



Efficient Characterization and Testing of MRAM Devices

Parametric Testing for In-Line Monitoring



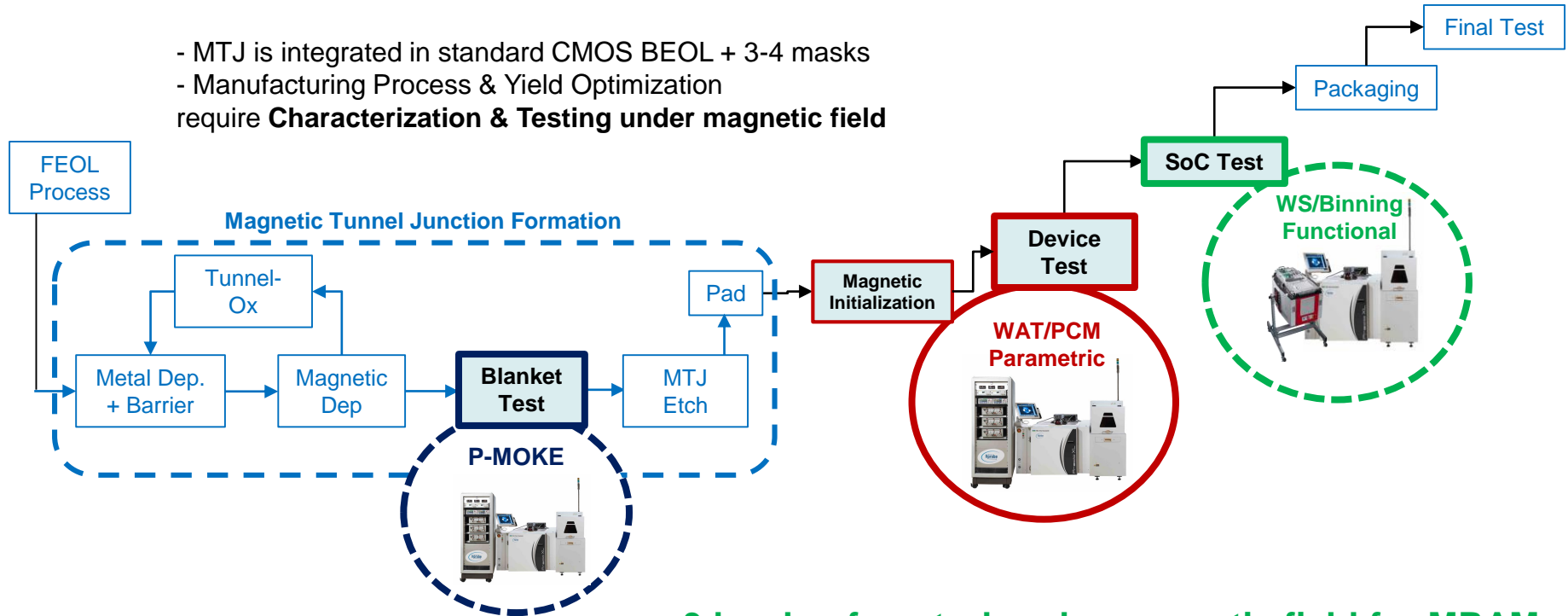
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Antoine CHAVENT, Isabelle JOUMARD

MRAM Control & Monitoring Flow

- MTJ is integrated in standard CMOS BEOL + 3-4 masks
- Manufacturing Process & Yield Optimization require **Characterization & Testing under magnetic field**

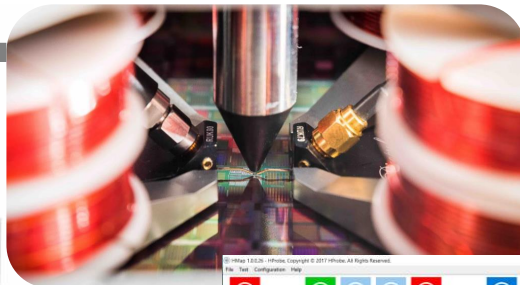


3 levels of control under magnetic field for MRAM

Test Equipment for Device Parametric Testing

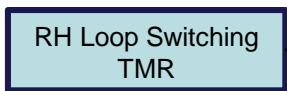
We developed a dedicated MTJ Electrical/Magnetic Parametric ATE

- Wafer Level testing under magnetic field
- Compatible with R&D and production requirements

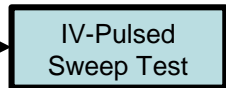
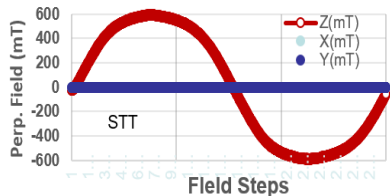


