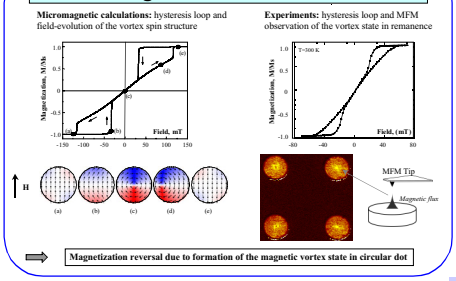
# Interacting Laterally Patterned Magnetic Structures

V. Novosad, M. Grimsditch, J. Darrouzet, J. Pearson, and S. D. Bader (MSD-ANL)
K. Yu. Guslienko, R. W. Chantrell (*Seagate* Research, *PA), V.* Metlushko (UIC), *and* Y. Otani (RIKEN, Japan)

## Motivation:

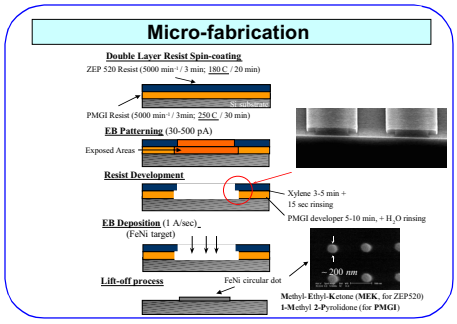
The magnetization reversal in an array of identical well-separated dots is mainly determined by the magnetic properties of the elements. Conversely, the interdot interaction due to stray fields is important in determining the switching behavior for high-density arrays. In order to estimate how long-range magnetostatic interaction varies across the patterned sample we have studied a model system of arrays of magneto-statically coupled dots with magnetic vortex ground state.

### Magnetic Vortex State

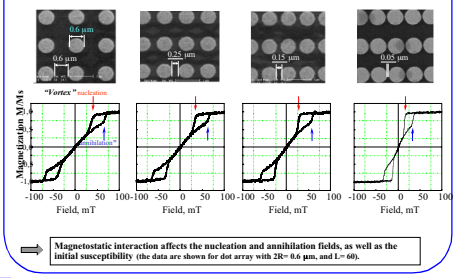



Magnetization reversal due to formation of the magnetic vortex state in circular dot

### Micro-fabrication

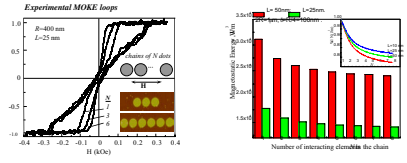



### Magneto-statically coupled dot arrays




Magnetostatic interaction affects the nucleation and annihilation fields, as well as the initial susceptibility (the data are shown for dot array with 2R= 0.6 μm, and L= 60).

### Long-range magneto-static interaction

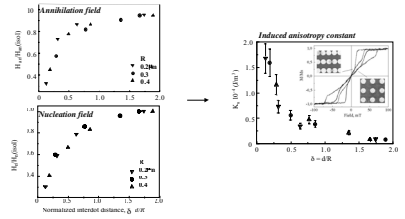



Effect of interdot coupling on magnetization reversal in truncated dot chains depends on the number of interacting elements.

## Sub-μm ferromagnetic dot arrays

Recent interest in magnetic systems with reduced dimensions has been stimulated by the rapid evolution of various nano-fabrication techniques. In particular, it enables us to fabricate well-defined 2D arrays of sub-micron ferromagnetic particles (dots). This offers various opportunities to test new concepts of *spintronic devices*, such as *magnetic random access memory* (MRAM), high-density *patterned recording media*, or ultra-small magnetic field *sensors*. Prior to the technological applications mentioned above, it is indispensable to understand fundamental properties, such as switching fields, susceptibility, spin dynamics and interdot interaction of the magnetic elements with reduced dimensions.

