Magnetism Studies with Microfocused X-rays

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Three Examples

(1) ~ 10 μ m resolution

Imaging of Spiral Magnetic Domains

Scanning microscopy - diffraction contrast

(2) ~ 1.0 μ m resolution

Biquadratic Exchange in SmCo/Fe Bilayer

Scanning microscopy - absorption contrast

(3) ~ 0.1 μ m resolution

Imaging of Co Nanodot Arrays

Full field microscopy - absorption contrast





Common Features

• In Sector 4



• All experiments performed with circularly polarized x-rays

4-ID-C: Circularly polarized undulator

4-ID-D: Phase retarder





1. Imaging of Spiral Domains



Φ : turn angle between atomic layers

Left handed or right handed spiral

polarized beam to measure *chirality* of domains at a particular τ







Linear Undulator







Spiral Domains in Holmium



Pioneering Science and Technology



Temperature Dependence of Ho Domains



Domains freeze in; not many changes







Imaging of Dysprosium Spiral Domains







T=90K cooling

J.C. Lang, D. McWhan, D. Haskel, D. Lee and G. Srajer,

in preparation



Warming from ferro phase yields many smaller domains which merge with larger domain upon heating.







2. Biquadratic Exchange in Sm/Co Bilayer

(G. Srajer, D. Haskel)



Microfocusing on 4-ID-D



Experimental Setup





J.C. Lang et al. SPIE Proc. 4499, 1 (2001)

Office of Science U.S. Department of Energy

J. Pollmann et al. J. Appl.Phys. 89, 7165 (2001)



Sm Remanent Hysteresis Loop

Goal is to determine the field at which SmCo layer is demagnetized



If Fe domains large, Fe magnetization direction frustrated!

H = -3.4 kOe





Fe Domains for Demagnetized SmCo Layer



-3

-4

Field (kOe)

-2

-

0

Fe-remanent

-5

CP-xrav

-6

Fe Remanence @ 90 deg. 30 0.001 25 - 0.001 20 **Two large** - 0.003 domains! 15 2 10 - 0.005 5 0 0.007 20 30 10 15 25 0 5 average value: -0.00105 ± 0.00002 , contour interval: 0.002





-0.004

-0.006

-0.008

-7

G. Srajer, D. Haskel, J.C. Lang, C. Kmety-Stevenson, S. Jiang and S. Bader, **Office of Science U.S. Department** in preparation



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3. Imaging of Co Nanodot Arrays







Chemical and Magnetic Image



Chemical contrast:

- Self-assembled systems
- Segregation
- Local electronic structure
- Buried layers (~5 nm)

Magnetic map (I*-I⁻)





Vortex domains

1x1x0.015µm Co

Magnetic contrast:

- Domain imaging
- Ground states on nanoscales
- Interactions in particle arrays
- Finite size effects





Rectangular Cobalt Arrays



Technology

of Energy



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Micromagnetics Calculations

500 x 1000 nm dots

Two configurations:

 M_s =1350 emu/cm³; A=3.05 µerg/cm







- Chirality and temperature dependence of spiral and conical domains in *single crystals*
- Direct evidence of biquadratic coupling in a Fe/SmCo *bilayer*
- Length scales of magnetic interactions in Co patterned arrays