Ultra-Fast MRAM Parametric Test Program

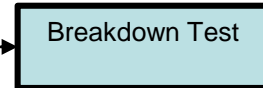
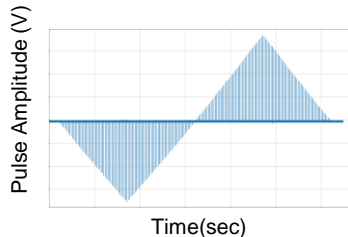
Proposed Efficient test Program at device level on MTJ test structures



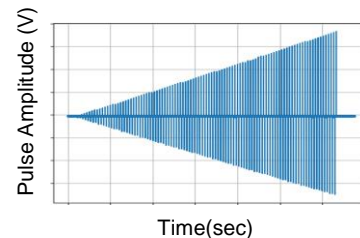
Field Switching Probability
Stability Factor , Anisotropic Field



Current Switching Probability



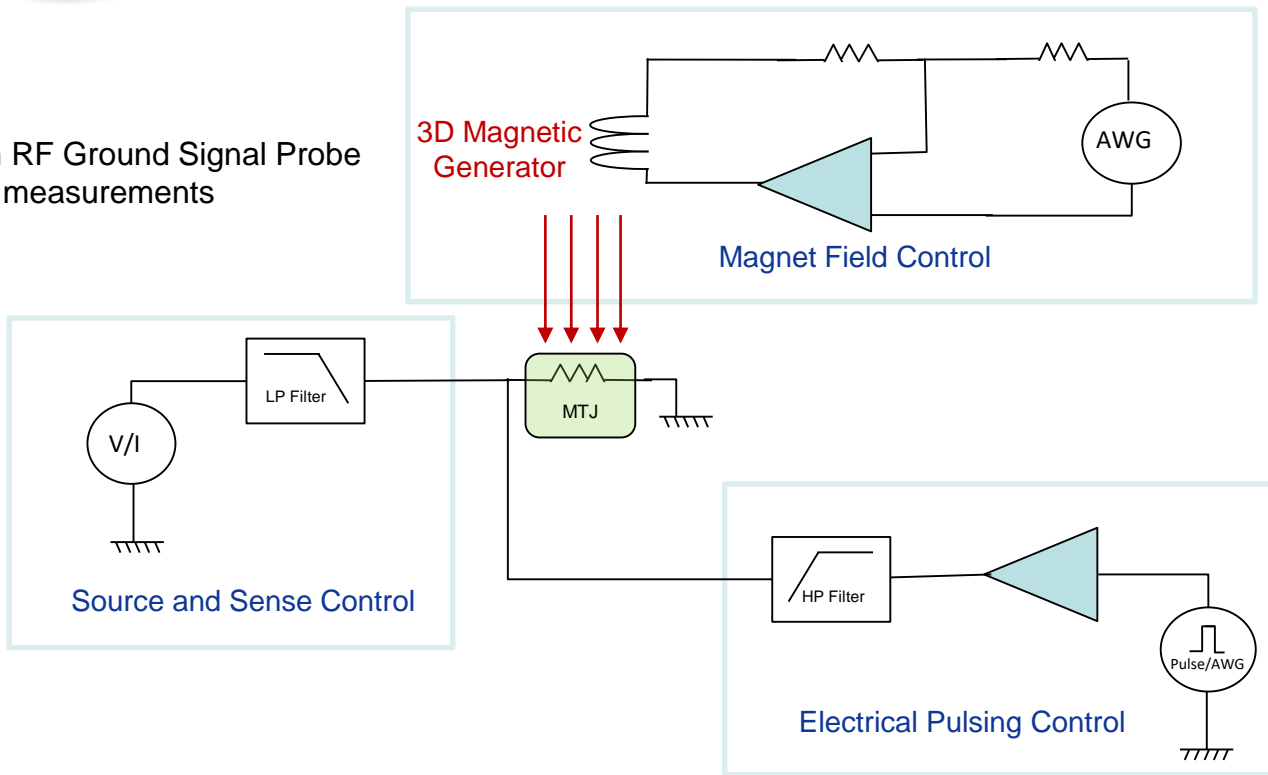
