Nano-structured magnetic materials for high density storage applications

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Magnetic storage has played a key role in audio, video and computer development since its invention more than 100 years ago by Valdemar Poulsen [1]. In 1956 IBM built the first magnetic hard disk drive featuring a total storage capacity of 5 Mbytes at a recording density of 2 kbits/in^2. Since then the density of bits stored on a surface of a disk has increased by 35 million fold to current densities of 70 Gbits/in^2 and has been doubling every year over the past five year. At such densities, the bits must be positioned on the disk with nanometer resolution.

Present magnetic disk drives are based on longitudinal recording systems where the magnetization of the recorded bit lies in the plane of the disk. These systems contain a recording head composed of a separate read and write element, which flies in close proximity to a granular recording medium, as illustrated in Fig. 1. The recording media signal-to-noise ratio (SNR) needed for high-density recording is achieved by statistically averaging over a large number of weakly interacting magnetic grains per bit. The granular microsctructure limits the magnetic correlations to length scales comparable to the grain size and allows information to be written on a finer scale than possible in a homogeneous magnetic film. This structure is currently achieved in CoCrPtB alloy thin films. When grown at elevated temperatures, these alloys phase segregate into high-moment magnetic grains surrounded by non-magnetic boundary regions (Fig. 2).

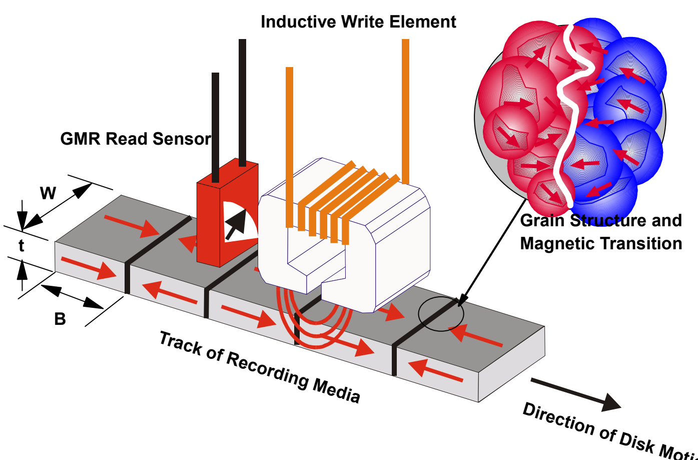

Figure 1: Schematic representation of a longitudinal recording system.

Resonant spectroscopies of 3*d* transition-metal films at the *L* edges provide various opportunities to investigate magnetic and chemical structure of recording media at these nano-meter scale [3]. In resent years we have exploited emerging resonant small-angle scattering (SAS) techniques to probe in-plane structural and magnetic order over length scales ranging from the x-ray wavelength λ, 1-2 nm, up to ~300 nm [4-7]. By tuning both the energy and polarization of the incoming x-ray radiation, the magnetic and structural heterogeneities can be separated and quantified. For the case of CoPtCrB alloy media the Cr is predominantly non-magnetic. Tuning to x-ray energies through the

Cr edge enhances the chemical contrast, while tuning to the Co edge enhances both chemical and magnetic contrast.

The continued evolution of current recoding technologies towards higher areal densities is limited, in part, by enhanced thermal effects, known as the "superparamagnetic effect" [2]. This become increasingly important in nano-structured materials as the magnetic energy within the particles is comparable with thermal energies (k_BT) and the stored information is no longer stable against thermal fluctuations. Continued growth of storage densities will require the development and characterization of new nano-structured materials and architectures that control magnetic interaction and correlations on the nanometer scale [2]. Examples of these include multilayered recording media (Fig. 3) [8-11], perpendicular recording, thermally-assisted recording, patterned media and self organized magnetic nano-particles. I will highlight the potential of these new structures and the opportunities for magnetic x-ray studies. In particular, I'll focus on multilayered magnetic recording media (Fig. 3) and the importance of inter- and intra-layer magnetic correlations.

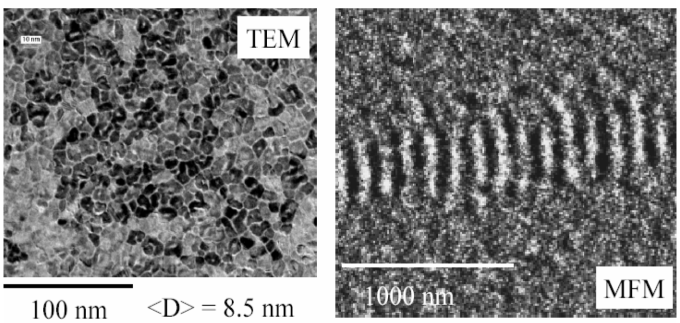

Figure 2: (left) Plan-view TEM image showing the CoPtCrB two-phase microstructure with an average grain size of 8.5 nm. (right) High-resolution MFM image (E. D. Dahlberg *et al*., U. of Minn.) of magnetic transitions.

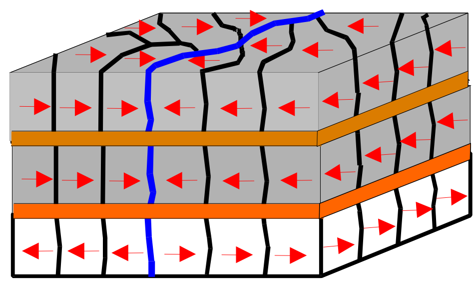

Figure 3: Schematic representation of a three-level magnet recording media with a single magnetic transition [9-11].

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