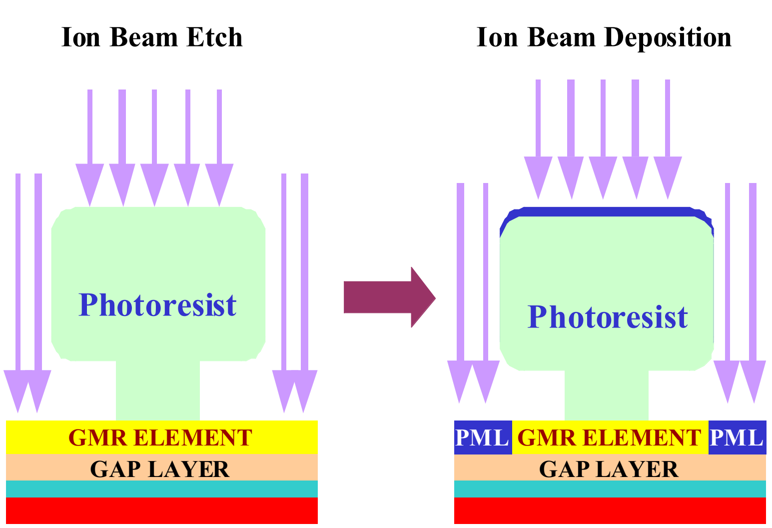
Advanced Sensor Fabrication Using Integrated Ion Beam Etch and Ion Beam Deposition Processes

Jhon F. Londoño, Kurt E. Williams,
Adrian J. Devasahayam

Veeco Instruments Inc.
Plainview, New York
U.S.A

Figure 1
Schematic of an Abutted Junction Device fabrication process.



Introduction

Digital data storage and memory (MRAM) devices based on Giant Magneto-Resistant (GMR) effect elements are pushing the envelope of fabrication techniques used in their manufacture.

Fabrication of these advanced sensors for magnetic data storage applications involves optimization of device definition processes. Figure 1 is a schematic illustration of an Abutted Junction Device, representing a manifestation of an advanced sensor requiring optimal control of Ion Beam Etch (IBE) and Ion Beam Deposition (IBD) techniques.

Figure 2
Process flow for the formation of the abutted junction.

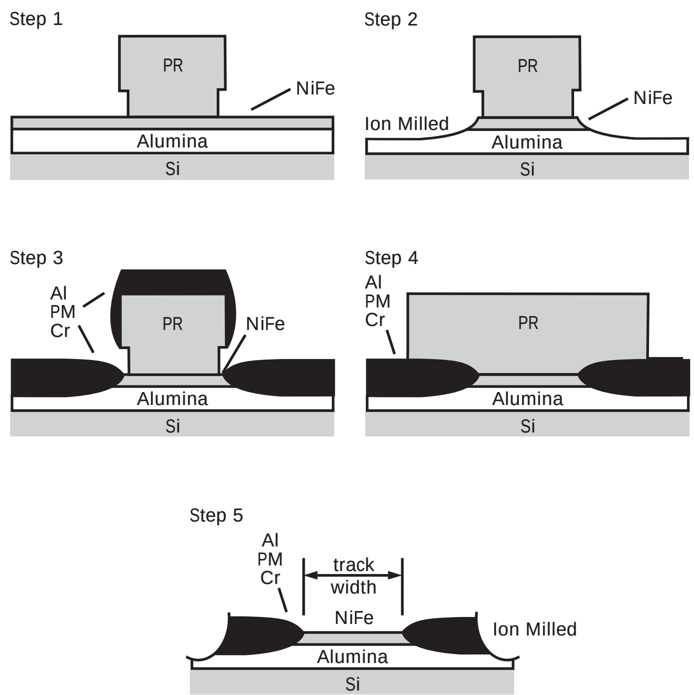


Figure 3
Schematic of a typical spin valve GMR structure found in advanced read sensor devices

Figure 2 illustrates in further detail the process steps involved in the formation of such a device.

Paramount to the fabrication process is precise control over the etch technique used. The following factors are critical in this endeavor:

- Controllable and repeatable etch rates for a wide range of metallic, magnetic and dielectric materials commonly found in GMR elements such as Ta, NiFe, Cu, Co, PtMn, Al_2O_3, Ru, FeMn, IrMn and PdPtMn.
- Optimal etch uniformities over large wafer areas, up to 150 mm diameter.
- Controlled and optimized ability to terminate the etch process. Secondary Ion Mass Spectrometry (SIMS) endpoint technique is preferred for device wafers with ultra-small exposed areas (<5%), and high mass material layers (such as Tantalum) that are unsuitable for standard optical endpoint techniques.

Figure 3 schematically depicts a typical spin valve GMR structure commonly found in advanced read sensor devices. As illustrated, the angstrom level dimensions of the layers are such that maximum control of the etch technique used to define the sensor is required. In principle what is required is a multi-etch rate, low energy process. This ensures that optimal control of shallow etches is achieved. For example, this allows etching of non-crtitical layers at high rates while critical layers are etched at low rates.

