# Process Equipment Capabilities for STT MRAM Manufacturing

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# OUTLINE

- Background, including need for STT MRAM as embedded memory
- Process Flow and Key Process Equipment for STT MRAM
- Summary and Outlook

# Embedded Flash and SRAM Scaling

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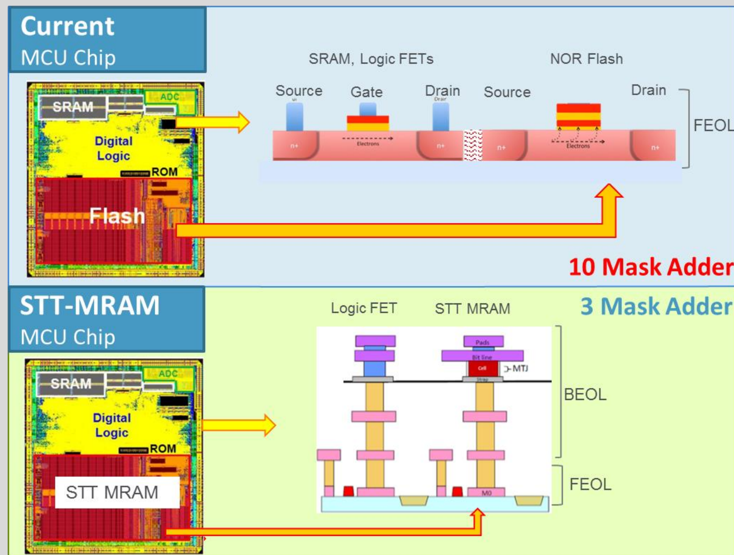
## Embedded Flash

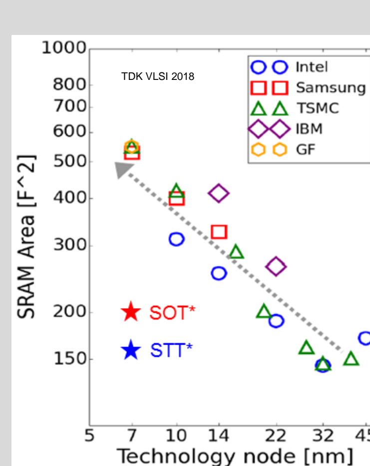



**Scaling limiters:**

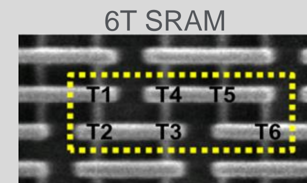
**Cost: Additional mask/process steps**

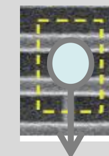
**Performance: Integration of HKMG logic with embedded Flash**

## Embedded SRAM




6T SRAM



1T STT-MRAM

**~65% shrink**

**Scaling limiters:**

**Area (Cost): 6T SRAM scaling challenged, while many AI applications call for more on-DIE working memory**

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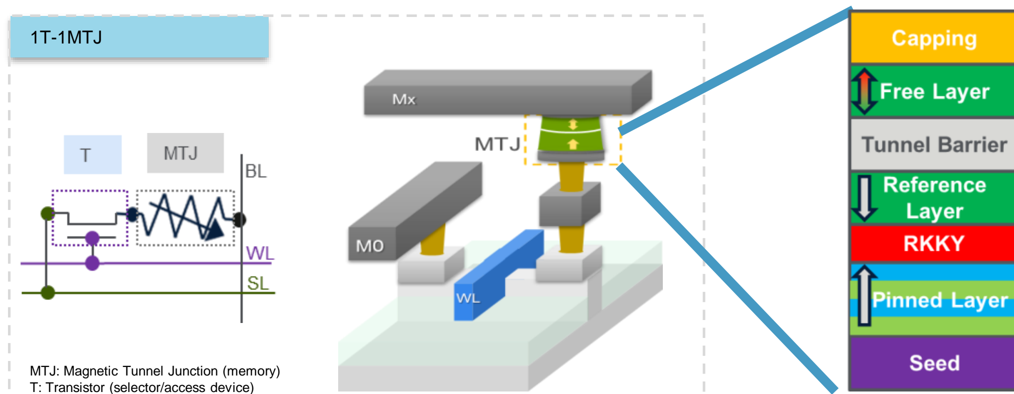
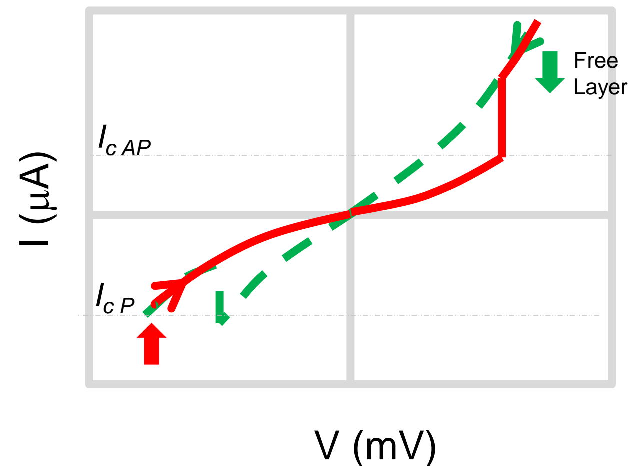
# STT-MRAM Unit Cell Operation




