Patterned Magnetic Recording Media

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After years of rapid advances in electronics and information technology, researchers face new challenges due to the approach of various fundamental physical limits that may inhibit further device and bitcell miniaturization. In magnetic recording, the 50-year cumulative improvement of 10^8 in areal density may not be extendible beyond 1 Tbit/in^2 because of mutually exclusive requirements for thermal stability, writability, and signal-to-noise ratio, all related to scaling of the grain size in thin film magnetic media. Solving these problems may require adoption of either patterned media (PM) or energy-assisted writing.

There are two versions of PM: discrete track media (DTM), in which a conventional granular recording film is patterned into physically separated tracks, and bit patterned media (BPM), which is patterned into single-bit islands. While DTM does not significantly improve thermal stability, it may offer an increase in density (probably <2X) via reduced adjacent track interference and related improvements in down-track density. BPM, in contrast, is significantly more difficult to fabricate due to smaller feature size, but offers the potential for substantial (perhaps >10X) density gain by changing from multiple independent grains per bit to a single-domain thermally stable magnetic island per bit.

To fabricate PM, a master pattern is first generated by e-beam lithography. The small feature size (10–50 nm), tolerance requirements, and pattern extent drive the use of measures such as rotary-stage e-beam architecture, cold ultrasonic development, multiple exposure of features, and blankerless writing. To go beyond the reach of e-beam, innovative self-assembly methods are being used, in which a chemical contrast pattern derived from an e-beam pattern provides dense guiding information for the self-assembly of block-copolymer domains with tightly controlled tolerances, and defect-free long-range order in circular track patterns. UV-cure nanoimprint lithography is used to replicate master patterns over large volumes of disks. Since PM only requires a single patterning step (no overlay), tools and process are greatly simplified compared to what is needed semiconductor device fabrication. Figure 1 shows a DTM imprinting template.

Successful recording on BPM (Fig. 2) requires high write field gradient and a tight distribution of island switching fields. Creation of magnetically uniform islands requires stringent control of magnetic anisotropy and moment, as well as island dimensions and placement tolerances. Precisely synchronized writing and use of pre-patterned tracking servo features are also needed. Modeling suggests that a density as high as 10 Tbit/in^2 may be achievable with BPM; beyond that, it may be necessary to combine energy assisted writing with BPM.

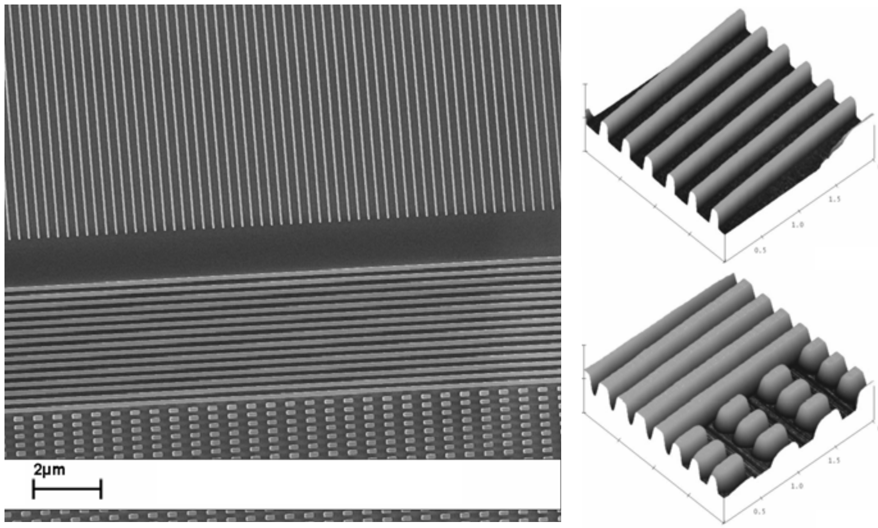

Figure 1. SEM and AFM micrographs of the surface of a nanoimprinting template for DTM. Negative-tone topographic patterns for discrete recording tracks (top) and part of the servo pattern area (bottom) are visible. Feature height is about 80 nm.

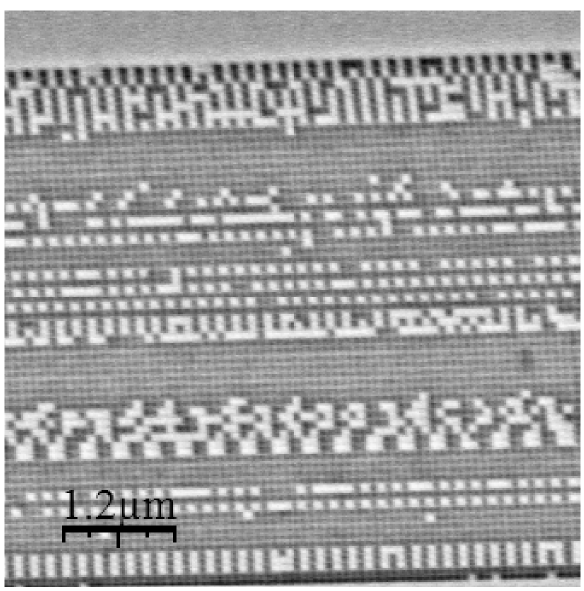

Figure 2. Data tracks (running horizontally) on a BPM disk, recorded by a magnetic head on a spin stand and imaged by magnetic force microscopy. Density of islands on this disk is 100 Gbit/in^2 (80 nm period).