Multi-etch Rate, Low Energy Ion Beam Etch Processes

Ion Beam Etch Processes, using a Veeco Instruments combination IBE and IBD cluster tool, have been developed for these advanced sensor etch and deposition applications. Ultimate vacuum base pressures in the low 10^{-7} Torr range used for this etch development work. Optimal high vacuum base pressure is required to ensure etch rate repeatability and to minimize charge exchange events. The former is critical, as many of the active layers in GMR devices (such as the NiFe magnetic layers, and the Ta capping layer) are easily susceptible to oxidation. The latter is important to avoid any interactions between non-process related gaseous particulates in the chamber and the highly collimated ion beams extracted from a self-contained, Radio Frequency Inductively Coupled Plasma (RF-ICP) source.

Using a proprietary Low Power Three Grid Ion Optics System, multi etch rate processes with beam energies as low as 175 eV and up to 475 eV have been successfully and repeatably demonstrated. Table 1 lists representative etch rates achievable with these processes (materials found in GMR devices as well as other metals of general interest are listed).

Table 1

Material etch rates using low power ion beam etch processes.

Extensive etch rate and uniformity tests were conducted to optimize these low power ion beam etch processes. Representative results are outlined in table 2 for a series of tests conducted on a tri-layer film stack. Additionally, similar tests have been conducted and reproduced repeatably for all materials listed in table 1.

Material	Etch Rate Range (Angstroms/minute)
Ta	10 _ 165
Cu	15 _ 285
NiFe	20 _ 150
PtMn	25 _ 140
Al_2O_3	4 _ 32
Au	95 _ 500
Cr	25 _ 115
SiO_2	5 _ 125

Etch Uniformity and Relative Etch Depth for a Tri-Layer Film Stack

Ta(100)/Cu(1000)/Ta(100)
Layer thickness in Angstroms
Relative Cu etch rate of 40 Angstroms/minute for 5 wafers processed consecutively using a low power etch process

Wafer #	Uniformity % (130 mm Diameter)	Relative Etch Depth (130 mm)
1	3.1	0.5114
2	2.8	0.5162
3	2.1	0.5157
4	3.4	0.4948
5	2.2	0.4910
Average	2.7	0.5058
High	3.4	0.5162
Low	2.1	0.4910
Wafer-To-Wafer Repeatability (WTW)		2.5%

Table 2

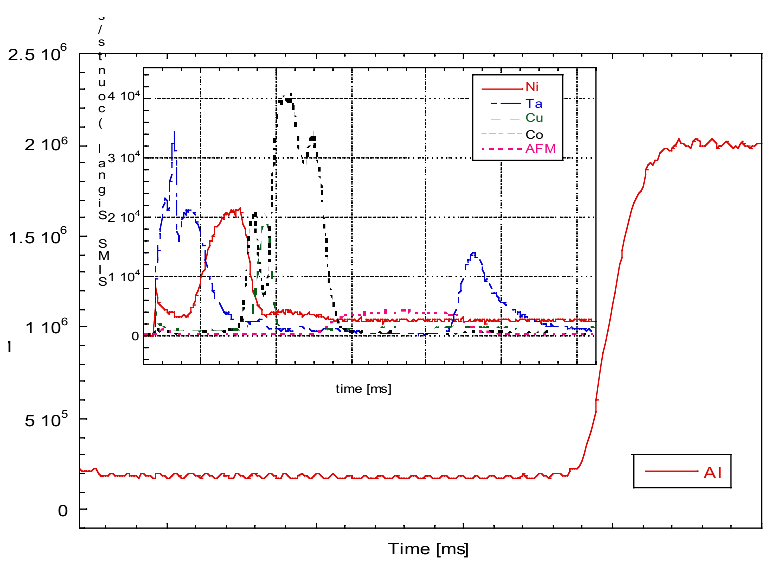
Etch uniformity for 5 wafers processed consecutively using low power process.

SIMS Endpoint Control

As illustrated in Figure 3 (see page 2), the dimensional scale of the individual layers in these advanced sensors can be as low as several multilayers. This necessitates the use of a low power etch technique to sculpt the device as the ion milling proceeds, and critical and/or active layers are exposed. By extension then, and when combined with ion beam milling in the ultra low etch rate regime, the process requires a highly sensitive endpoint technique to terminate the etching process. This is required to ensure minimal over-etching into the active layers of the device, and thereby avoiding deleterious sensor performance.

Figure 4

SIMS plot for a Spin Valve structure etched via a low power process; Stack etched through to the Alumina gap layer of an abutted junction device .