## Achieving basic functions of memory

1. Store: Energy barrier ($\Delta \sim E/k_BT$) between 2 magnetization state
2. Read: Sense amplifier to distinguish the two resistance states (TMR%)
3. Write: FL magnetization direction switching at current > critical current ($I_C$)

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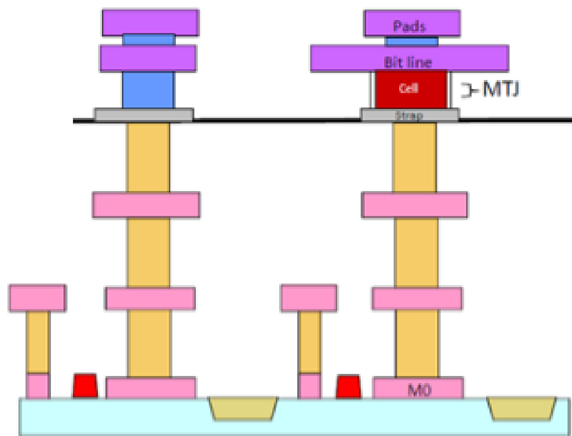
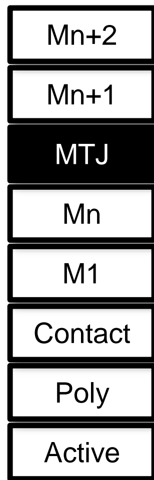
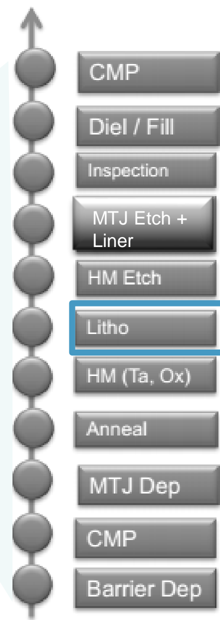
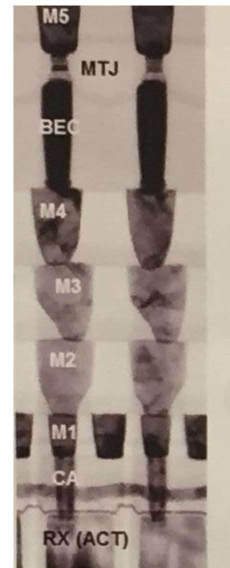
# Backend (BEOL) Insertion of MTJ




SEC IEDM 2016

- Insertion in BEOL with up to 4 additional masks*, on top of logic that resides in FEOL

** Optional bottom and top contact and mark open mask steps*

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# Key Integration Steps for MTJ Module

