Magnetization Reversal of Arrays of Micron Sized Dots under the Influence of Dipolar Coupling

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Up to now, only few results have been reported on the magnetization reversal of films with columnar structure and perpendicular easy axis under the influence of dipolar coupling1-6. To our knowledge, only one team has performed studies on regular 2D arrays of perpendicularly magnetized dots with dipolar interaction7,8. In all these cases, the lack of homogeneity and the dispersion of nucleation fields in the studied systems prevented to retrieve valuable data concerning the influence of dipolar coupling on the collective magnetization reversal of particles, and also the local studies were hampered by these drawbacks. The aim of the present contribution was to investigate into detail the effect of dipolar coupling on the local and collective magnetization reversal of a very well characterized system of perpendicularly magnetized dots. This effect will be important in future ultrahigh density magneto-optical (MO) recording applications where written bits have to be reduced in dimension and closely packed.

MO Faraday effect magnetometry measurements and imaging have been used to investigate the static and dynamic magnetic properties of two-dimensional arrays of rectangular dots. The arrays were fabricated in highly homogeneous ultrathin epitaxial Pt(3.4nm)/Co(1.4nm)/Pt(4nm)/Al₂O₃(0001) sandwiches with high perpendicular anisotropy and easy domain wall propagation. Arrays were patterned directly by writing regularly spaced lattices of crossed lines using high resolution focused ion beam (FIB) etching at very low doses of Ga⁺ ions. In this way, the film surface stays even (there is no milling of grooves) and the created pattern is of purely magnetic nature. This causes very little optical contrast, allowing MO imaging of the same quality as in continuous films. The dots are separated from each other by narrow paramagnetic stripes of widths of only 20 to 40 nm. The dimensions of the dots are 1.3 μm x 1 μm.

Our experiments give clear evidence for the presence of magnetic dipolar coupling between adjacent dots. As shown by hysteresis loops and relaxation curves, the domain nucleation and propagation properties are changed with respect to those of the continuous part of the film, which helps to avoid the problem of random nucleation of reversed magnetic domains, so that the magnetization reversal depends only on domain wall propagation. The latter is very uniform due to the highly homogeneous system, hence dipolar coupling plays the major role in altering the reversal properties of individual dots. Based on the magnetization reversal of individual dots, we estimated the strength of dipolar coupling, and we calculated the highly inhomogeneous dipolar field which acts on a dot due to the state of magnetization of its neighbors.

As expected, images of the demagnetized dot arrays show an obvious tendency towards checkerboard-like magnetization patterns where the net magnetic energy of the arrays is minimized. The latter experiments are in good agreement with numerical simulations based on dipolar interactions between giant Ising spins without exchange coupling. Despite the simplicity of the applied model, the magnetization patterns can be reproduced to great extent. This also proves the qualification of the studied system as a model system of magnetic Ising dots. We believe that both, our patterning technique and our observations open the way to the realization of new magnetic nanodevices.
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