MTJ Breakdown voltage



Test setup for MTJ Device Parametric

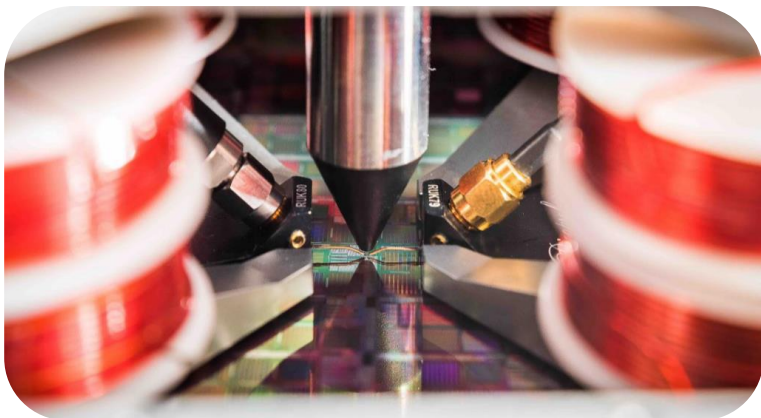
Test Setup

The probing is done with RF Ground Signal Probe
By 2 and 4 –point probe measurements

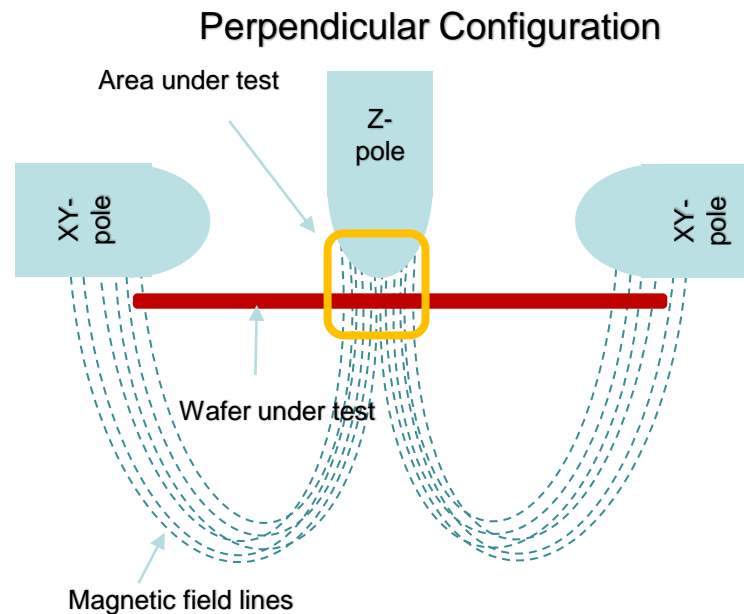


Test Protocols – Magnetic Field Sweep

3D Magnetic Generator TM

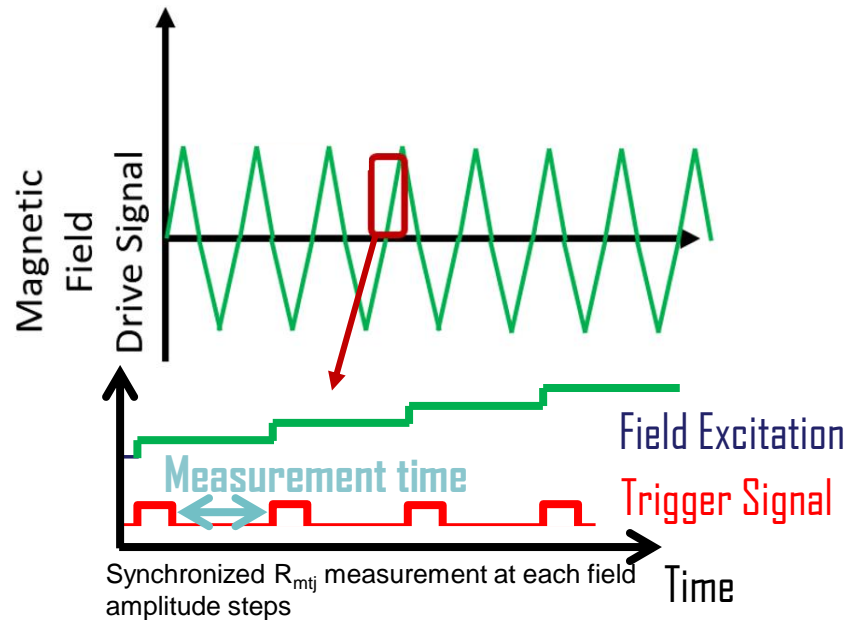
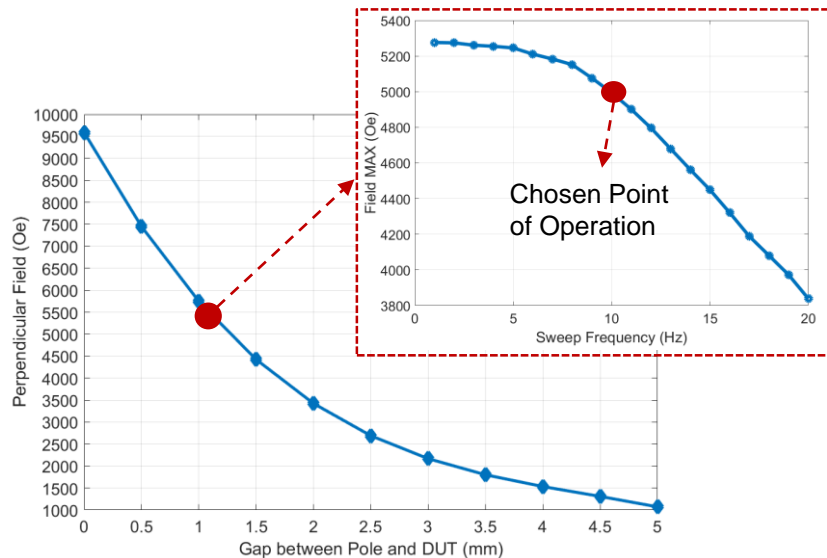


