Vibrating Sample Magnetometry Study of High-Permeability Dielectrics on Nanomagnets

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Background and Motivation

- Nanomagnet logic (NML)
  - Single domain magnets to represent information
  - Magnetic coupling to propagate information
  - Low power dissipation
  - Non-volatile

- High/Enhanced Permeability Dielectrics (EPD)
  - Magnetic field is generated in the clocking structure to bias magnets in the hard axis for re-evaluation
  - Enhanced permeability dielectrics is expected to constrain flux lines and improve the efficiency of field generation

Measurement of EPD on Nanomagnets

- EPD Morphology
  - STEM Image showing discrete EPD CoFe particles
  - Image – Particle recognized

- Magnetization Properties
  - Single layer EPD consists of CoFe particles with a size of 4.6 nm ± 1.1 nm

- Magnetization curve of EPD shows that it is superparamagnetic at room temperature

Measurement of EPD

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  - Image showing discrete EPD CoFe particles

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Measurement of EPD on Nanomagnets

- Nanomagnet samples
  - Isolated magnets (~10^5)
  - Coupled magnets (~10^5)

- TMM - Nanomagnet Switching without EPDs
  - Coupled magnets: 4 times reduction, translating to 16 times reduction in power
  - Remanent magnetization keeps unchanged – EPD does not add bias to NML

- TMM - Nanomagnet Switching with EPDs
  - Reduction in clock field is well predicted, which is consistent with experiments
  - Reduction in remanent magnetization – improvement of model may be needed

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  - Best Poster Award, NRI-MIND Meeting, 2012
  - Best Student Paper Award Finalist, IEEE International Magnetics Conference, 2012

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Transverse Magnetization Metrology (TMM)

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  - MOKE SQUID
  - Photoelectron Emission Microscopy (PEEM)
  - X-ray Microscope
  - Spin Polarized-SEM
  - Spin Polarized-TEM
  - Scanning Hall Probe Microscope-250 nm

- Direct measurement of magnetic coupling
  - Magnetization Sensing H_m
  - External Field H_x
  - M_y vs. H_x curves
  - M_y vs. H_x curve demonstrates magnetic coupling and reveals switching behaviors of coupled magnets
  - Measurement results are well correlated to the simulation data, which validates the simulation model and improves its accuracy

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