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Nano-Patterning of Co/Pt Multilayers

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One of the most promising new systems for both basic research and technical development are the periodic arrays of nano-magnetic elements, as shown in **Figs. 1** and **2**. Such arrays show remarkably rich and novel magnetic behavior. Periodic magnetic arrays not only provide excellent opportunities for new science but also constitute a promising candidate for new applications such as high-density, patterned magnetic memory for advanced computer designs in the next decade. In our presentation we will focus on patterned [Co4Å/Pt10Å]n multilayers, which demonstrate an unusually strong out-of-plane magnetic anisotropy (**Fig. 1b**) and sensitivity to structural modification. This strong out-of-plane anisotropy makes Co/Pt ML the favorite candidates for perpendicular magnetic recording. The patterned Co/Pt ML are representatives of a new generation of magnetic nanostructures with lateral dimensions in 100nm range, and individual layer thickness approaching a monolayer scale (e.g., 4 Å of Co and 10 Å of Pt).

In addition to traditional lithography (**Fig. 1**), we are developing a new approach to tailoring the local magnetic properties of Co/Pt ML. In this process the local magnetic properties are modified not through conventional modulation of the chemical composition, but through structural modification induced by low energy ion implantation. The ion implantation technique begins with a uniform Co/Pt ML, which is implanted with low energy He ions through a mask formed either by patterned e-beam resist deposited on top of the Co/Pt ML (**Fig. 2c**), or through a prefabricated stencil mask like that shown in **Fig. 2a**. The holes in the mask allow the He ions to disorder the Co/Pt structure, and the perpendicular moment is dramatically reduced or destroyed (**Fig. 3**) within the implanted area. The film topography and chemistry remain unaltered, and only the local atomic structure and magnetic properties are modified by implantation. Therefore this method achieves "magnetic patterning" of a continuous magnetic film without significant modification of surface roughness or the film optical indices, which is important for magneto-optical media. The key feature of this technique is that magnetic parameter changes can be precisely tuned by varying implantation dose (**Fig. 3b**). The results of systematic characterization of arrays for different doses ranging from 10^{15} to $5x10^{16}$ ions/cm^2 with SQUID magnetization to determine the magnetic anisotropy and moment size, with atomic force microscopy (AFM) and magnetic force microscopy (MFM) to determine the topography and the magnetic order in the periodic arrays, and with magneto optical imaging (MOI) to visualize the moment reversal process during a magnetization cycle, will be presented.

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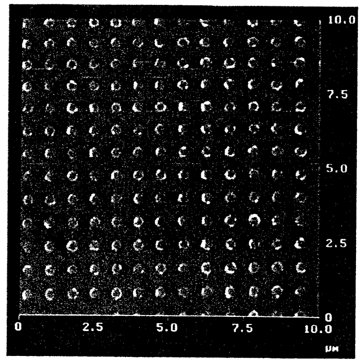

Fig. 1a. Atomic Force Microscopy image of patterned [Co4/Pt10]5 multilayer dots.

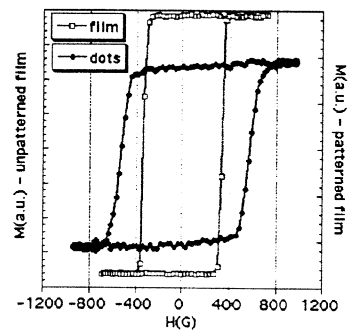

Fig. 1b. Out of plane MOKE magnetization loops for unpatterned Co/Pt ML (open squares) and array of Co/Pt dots of **Fig. 1a**. Patterning yields an increased switching field.

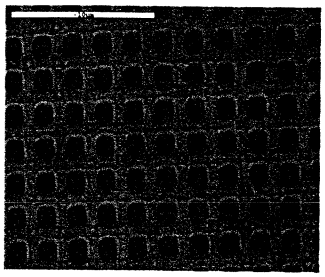

Fig. 2a. Stencil mask provided by Bruce Terris of IBM Almaden for magnetic patterning with He ion implantation. He ions penetrate through the holes in the mask and locally destroy the layering of Co/Pt ML.

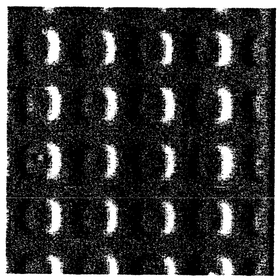

Fig. 2b. MFM image of a square array of dots magnetically patterned in Co/Pt implanted with 30ke V He ions through the mask shown in **Fig. 2a**. Irradiated dots are magnetized in-plane, and unirradiated film between dots is magnetized perpendicular to the film.

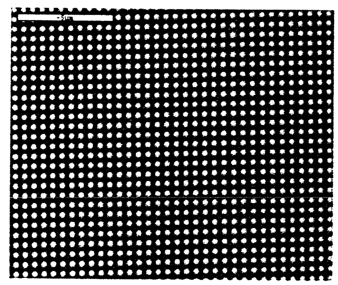

Fig. 2c. SEM image of an array of e-beam resist pillars (period 500 nm, diameter 300 nm) on top of a Co/Pt ML. The pillars serve as an effective mask to stop He ions. This method can be extended to smaller, nano-scale sizes.

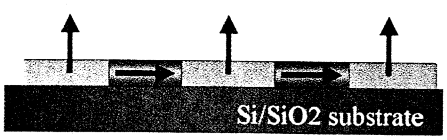

Fig. 3a. Schematic of the local magnetization direction in the magnetically patterned [Co4Å/Pt10Å]5 ML from **Fig. 2b**. Dots implanted through a mask with dose 5×10^{16} ions/cm^2 are magnetized in-plane.

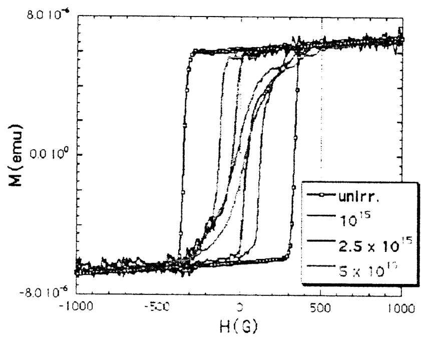

Fig. 3b. Hysteresis loops for perpendicular magnetization of [Co4Å/Pt10Å]5 ML implanted with different doses of 30keV He ions. The coercive field is smaller for higher irradiation dose.

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