

Thin-film magnetic device characterization in a production environment

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Abstract

There are many challenges in the characterization of thin film magnetic devices such as sensor, galvanic isolators and magnetic random access memory (MRAM). Many of these challenges are due to the unique operation and applications for which these sensors are used. Characterizing magnetic behavior as well as electrical response over a range of environments involves specialized equipment which is not always commercially available. This tutorial will be aimed at introducing the different instrumentation and test methodologies used in bringing a thin film magnetic device from the research and development stages and into full production. Early stage work is often performed to understand the basic properties of the magnetic materials. Here, different methods of Magnetometry are used to evaluate the magnetic properties while four point electrical probing in an externally applied magnetic field is used to look at the magnetoresistance. Key parameters that are evaluated here include sheet resistance, magnetization, pinning field strength and magnetization switching behavior. Oftentimes these parameters are affected by more than just the material deposited. Thus, characterization of the substrate, namely film stress and roughness is essential to ensure production readiness. When the magnetic films are patterned into devices the magnetic properties often change significantly due to the introduction of additional magnetic interactions (e.g. magnetic dipole fields) as well as from inhomogeneities due to lithographic processing. This requires additional testing to characterize the patterned devices and can be a costly and high risk first look into the actual device performance due to the lithography steps. Thus, some form of analytical or numerical predictive modeling software can be useful, such as NIST's Object Oriented Micromagnetic Framework (OOMMF) code, to guide the device and materials design. Most of the time patterned devices are probed using electrical contacts, similar to other semiconductor technologies. The one main difference is the application of a magnetic field is required to exercise the device. For most applications this can readily be done using commercially available electromagnets with pole pieces that focus the field at the device. However, problems can emerge when large magnetic fields (i.e. greater than 1 kGauss) are required due to difficulty in cooling the magnet as well as inductive forces on the probes potentially being great enough to cause mechanical shifting. Once a design has been obtained and production begins, the testing process becomes concerned with ensuring significant device yield within determined specifications. It is important to have high testing throughput to provide for statistical analysis at different points in the production process. These key points occur after each of the following steps: film deposition and annealing, device patterning, post-processing of additional layers (magnetic shielding, flux concentration, conducting straps and passivation layers), and packaging. All but the final step can be performed at the wafer level with post packaging testing done by custom equipment to ensure only parts that meet specifications are placed into inventory.