

Thursday, July 20

7:30-8:10 Breakfast

8:10-8:30 Welcome and Introduction

Morning Session: The Path Towards MRAM

Session Chair: Bob McMichael

- ❖ 8:30-9:15 MRAM Technologies and Metrologies: Present State and Future Challenges
Nick Rizzo, Northrup Grumman

In my talk, I will describe how the various MRAM types operate, give the current state-of-the-art, and the challenges of future development, while also discussing what advanced metrology methods are currently in use, and what is needed for the next generation of MRAM. The types of MRAM to be discussed will include Toggle, Spin Torque (in-plane and perpendicular), Spin Hall Effect, and many, many more!

- ❖ 9:15-10:00 Metrology needs for Spin Transfer Torque MRAM
Guohan Hu, IBM

This talk will discuss metrology techniques that would be helpful for developing Spin Transfer Torque MRAM. These include methods to measure damping and exchange stiffness in blanket and patterned thin films. I'll also identify areas where improvements in testing Spin Transfer Torque MRAM would make a large impact.

- ❖ 10:00-10:45 Data Retention of STT-MRAM Cells from Single Devices to Memory Arrays
Luc Thomas, TDK/Headway Technologies

Accurate measurements of the energy barrier of STT-MRAM cells are needed to design memory chips according to data retention targets. In this talk, we will present different measurement methods based on accelerating the relaxation rate by using magnetic field, spin transfer torque, and temperature, both at the single device and memory chip levels. We will discuss the challenges of interpreting these data in the context of complex switching mechanism, distributions, and temperature dependence of magnetic properties. The relationship of the energy barrier with magnetic parameters such as anisotropy field, magnetization and exchange stiffness measured both at device and film levels will also be addressed.

- ❖ 10:45-11:00 Coffee/Tea Break

- ❖ 11:00-11:45 TBD
Ajey Jacob, Global Foundries

- ❖ 11:45-12:30 An Overview on Challenges in Depositing Ultrathin Magnetic Layers
Stefan Tibus, Singulus

There is definitely a need to discuss further measurement equipment in the field of magnetic nanotechnology. Our expertise is in the field of providing reliable PVD tools for mass manufacturing. So what we think we can contribute is on giving an overview on challenges in

depositing ultrathin magnetic layers. Based on this we may stimulate the discussion on what will be innovative characterization tools for a fast characterization of unpatterned films.

12:30-1:30 Lunch

Thursday, July 20

Afternoon Session: Ultra-Thin Films

Session Chair: Hans Nembach

- ❖ 1:30-2:15 Dzyaloshinskii-Moriya Interaction in Magnetic Thin Films
Chris Marrows, U. Leeds

The DMI has become remarkably important in recent years for chiral domain walls, skyrmions, and the switching properties of magnetic nanoelements, but is difficult to measure directly and it is not clear that the different experimental techniques used at the moment all necessarily arrive at the same measured value.

- ❖ 2:15-3:00 New Measurement Solutions for Magnetic Materials Research
Randy Dumas, Quantum Design

Quantum Design Inc. develops and manufactures automated temperature and magnetic field testing platforms for materials characterization. A wide variety of measurement options are available and are frequently used in the fields of physics, chemistry, biotechnology, materials science and nanotechnology. My talk will primarily focus on two of the newest measurement options offered by Quantum Design, namely broadband ferromagnetic resonance (FMR) and dilatometry for magnetic materials.

- ❖ 3:00-3:45 Opportunities in Magnetic Metrology Using Nitrogen-vacancy Defects in Diamond
Bob McMichael, National Institute for Standards and Technology (USA)

Interest in nitrogen vacancy (NV) centers in diamond has grown dramatically over the last decade, with proof-of-concept measurements in a variety of fields, including magnetic resonance imaging of cells, single electron spins and even single nuclear spins. The “NV” center is a remarkable sensor with nT/Hz^{1/2} field detectivity and 10 mK/Hz^{1/2} temperature detectivity -- all in an atom-sized “active element.” So far, however, the NV’s impact on magnetic device measurement has been modest. In this talk, I will present an “operator’s manual” introduction to the NV center, describe its measurement capabilities and briefly report on recent progress and plans in my lab to put the NV to work for magnetic nanodevices.