**3. HM Dep & Etch:**

*Low Temp Dielectric Deposition*

**2. MTJ Stack PVD:**

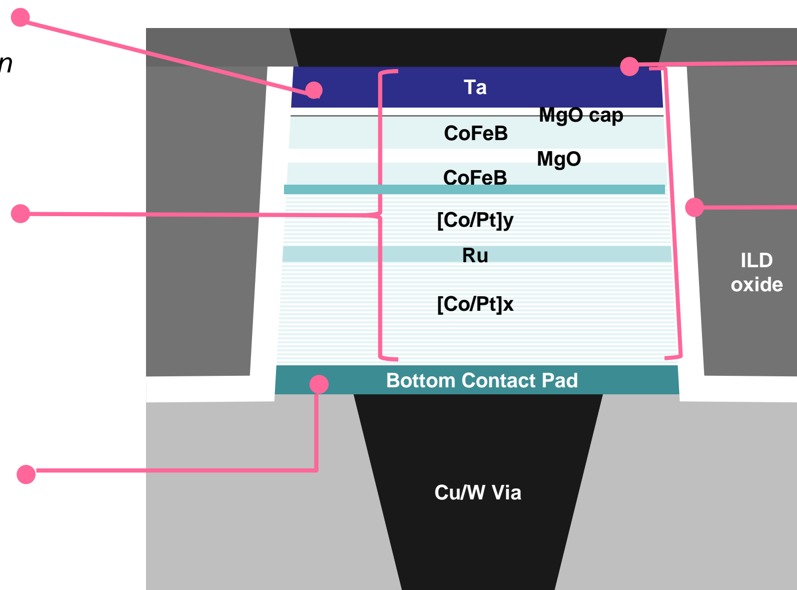
*Complex stack of 10+ layers*

*Precise thicknesses control (sub Angstrom)*

*Interface and texture control*

**1. Bottom Contact:**

*Atomic level smoothness*




**5. Oxide CMP:**

*Precise stop on iso/dense metal*

**4. Stack Etch & Encapsulation**

*No metal re-dep on edge*

*Minimize damage/intermixing*

*Low Temp Encapsulation*

**Critical: Controllability of uniformity, stoichiometry, structure, interfaces & damage free patterning**

**MTJ CD of 20-50nm and dense pitch is desired**

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# Key Process Equipment

Bottom Contact → MTJ Stack Dep → Pillar Patterning → MTJ Etch & Encapsulation → Oxide Fill & CMP

LK Prime™ (CMP)

Endura™ M/C PVD

Centura™ (HM Etch)

VeritySEM™ (Metrology)

Centura™ Etch, Nitride

Producer™ (Dielectric)

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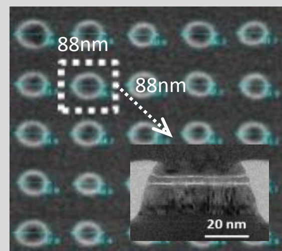
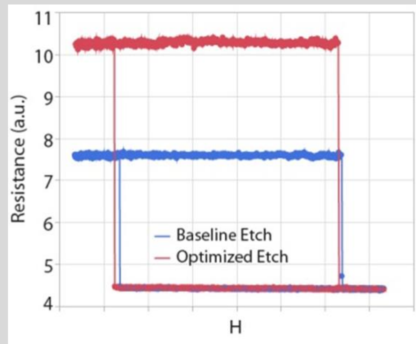
# STT MRAM for “SRAM” Applications

## Etching of Dense MTJ Arrays

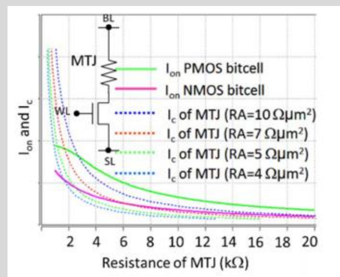


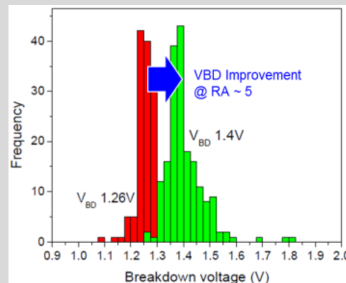

Cell size ~ 0.008um2




*AMAT, IEDM (2017)*

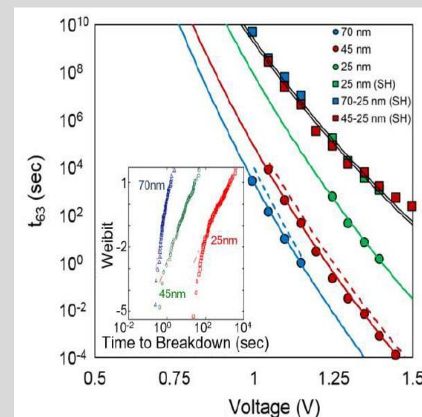
## Low RA MTJ stack




*QCOM+AMAT, IEDM 2017)*

## Distribution & Reliability at smaller critical dimensions




*QCOM+AMAT, TED vol 64 9(2017)*

**Materials & Etch process improvements key to enabling SRAM replacement**

# Summary

- Applied Materials focusing on High Volume Manufacturing Equipment that enables STT MRAM device performance, yield and cost. Multiple tools shipped.
- Initial adoption is being seen for STT MRAM as eFlash replacement, where device specs have been demonstrated
- Stack deposition and etch performance improving to a point that we expect to see STT MRAM expanding into some SRAM replacement in near future