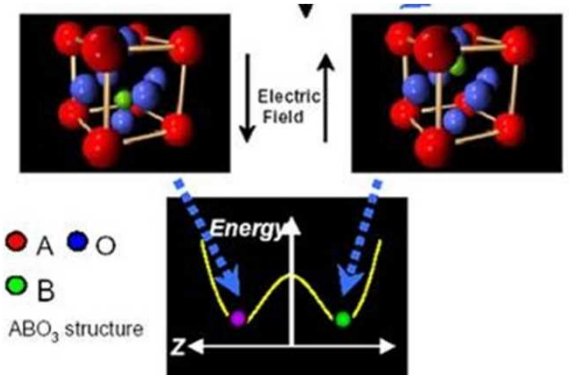


PZT and SBT based 2T-2C and 1T-1C memories

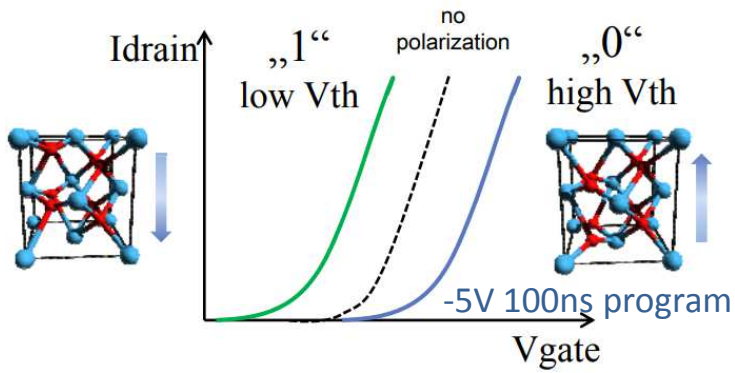
1950 1960 1980 1990 2000 2010 2020

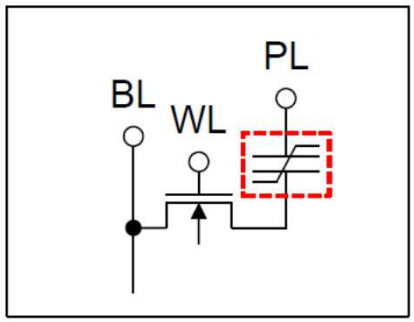
FeFET and FeRAM

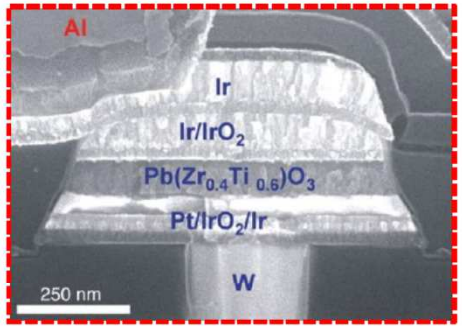




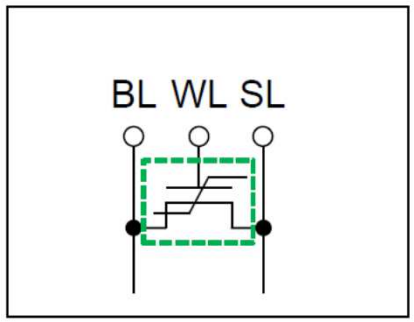
+5V 100ns erase

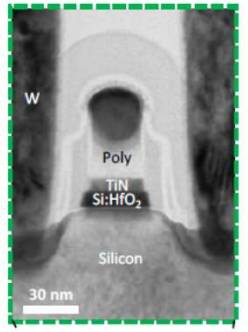






Source: Science, Vol. 315,, pp. 954-959





Source: S. Mueller, EMF, 2015.