- ❖ 3:45-4:00 Coffee/Tea Break

- ❖ 4:00-5:15 Panel discussion.
Panel Moderator: Guohan Hu

- ❖ 5:30 Departure for Dinner

Friday, July 21

7:30-8:30 Breakfast

Morning Session: Imaging

Session Chair:

- ❖ 8:30-9:15 Future Opportunities for Magnetic Metrology with X-ray Spectro-microscopies

Peter Fischer, Lawrence Berkeley National Laboratory

The magnetic characterization with x-ray spectro-microscopies offers a unique combination of spatial, temporal, and element-specific information ultimately reaching into fundamental magnetic length and time scales with high sensitivity to individual components that will enable to study static properties, dynamic behavior, and functionality of magnetic devices. Harnessing the various interactions of x-rays with matter, such as x-ray absorption, scattering, and reflection has led to a multiple suite of surface, interface and bulk sensitive techniques. Future sources of x-rays, such as X-ray Free Electron Lasers (XFEL), diffraction limited storage rings (DLSR), and high harmonic generation sources will provide

- peak intensities enabling single shot ultrafast experiments
- high coherence allowing interferometric techniques with ultrahigh sensitivity, and
- diffraction limited x-ray spot sizes leading to ultrasmall spatial resolution.

- ❖ 9:15-10:00 EUV Imaging: Prospects for Imaging Magnetic Nanostructures

Henry Kapteyn, U. Colorado at Boulder/JILA

- ❖ 10:00-10:45 Magnetic Imaging with Diamond NV-Centers

Ania Bleszynski Jayich, U. California at Santa Barbara

- ❖ 10:45-11:00 Coffee/Tea Break

- ❖ 11:00-11:45 High Resolution Electron Microscopy Studies of Nanoscale Magnetization

Ben McMorrان, U. Oregon

Electron microscopy can be applied in several ways to form quantitative images of magnetic vector fields at the nanoscale. For example, Lorentz TEM, which only requires defocused TEM images, can provide vector maps of the in-plane magnetic induction projected through the thickness of a thin specimen. New techniques using structured electron beam probes are being developed to measure the perpendicular-to-plane component of the magnetization and to improve spatial resolution of magnetic images.

- ❖ 11:45-12:30 Magneto-optical Imaging Aiming at the Visibility of Small Objects that are Below the Resolution Limit (like skyrmions) by using Advanced Technology

Rudi Schaefer, IFW Dresden

12:30-1:30 Lunch

Friday, July 21

Afternoon Session: Testing and Measurements

Session Chair:

- ❖ 1:30-2:15 Measuring Physical Properties Governing Spin-Torque-Transfer MRAM Performance
Robert Beach, Samsung

This presentation will discuss aspects of testing to optimize STT-MRAM. Reliable characterization of electrical, magnetic and spin-momentum-transfer is vital to realize a working MRAM array. MRAM must simultaneously satisfy four demands: readability, writeability, retention and reliability. This presents a very difficult engineering challenge. We will cover testing issues that apply both to a large number of bits, and to repeated measurements on isolated bits. Recent advances in modeling have enhanced the value of comprehensive film-level metrology, including anisotropy H_k , Gilbert damping, and the exchange-coupling constant A_{ex} . Lastly, we cover how an understanding of bit-level physics and failure modes can be gained using the technique of spin-torque FMR.

- ❖ 2:15-3:00 Theoretical proposal on evaluation method of spin torque efficiency due to anomalous Hall effect
Tomohiro Taniguchi, Advanced Industrial Science and Technology (Japan)

Excitation of spin transfer torque by spin Hall effect in nonmagnetic heavy metals and its related phenomena have attracted much attention. Recently, we propose that the anomalous Hall effect in ferromagnets can also excite spin torque, similar to the spin Hall effect. However, the efficiency of the spin torque by the anomalous Hall effect is still unclear. In this talk, we give a theoretical proposal to estimate the efficiency by measuring the magnetoresistance in ferromagnets, similar to the determination of the spin Hall angle in the nonmagnets by the spin Hall magnetoresistance effect.

- ❖ 3:00-3:15 Coffee/Tea Break

- ❖ 3:15-4:00 Understanding Process-induced Damages to Magnetic Tunnel Junctions: Towards In-line Compatible Metrology
Mauricio Manfrini, IMEC (Belgium)

The commercialization of MRAM technology has brought to conventional CMOS platforms the world of complex magnetic materials. Here at imec we are pushing STT-MRAM and spintronic logic technologies to very advanced nodes. To be able to understand and evaluate process-induced damages to MTJs at very small scales is detrimental. We will give an overview of our internal effort on in-line and off-line metrologies for MTJs and what are the hurdles and the wish list to make these technologies possible.

- ❖ 4:00-4:45 Novel metrology methods for spintronic device applications
Hans Nembach, National Institute for Standards and Technology (USA)
U. Colorado at Boulder/JILA

- ❖ 4:45-5:00 Coffee/Tea Break
- ❖ 5:00-6:00 Panel discussion.
[Panel Moderator: Bob McMichael](#)