SHAPE ENGINEERING OF DIPOLE-COUPLED NANOMAGNETS FOR MAGNETIC LOGIC DEVICES

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Magnetic logic devices are, in principle, capable of transmitting and processing binary information in an entirely magnetic way. Magnetic quantum-dot cellular automata (MQCA) [1, 2] realize logic functionality based on arrays of dipole-coupled nanomagnets. Recent experimental studies investigated the correlation length of antiferromagnetic ordering on chains of coupled single-domain ferromagnets [3, 4]. Switching-field variations of the nanomagnets was identified as a critical issue during the ordering process.

We present a combined experimental and theoretical study on arrays of closely-spaced magnetic dots with varying shapes in the size of 70 - 300 nm. The goal of our study is to identify those shapes which yield the longest correlation lengths for MQCA applications. We have investigated a variety of nanomagnet shapes, such as rectangular, ellipsoidal, triangular, trapezoidal, and others. As a general rule, we find the longest correlation lengths for shapes which maximize local dot-dot stray fields, and which also provide well-defined nucleation sites for magnetization reversal. In addition, we find a dependence on the demagnetization process, such as rotating- or pump- field. As an example, Figure 1 shows perfect antiferromagnetic ordering along a chain of 64 dots. According to our micromagnetic simulations [5], designed asymmetry can be used to guide switching dynamics, such as in Figure 2. Moreover, triangular or trapezoidal shapes are expected to exhibit directionality in switching when a pump field is applied, which would endow the MQCA with rectified signal propagation. Figure 3 shows ordering for a triangular shape as a result of horizontal pumping.

Acknowledgements

This work was supported in part by grants from the Office of Naval Research, the W.M. Keck Foundation, and the National Science Foundation..

References

[1] R. P. Cowburn and M. E. Welland, *"Room temperature magnetic quantum cellular automata,"* Science **287**, 1466, 2000
[2] György Csaba, Alexandra Imre, Gary H. Bernstein, Wolfgang Porod, and Vitali Metlushko, *"Nanocomputing by field-coupled nanomagnets,"* IEEE Trans on Nanotechnology **1**, 209, 2002.
[3] R. P. Cowburn, *"Probing antiferromagnetic coupling between nanomagnets,"* Phys. Rev. B **65**, 092409, 2002.
[4] Alexandra Imre, György Csaba, Gary H. Bernstein, Wolfgang Porod, and Vitali Metlushko, *"Investigation of antiferromagnetic ordering along chains of coupled nanomagnets,"* presented at *IEEE-NANO 2003*, San Francisco, August 12-14 2003.
[5] M. J. Donahue and D. G. Porter, "OOMMF User's Guide,Version 1.0," *Interagency Report NISTIR 6376* http://math.nist.gov/oommf/

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Figures

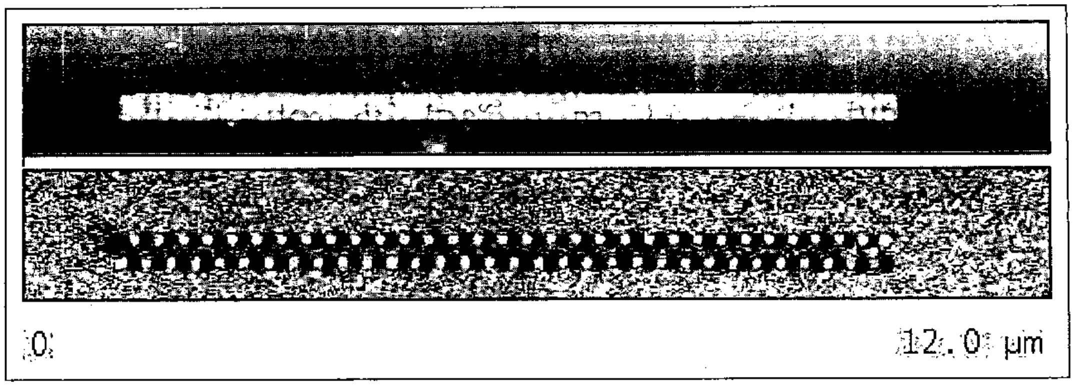

Figure 1. Perfect antiferromagnetic ordering along chains of 64 permalloy nanomagnets for rotating-field demagnetization. Top panel shows topographical AFM, bottom panel shows magnetic force microscopy (MFM) image.

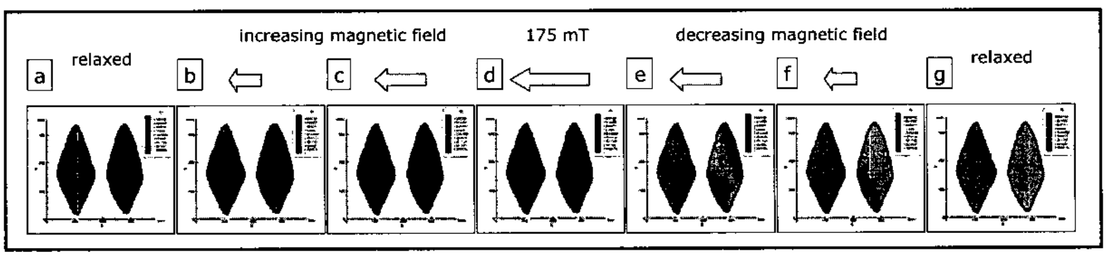

Figure 2. Illustration of simulated switching dynamics of two coupled deltoid-shaped nanomagnets. The slightly asymmetric shape and the direction of the external field define the final magnetization of the dots; the initial magnetization determines whether the right or the left dot switches. This effect has been confirmed experimentally.

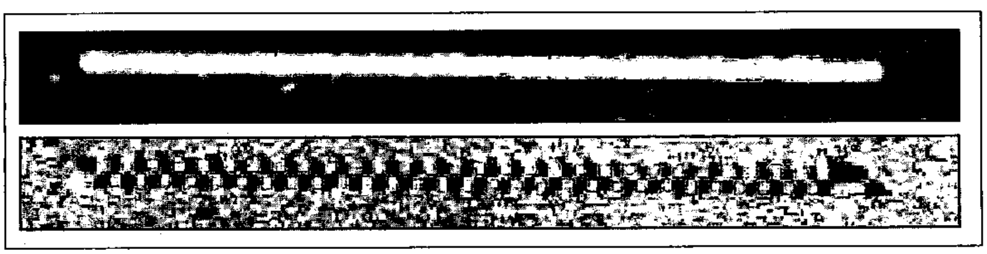

Figure 3. Antiferromagnetic ordering along a chain of 64 triangular nanomagnets for horizontal pump-field demagnetization. Top panel shows topographical AFM, bottom panel shows magnetic MFM image.