- 1T-1C memory cell
- Exotic ferroelectric materials (PZT)
- Stuck at 130 nm

- 1T memory cell
- Ferroelectric HfO_2
- In dev. at 22 nm

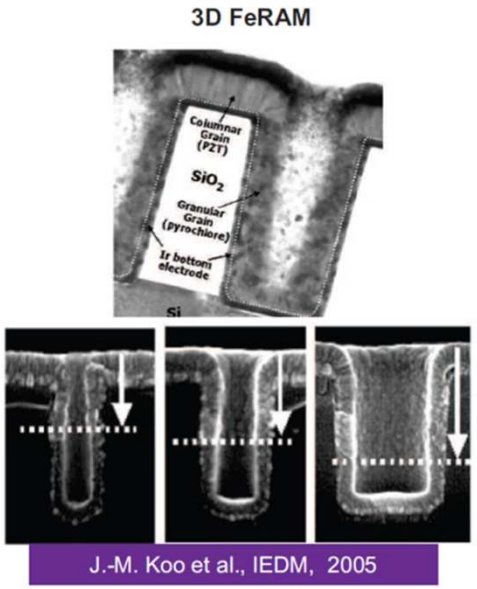
to actual scale...

Stefan Müller(FMC), Flash Memory Summit 2018

Perovskite FeRAM

Advantages:

- Low power consumption
- Switching speed in ns-time
- Excellent endurance performance
- Radiation Hardness



Disadvantages:

- Destructive read out
- low density unable to scale beyond 130nm
- Compatible problem with CMOS process
- Environmentally unfriendly material
- Hydrogen forming gas degradation

From Perovskite to Ferroelectric HfO_2

All properties must be revaluated

Advantages:

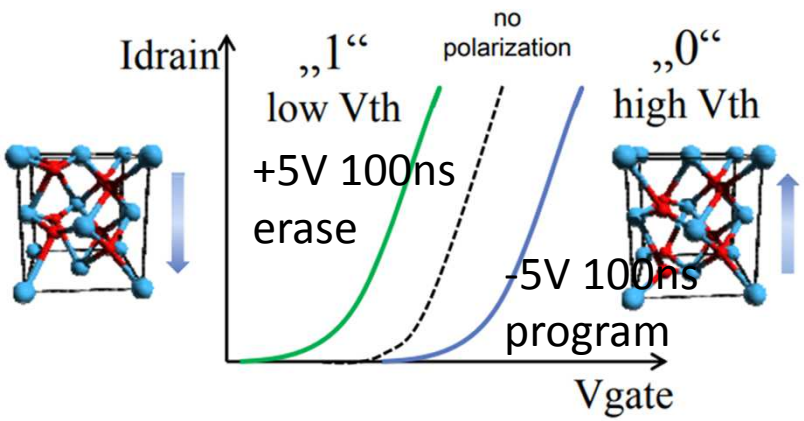
- Non-destructive read out-1T
- CMOS compatible-embedded
- ALD process available:3D
- Hydrogen forming gas hardness
- Environmentally friendly material
- Low power consumption
- Radiation hardness
- Retention property
- Low operation voltage(~5V)

Disadvantages:

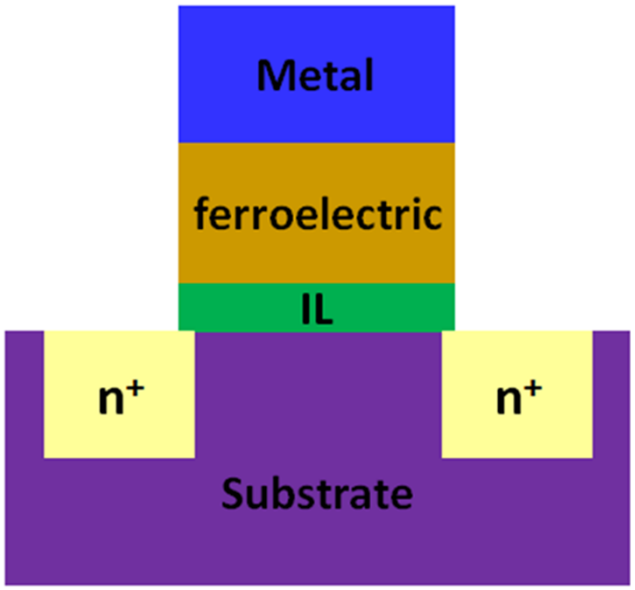
- Poor endurance property
- Low memory window

Unclear :

- Switching kinetics



Operation of 1T FeFET



Major Challenges of 1T-FeRAM

- **Scaling limitation ?**
  Coexist phase , poly-crystal
- **Small voltage window, decrease with thickness and dimension**
  MW=$2E_c$xd
  MLC?
- **Reliability problem of interface**
  High K interface
  Substrate
- **Reliability problem of material**
- **Switching kinetics , distribution of E_C ?**