### Universal scaling f interacting effects

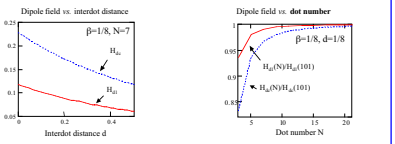



The experimental results clearly show that the interdot distance normalized to dot radius can be used as a key parameter to determine the strength of the interdot coupling.

### Modeling of interdot dipolar interaction

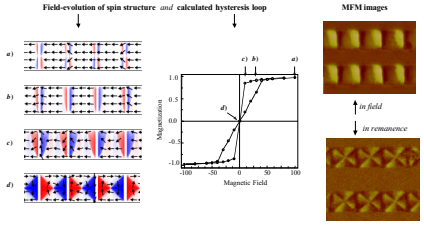
$$\mathbf{H}_d^{\alpha} = \mathbf{H}_d^{\alpha}(self) + \mathbf{H}_d^{\alpha}(\text{int}) \qquad \mathbf{H}_d^{\alpha}(\text{int}) = -\sum_{\alpha' \neq \alpha} \mathbf{D}(\mathbf{R}_{\alpha} - \mathbf{R}_{\alpha'})\mathbf{m}_{\alpha'}$$

$$D_{eff}(\mathbf{R}_{\alpha}, \mathbf{R}_{\alpha'}) = \frac{\delta_{\alpha\beta}}{R_{\alpha\alpha'}^3} - 3\frac{R_{\alpha\alpha'}^{\alpha} R_{\alpha\alpha'}^{\beta}}{R_{\alpha\alpha'}^5} \qquad \mathbf{m}_{\alpha'} = \langle \mathbf{M}_{\alpha'} \rangle / V_{\alpha'} \qquad \mathbf{R}_{\alpha\alpha'} = \mathbf{R}_{\alpha'} - \mathbf{R}_{\alpha}$$



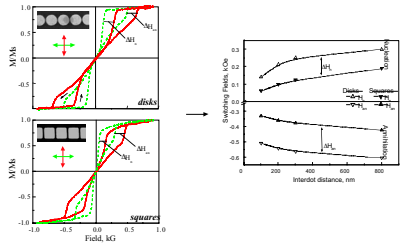

**Notations:** d is the interdot distance in units of dot radius R, β=L/R is the dot aspect ratio, interdot dipolar field $H_d$ is in units of $M_{\alpha}$, indexes "1" and "c" correspond to the edge and central dot, respectively.

### Chain of interacting square particles




In chain of square particles the vortices are formed only in remanence. The effect of interdot interaction accounts for the coherent vortex chirality in neighboring elements.

### Shape effect on interdot coupling




The interdot coupling appear to be independent on the shape of the dots.

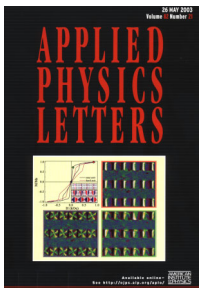
## Results:

- ✓The interdot interaction has a strong destabilizing effect on the vortex spin state.
- ✓The interdot distance normalized to dot radius is found to be a key parameter that determines the strength of the coupling.
- ✓In truncated chain of interacting dots, the magnetization reversal is initiated from the chain edges due to the symmetry breaking.
- ✓The interaction effects account for the coherent vortex chirality in neighboring dots.

## Future Directions:

- ✓Exploring the inter-dot interaction effects in vertically organized dots and patterned multi-layers.
- ✓Inter-particle interaction for generation and propagation of magneto-static spin waves.
- ✓Role of the interaction effects in damping phenomena in high density magnetic recording media.

*Reference: V. Novosad, M. Grimsditch, J. Darrouzet, et. al., Applied Physics Letters, 82 (2003) 3716.*




**BES - DOE**

Work was supported by US Department of Energy, BES Materials Sciences under contract W-31-109-ENG-38 and the U.S. National Science Foundation, grant # ECS-0202780, and by the Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture in Japan.

**MSD - ANL**

ARGONNE NATIONAL LABORATORY · UNIVERSITY OF CHICAGO