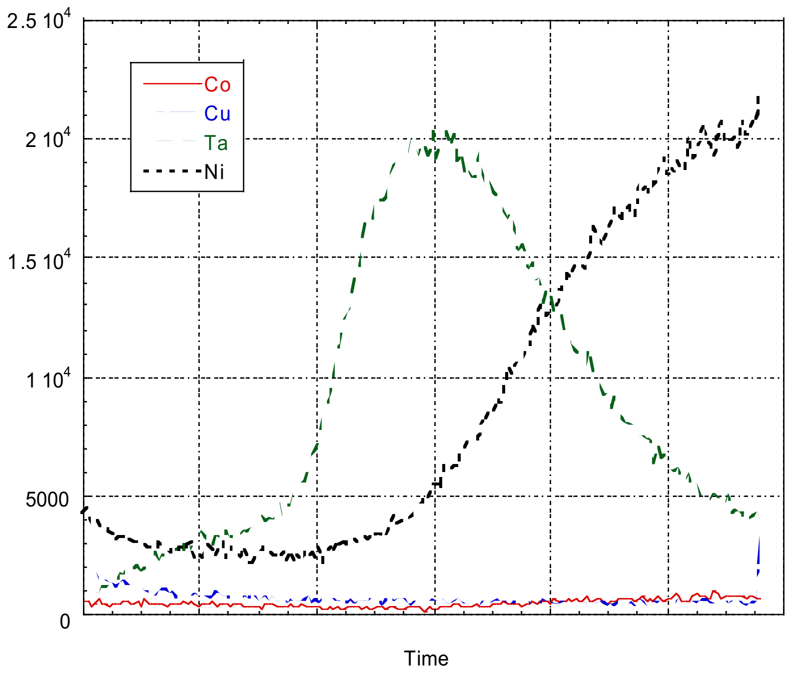


As a result of the low ion energies involved, the use of high mass materials typically found in GMR elements, and the minimal exposed area of pre-etched device wafers (typically less than 3% open area over a 150mm diameter wafer), SIMS provides an optimal, highly sensitive, and reproducible endpoint scheme suitable for these low power etch processes. In the range of energies used, most materials of interest do not fluoresce readily, thereby making optical endpoint schemes unsuitable for this endeavor. Developed and refined concurrently with the etch processes described previously, we have demonstrated the use of SIMS endpoint technique.

Figure 4 illustrates the relative SIMS signal intensities from the various layers of a spin valve structure. As depicted in the figure, the signal level is quite high for all materials involved, and in particular for Aluminum secondary ions in the Al_2O_3 gap layer. This is important as typically read sensing elements, such as the abutted junction hard bias device, requires etching through the entire multilayer stack and stopping at the Alumina gap layer.

The precision of the etch and SIMS technique is further illustrated in Figure 5. Shown in that figure are the secondary ion intensities of a similar spin valve structure of an exchange tab device. This type of device requires ion milling to, and terminating the etch process at, the midpoint of the NiFe layer in the spin valve stack.

Figure 4
SIMS plot for a Spin Valve structure etched via a low power process; Stack etched to the midpoint of NiFe layer in an *exchange tab* device.



Summary

Low power ion beam etch processes for advanced sensor and device fabrication have been outlined. Techniques developed allow for a multi-etch rate, low energy ion milling process to define sensors/devices uniformly and repeatably in a wide range of material etch rates. A SIMS endpoint technique developed concurrently has been successfully implemented, allowing for optimal and precise control when etching critical device layers. Combined with the IBD process for post-etch deposition of Permanent Magnet Layers (PML), achieved in a cluster IBE-IBD arrangement with a high vacuum wafer handling system, yields sensor devices with superior performance and quality.

About Veeco

Veeco Instruments, Inc. is a worldwide leader in process equipment and metrology tools for the optical telecommunications, data storage, semiconductor and research markets.

Veeco's Process Equipment Group provides the etch and deposition technology that data storage manufacturers require to increase areal density. Veeco's combination of ion beam etch, ion beam deposition and physical vapor deposition makes us the undisputued leader in current and next generation GMR (giant magneto-resistive) TFMH solutions for the data storage industry.

Veeco is the leading supplier of ion beam deposition equipment to the fast-growing dense wavelength division multiplexing (DWDM) filter market—a crucial part of the world's telecommunications and data infrastructure. Veeco's broad line of leading edge technology allows customers to improve time-to-market of next generation products. Veeco is driving forward to narrower bandwidth filters for higher overall capacity.

Veeco's Metrology Group is the world leader in 3D surface metrology—advanced measurement tools that allow data storage and semiconductor manufacturers, and researchers, to see featurers in their process with high resolution. Our broad array of technologies and range of products provide industry leaders with high resolution measurement and yield-improving tools.

In data storage, optical telecommunications and semiconductors, Veeco helps our customers improve their critical time-to-market for next generation products. We provide total solutions for advanced etch and deposition processes, as well as improving yield and process control in both manufacturing and research environments.

Veeco's manufacturing and engineering facilities are located in New York, California, Colorado, Arizona and Minnesota. Global sales and service offices are located throughout the United States, Europe, Japan and Asia Pacific.

Veeco
Process Equipment

Veeco Instruments Inc.
Terminal Drive
Plainview, NY 11803
Find out more at www.veeco.com
or call us at 1.888.24.VEECO

Printed in U.S.A. Etch Apps 3 – 12/00