Magnetic domain engineering with Focused Ion Beam Irradiation

Motivation
We have created nanodot arrays in order to control the magnetic domain structure. The ongoing scale reduction of magnetic storage calls for refined methods of controlling domain size. A flexible method is Focused Ion Beam (FIB) patterning, which offers the possibility of local anisotropy engineering on a length scale comparable to the domain wall width (10-100 nm).

FIB: focused ion beam implantation
- 30 keV Focused Ga+ ion Beam
- Size of dots = Ion focus = 30 nm
- Ion fluence: 1 - 50 Ga+ ions/μm²
- Interdot spacing: 150-400 nm
- Ion penetration range: 14 nm

Local reduction of perpendicular magnetic anisotropy

AFM / MFM: topology & magnetic structure
- Despite the minute ion fluences, AFM reveals the anisotropy dot array as lattice of ~1.5 nm indentations.
- Magnetic domain alignment with domain walls on the dots.
- In magnetic field, the down domains align with the dots.
- Wormlike domains shrink to bubble domains that are positioned on the dots.

VSM and SQUID: Hysteresis loops
- Bulk magnetic properties such as the saturation magnetization, remanence, and coercivity can be obtained from the hysteresis loop.
- \( \text{Gd}_{11.3}\text{Tb}_{3.7}\text{Fe}_{85} \) has much higher perpendicular magnetic anisotropy.

Soft x-ray resonant microscopy
- Nucleation of domains and saturation takes place at the dots.
- Opportunity for increasing data storage density.

Soft x-ray resonant magnetic scattering
- The scattered intensity of a patterned area before domain nucleation clearly displays the PMA reduction at the dots.
- Scattering patterns of pristine and three patterned areas with different interdot spacings.
- Angularly integration of the scattered intensity shows the dependence of ion fluence, interdot spacing.

Conclusions
- Focused Ion Beam irradiation can locally reduce the perpendicular magnetic anisotropy.
- This makes it possible to control magnetic domains on the length scale of the domain wall thickness (10-100 nm).
- Dots align domain walls at zero field and down domains in field.
- Dots determine the position of nucleation and saturation but do not lower the nucleation field.

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