Advanced Magnetic Metrology Instrumentation

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Abstract

The extraordinary progress in magnetic peripheral storage systems has been fueled by the advancements in heads (MR, GMR, spin valves) and in very high coercivity, low remanence-thickness product (M_rt) media. These advancements are imposing new performance requirements on the magnetometers (VSMs) used to characterize these materials. At the same time, they have introduced a new paradigm for in-process (non-destructive, robotic) magnetic metrology tools to assure the stringent product uniformity requirements. In this paper, we discuss the recent advancements in magnetometry for characterizing state-of-the-art media and heads, as well as other magnetic materials.

Advancements in Vibrating Sample Magnetometers (VSMs)

The VSM is the basic instrument for characterizing magnetic materials as a function of magnetic field and temperature. Its simplicity, versatility and speed have made it the instrument of choice for both laboratory and production environments, ever since its invention some forty years ago. Recent advancements in magnetic materials, particularly for the data storage industry, have imposed new demands on the performance of VSM systems. They pertain primarily to the following areas:

- Higher sensitivity, required to measure the low M_rt of thin magnetic films used for storage media and heads.
- Higher field, required to saturate the higher coercivity and higher anisotropy materials encountered in advanced magnetic recording and magneto-optic storage media and in permanent magnet materials.
- Higher stability, required to measure magnetization decay in storage media.
- Extended functionality, to measure temperature effects, vector magnetization, torque characteristics, and magnetoresistive (MR) properties.
- Advanced software, required for faster measurements, automatic extraction of all the pertinent parameters, and manipulation and transport of data files.

Getting an accurate, repeatable measurement from your VSM requires the selection of an instrument with the optimal combination of performance attributes, as well as diligently applying good techniques and procedures in using the system.

Checklist for Selecting a VSM

Sensitivity, Stability, Measurement Speed:
Does the system have:

- An RMS noise level better than 5 μemu at 1 average, 100 ms time constant, even if the oven is installed
- Sufficient sensitivity to allow for full magnetic characterization even when very small samples are available or preferred
- Signal stability of better than 0.1% per hour so that useful time decay studies can be done
- Sensitivity which is sufficient to allow for fast measurements without the necessity of long time constants or long signal averaging

Field:
Does the system have:

- A maximum field that is large enough for present and future requirements (4 x H_c for scalar measurements, more for anisotropy studies)
- A homogeneous field over the entire sample area
- Direct field control rather than indirect field control through computer control of the magnet current
- Stepped Field Control rather than Swept Field control
- A field resolution of at least 0.01 Oe
- A resistive magnet, which saves thousands of dollars per year compared to a liquid helium cooled magnet

Background signal:

- The background signal must be sufficiently linear and reproducible so that it can be subtracted adequately from the measured signal, leaving only the sample signal.

Vector:

- The length and angle of the magnetization vector (relative to the sample) of a sample in remanence must stay constant (within 1.5% and 1.5 degrees) when the sample is rotated in zero field.

Ease of use:

- Ability to replace a sample within 1minute
- Ability to change system configuration from room temperature to variable low or high temperature in less than 1 minute
- Ability to control sample temperature from 100 K to 1000 K continuously without a change in the VSM hardware

- Ability to allow less experienced operators to perform measurements without damage to the equipment and obtaining high performance results

Software:
Does the software:

- support all measurements required for your application
- allow you to create your own measurements without the need of programming
- correctly calculate all parameters you want to measure
- store the data in an ASCII format for portability
- allow a System Administrator to create System User accounts with different levels of access to software functions
- allow for the creation of recipes that can be used by operators to repeat measurements in a one-click fashion
- allow for the setup of long sequences of experiments for complete analysis of samples overnight
- maintain experiment test parameters with experiment data for future recall
- automatically export graphs to word processors
- automatically export graph data to MS Excel™
- automatically export parameter tables to MS Excel™
- allow you to follow your measurements on your network using your standard web browser (such as Netscape™ or MS Explorer™)
- print professional, ready-to-use graphs and tables
- include an indexed online help system

In-Process Magnetic Metrology

The magnetic media and heads used in the rapidly advancing hard disk storage systems must satisfy stringent uniformity requirements. This can only be achieved by in-process mapping of the magnetic properties of these components through the use of fast, robotic, non-destructive magnetic metrology tools. Thus, defective media and heads can be detected early in the production process to eliminate the cost of subsequent processing and certification. Furthermore, the product life cycles are becoming shorter, requiring that sputter lines be re-tuned and optimized to new product specifications at more frequent intervals. This can be greatly facilitated by the rapid mapping of the magnetic properties of disks, as well as the magnetic and magnetoresistive properties of head wafers.

Disk Mapping System

These systems usually employ large write/read transducers to write and read multi-sector and multi-radius data on both sides of a disk. The magnetic properties at each point are obtained by transfer calibration with a reference disk, which itself is calibrated by VSM.

The basic requirements for such a tool are:

- High speed, robotic and non-destructive
- Capable of measuring a large number of points on both sides of a disk in under 1 minute
- Capable of writing onto very high coercivity media (4,000 to 5,000 Oersteds and beyond)
- Capable of reading very low M_rt media (down to 0.1 memu/cm^2)
- Employ data plotting, manipulating, and exporting software, capable of displaying individual point maps, as well as track, side, and disk averages and standard deviations of the magnetic parameters.

Head Wafer Mapping System

These tools map the magnetic properties of many selectable points on a head wafer, utilizing the Kerr-Effect technique. Since the GMR and spin valve head configurations employ several layers with vastly different magnetic properties, it is necessary to use different applied field maxima to differentiate the magnetic characteristics of the various layers, including their coercivities, interaction fields, and angular dependencies. In parallel with this, it is also desirable to measure the magneto-resistive characteristics of a head wafer at many selectable points.

The basic requirements for such a tool are:

- Fast, robotic access to any number of points on a wafer
- Very fast high and low field sweeps, and the ability to measure many thousands of points for each hysteresis loop in a few seconds
- Capability of providing magnetic fields in excess of 1 Tesla
- Perform the mathematical operations to extract all the pertinent magnetic parameters for each film layer, and identify defective areas on the wafer
- Provide rapid feedback to correct and optimize the film deposition processes

Conclusion

The rapid pace of advancement in magnetic data storage has increased the use of materials which are more difficult to measure and made processes more difficult to control. The metrology tools used in the development and process control of advanced media are critical to their success.

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