

New PVD Systems for Advanced Memory Applications

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Challenges to Chip Performance, Power and Cost

IoT and Industry 4.0 Creating an Explosion of Data



Dramatic Slowdown of Moore's Law Scaling



SOURCE: Applied Materials model based on forecasts published by Cisco, Intel, Western Digital

Hennessy and David Patterson, December 2017

Current Computing Architectures are Not Sustainable



AI – Big Data Driving a Renaissance of Hardware Development and Investment

	INITIAL DEPLOYMENT	CLOUD	EDGE	
Accelerators GPU, TPU, ASICS, FPGAs	Now	\checkmark	Autos	
Near Memory DDR, SRAM, HBM, NAND, SCM	Now to 2 years	\checkmark	\checkmark	
New Memory MRAM, ReRAM, PCRAM, FeRAM	Now to 5 years	\checkmark \leftarrow		
In-Memory Compute Analog, ReRAM, PCRAM	2 to 5 years	\checkmark \leftarrow	✓	
Novel HPC Quantum, Synaptic	5 to 10 years	✓	\rightarrow \checkmark	





MRAM Magnetic Random Access Memory

PCRAM and ReRAM *Phase Change RAM and Resistive RAM*



New Memory Technologies Improve Computing Efficiency



New Memories Boost Computing Efficiency at Both Edge and Cloud



New Memory Accelerates PPAC Gains





Deposition Challenges of MRAM Manufacturing



- Ultra-high purity environment for pristine film and interface
- Complex cell stack
 - Complex stack: 10+ materials with 30+ layers
 - Ultrathin film in the range of a few angstroms

High quality tunnel barrier

- Critical for high on/off signal and endurance
- Special treatments
 - ► Surface preparation, thermal treatment for optimal performance
- Repeatability in HVM



Solution: Endura[®] Clover[™] MRAM PVD System



- Ultra-high purity environment for pristine film and interface
 → UHV platform (low E-9)
- Complex cell stack → Multi-cathode Clover PVD chamber
 - Complex stack: 10+ materials with 30+ layers
 - Ultrathin film in the range of a few angstroms
- High quality tunnel barrier → Clover PVD RF-MgO chamber
 - Critical for high on/off signal and endurance
- Special treatments → Cooling/Anneal chambers
 - ► Surface preparation, thermal treatment for optimal performance
- Repeatability in HVM → OBM real-time monitoring



30+ Layers, 10+ Materials in Single Integrated System



Most Sophisticated System Ever Created by Applied Materials



Clover PVD Designed for Complex MRAM Deposition Up to Five Materials in One Chamber



Sub-Angstrom Uniformity Sharp Atomic Interface No Cross-Contamination

Unique Addition to Applied's PVD Leadership



Clover PVD MgO Delivers Superior MRAM Results



Low Power and High Endurance are Ideal for Edge Devices





Deposition Challenges of PCRAM& ReRAM Manufacturing



- Safe handling of sensitive material deposition and preventive maintenance
- Composite sputtering
 - Compositional uniformity within wafer and within kit life
- Low defectivity
- Damage-free integrated stack
 - Minimal plasma damage and intermixing of materials
- Repeatability in HVM (repeatability and cost)



Solution: Endura[®] Impulse[™] PVD System



- Safe handling of sensitive material deposition and preventive maintenance → Effective passivation
- Composite sputtering → Impulse PVD
 - Compositional uniformity within wafer and within kit life
- Low defectivity → Large portfolio of coating technologies
- Damage-free integrated stack → Magnet turning
 - Minimal plasma damage and intermixing of materials
- Repeatability in HVM → OBM real-time monitoring



On-Board Metrology Enables Precise Thickness Control



Product Excursion Detection Comparison



Excursion Starting Point

- Enables real-time process monitoring and control
- Measures delicate films under vacuum
- Achieves faster ramps, better yields for production

Industry's Only On-Board Metrology with 1/100th of a Nanometer Resolution



Summary

- Explosive growth in data just as Moore's Law is slowing down
- New-memories improve computing efficiency in the Edge and the Cloud
- Manufacturing challenges with complex materials have previously limited new memory adoption
- Innovative PVD technologies enable high-volume manufacturing with higher performance films
- On-board metrology improving learning rates and yield by reliably measuring films that can not be otherwise be measured
- High-volume manufacturing systems are shipping today for MRAM, PCRAM and ReRAM