Operates in 1D, 2D, 3D with each spatial axis controlled independently



Test Protocols – Magnetic Field Sweep

Demonstration of performant field sweeping capability + R_{mij} synchronized measurement at high field



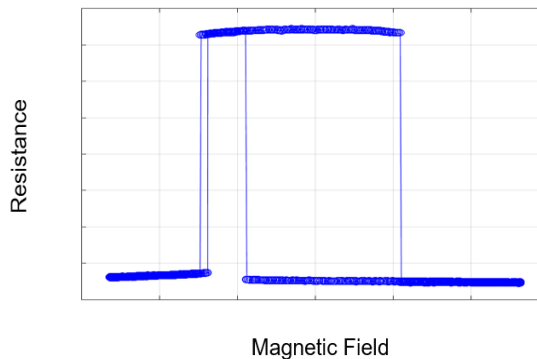
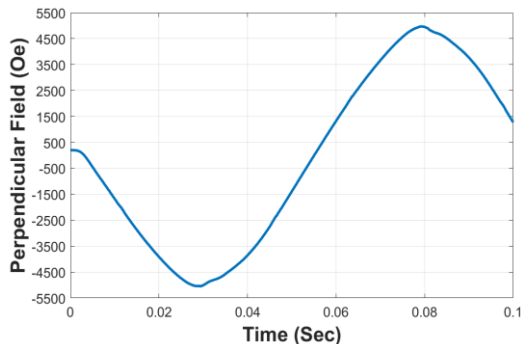


