TEL PVD Technology for the Spintronics Devices

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This talk will give you an overview of Tokyo Electron Ltd.'s PVD technology for the spintronics technology devices such as MgO tunnel barrier based MTJ process. It will introduce general concept of MTJ PVD module technology to fabricate sophisticated MTJ multilayer thin film. And the talk will share the latest performance of p-MTJ for STT-MRAM, ultra-low RA in-plane MTJ for HDD read sensor and lastly high RA TMR MTJ for the magnetic sensor application. And will briefly touch about the future roadmap for the mass production up to SOT MRAM

***Index Terms*—PVD, Magnetic Tunnel Junction, STT-MRAM, Tunneling Magneto Resistance, SOT-MRAM**

I. Introduction

The field of spintronics is rapidly evolving, ushering in a new era of memory technologies such as STT-MRAM**,** HDD**,** and TMR magnetic sensors**.** These innovative devices are poised to replace conventional solutions due to their superior performance, including enhanced speed**,** accuracy, reduced power consumption, and improved thermal stability.

However, the widespread adoption of STT-MRAM, HDD, and TMR devices hinges on overcoming key manufacturing hurdles, particularly in physical vapor deposition (PVD)**.** This talk will delve into the crucial role of TEL PVD tools in fabricating these advanced spintronic devices, highlighting how TEL's technology enables the precise material properties essential for their optimal function. Figure 1 shows how the MgO MTJ's RA decreasing by the STT-MRAM node size as well as the HDD AD (Areal Density) increases.

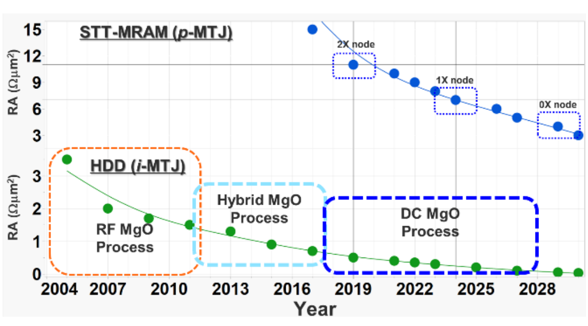

Fig. 1. RA requirement for the STT-MRAM node and HDD AD

II. p-MTJ for STT-MRAM Application

The landscape of embedded memory is undergoing a significant transformation, driven by the advent of perpendicularly magnetized CoFeB (p-MTJ) with an MgO tunnel barrier. This innovative technology, pioneered by IBM and Tohoku University, is propelling 22nm embedded STT-MRAM devices to the forefront, positioning them as a compelling replacement for eFlash in a wide array of microcontroller (MCU) and Internet of Things (IoT) applications. This shift is particularly impactful within 300 mm wafer-based semiconductor foundries.

The fabrication of these advanced p-MTJ devices primarily leverages multi-chamber Physical Vapor Deposition (PVD) technology. A critical aspect of this process is the highly specialized MgO growing technique, where TEL have developed industry-proven modules and technologies, ensuring the consistent and reliable production of these high-performance memory components.

This convergence of materials innovation and advanced manufacturing processes is enabling the widespread adoption of STT-MRAM, promising enhanced performance, lower power consumption, and improved scalability for next-generation embedded systems in 1x node and up to the SOT-MRAM era. As a result, TEL MTJ PVD is already being used far beyond the SOT-MRAM of the magnetic memory R&D area.

III. Ultra-low RA i-MTJ for Hard Disk Drive Read Sensor Application

The demand for high areal density per cost in the Hard Disk Drive (HDD) industry is experiencing a significant resurgence, driven by the growth of edge computing and nearline storage solutions. This renewed demand has accelerated the reduction of the resistance-area product (RA) in magnetic read sensors, specifically the in-plane magnetic tunnel junction (i-MTJ), at a pace far exceeding what was seen 20 years ago when the first MgO tunnel barrier i-MTJs were introduced.