Test Protocols – Magnetic Field Sweep

Hysteresis test at sweep frequency of 10Hz / 10kSamples/sec

1 RH cycle sweep w/ 1,000 field steps in 100 milliseconds

10 RH Cycles w/ 1,000 field steps in 1 second

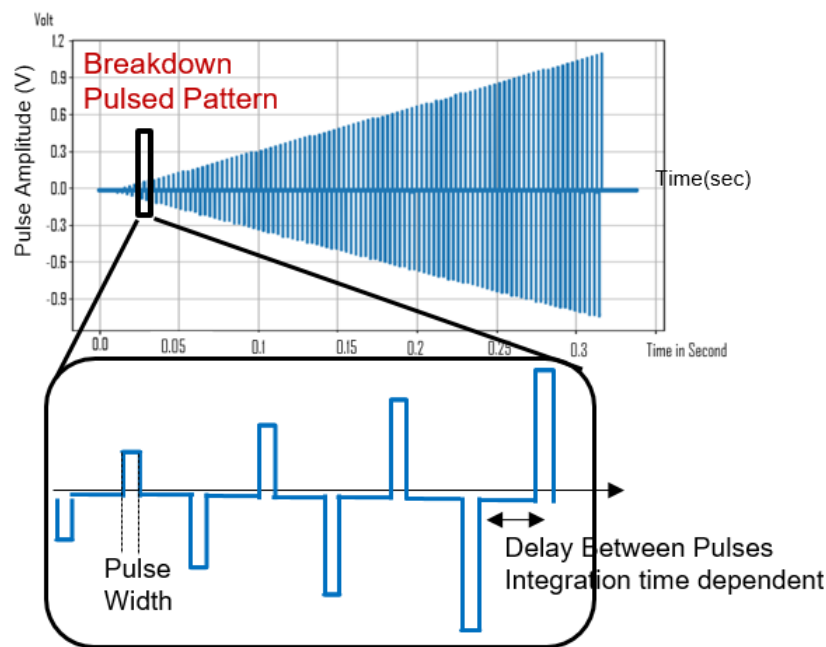
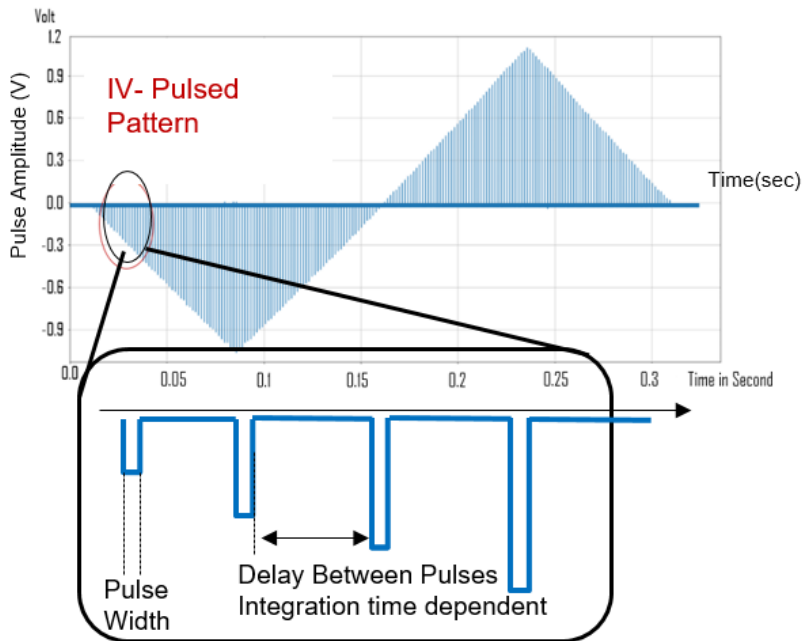


$$\text{Testing Time (sec)} = (1/Sf) \times Nbc$$

Sf = Magnetic field sweep frequency
Nbc = Number of magnetic sweep Cycles

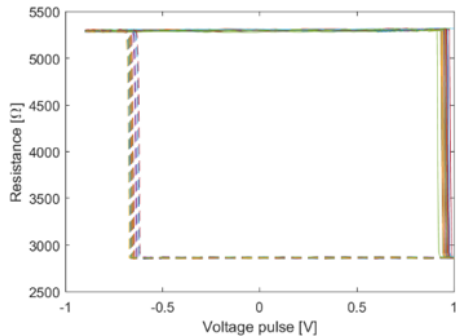
Test Protocols – Electrical Pulsed Sweep

- Current pulsing switching test with accurate resistance measurement
- Rmtj measurements synchronized with pulse sweep steps



Test Protocols – Electrical Pulsed Sweep

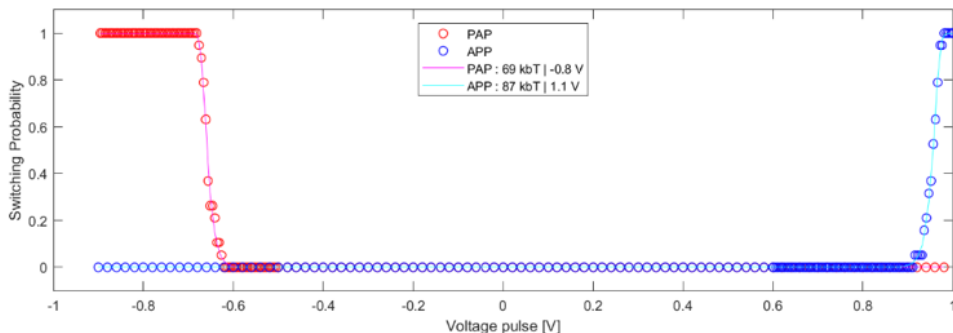
Pulsed Switching Test



$$\text{Testing Time (sec)} = (\text{Tin} + \text{Pw} + \text{Td}) \times \text{Nbc}$$

- Tin = Rmtj Integration Time
- Pw = Pulse Width
- Td = Delay between pulse and Rmtj measurement
- Nbc = Number of sweep cycles

Pulsed Switching Probability



- Leads to 300msec/cycle for +100sweep steps**
- Pw = 10nsec**
- Td = 1msec**
- Tin = 0.5msec**



Summary

- Magnetic ATE for parametric testing of MRAM MTJ
- Fast magnetic sweeping capability synchronized with acquisition
- Competitive Testing Time ~1sec for magnetic sweep and current pulsing test