The evolution of read sensor design and integration has moved beyond basic configurations, making the process repeatability and cost of ownership of PVD (Physical Vapor Deposition) tools for ultra-low RA i-MTJs critical business considerations. In response to these challenges, TEL has achieved a world-first record in ultra-low RA with high Tunnel Magnetoresistance (TMR) using its 8-inch MTJ PVD tool, which is now in mass production for HDD read sensor processes. This continuous improvement process (CIP) in existing modules enables areal densities capable of reaching 2 Tb/in^2 with technologies like Heat-Assisted Magnetic Recording (HAMR) and beyond, pushing the boundaries of HDD technology.

IV. TMR MAGNETIC SENSOR APPLICATION

The rapid advancements in visual intelligence (VI), electric vehicles (EVs), and autonomous control (spanning robotics, transportation, logistics, and delivery) have created a surprising surge in demand for high-performance, low-power system-on-chip (SoC) integrated Tunnel Magnetoresistance (TMR) sensors. Similar to other Magnetic Tunnel Junction (MTJ) device industries, the TMR magnetic sensor sector faces the crucial challenge of cost reduction and achieving a favorable Cost of Ownership (CoO). To expand the market and its roadmap, increasing wafer size and optimizing tool utilization are essential, alongside continuous technological assessment.
V.Interestingly, despite this push, the TMR magnetic sensor PVD (Physical Vapor Deposition) market is still in its early stages, with a less aggressive Compound Annual Growth Rate (CAGR). This means there's currently no immediate urgency for high-throughput PVD solutions with excellent CoO, making it a space to watch for long-term developments.

Given TEL MTJ PVD's established success in both STT-MRAM semiconductor foundries and the production of ultra-low RA (resistance-area product) HDD (Hard Disk Drive) read sensors with high TMR ratios, we are particularly interested in this application. Our goal is to provide omparable or superior technology and manufacturability for the long term, all while maintaining a focus on superior Cost of Ownership (CoO) and Cost of Consumables (CoC).

Lastly figure 2 is showing the overall TEL BKM p/i-MTJ performance of RA vs. TMR which can cover wide capability by unique TEL MgO and PVD technology

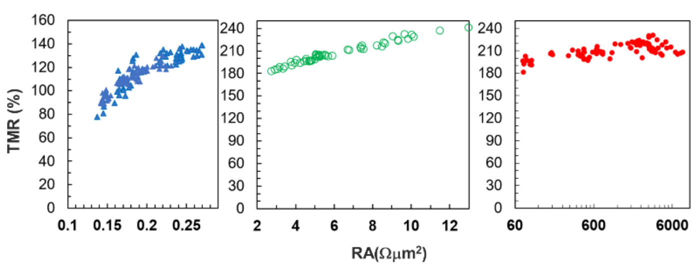

Fig. 2. TEL BKM i/p-MTJ performance for HDD, STT-MRAM and TMR magnetic sensor applications

Conclusion

After more than a decade of working closely with customers in spintronics semiconductor foundries and Hard Disk Drive (HDD) mass production, we've identified the critical requirements for contributing to cutting-edge technology and robust products. We dedicate our daily efforts to these key areas:

High-Quality MTJ Deposition

It's essential to achieve consistent Resistance-Area (RA) product, a high Tunnel Magnetoresistance (TMR) ratio, and optimal magnetic properties. This consistency must be maintained from the initial R&D phase all the way through to high-volume production.

Flexibility in MTJ Stacks

Our systems need the flexibility to deposit material stacks for both in-plane and perpendicular Magnetic Tunnel Junctions (MTJs). This adaptability, along with the ability to handle varying RA values, is crucial for accommodating future technological advancements in the field.

High Throughput and Consistency

Finally, enabling high-volume manufacturing demands both high throughput and exceptional consistency. This means ensuring uniform deposition across wafers and maintaining stable tool performance over extended periods.

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