Terabit-per-square-inch Magnetic Bit Patterned Media With a 26-nm Pitch and a 9-nm Square Bit

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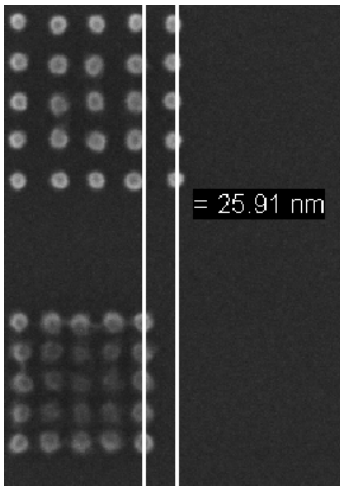

Bit Patterned Media (BPM) is considered as one of the most likely alternatives to take the multi-billion-dollar magnetic data storage industry to areal densities beyond 1 terabit/in^2 [1] Especially with the recent emergence of imprint lithography the traditional concern of hefty cost to justify mass production might be relieved in the near future [2]. Indeed, at least partial (one-dimensional) patterning is already finding its life in the form of Discrete Track Recording (DTR) – the magnetic recording technology in which tracks are physically separated (patterned) from each other to substantially reduce the track-to-track interference. However, to study the physics of BPM at such high areal densities it is critical to be able to make prototype devices with nanoscale patterns. In addition, to further advance mass-production-suitable imprint lithography techniques it is necessary to fabricate individual masks with such high density patterns. Though self-assembled patterns might eventually become available, it is still a non-trivial task to control bit and pitch (period) dimensions in patterns suitable for densities above 1 Terabit/in^2. Therefore, we decided to use electron-beam techniques to create such ultra-high density patterns. For example, to achieve an areal density of over 1 terabit/in^2, a square pattern should have a pitch (period) of approximately 26 nm and a square bit with approximately 13 nm or less on a side. It is not a secret that features as small as 5 nm can be indeed achieved with e-beam lithography. However, the challenge is to lower the pitch to values substantially below the beam tail width which can be as high as 50 nm on a side. To overcome the challenge, we used a lift-off based e-beam lithography on hydrogen silsesquioxane (HSQ) spin-coated films. To minimize the HSQ thickness, it was diluted with methyl isobutyl keton (MIBK) with a rato of 1:2.5. The final thickness of approximately 33 nm was measured through atomic force microscopy (AFM). The diluted HSQ was then spin-coated on a Si (110) substrate at a rotation speed of 5000 rpm for 60 seconds. After the coated substrate was baked for 2 minutes at 85 °C, arrays of 5 x 5 nano-dots were exposed by a JEOL direct write e-beam lithography system (JBX-5500FX) with 50 keV and 98 pA beam intensity and current, respectively. The pitch was varied from 26 to over 200 nm through the dosage variation from 6000 to 4920 µc/cm^2, respectively. A scanning electron microscopy (SEM) image of typical e-beam fabricated pattern with a pitch (period) of 26 nm and a square bit side of 9 nm is shown in the enclosed Figure. In this presentation, we will describe in detail the fabrication and characterization of such ultra-high-density patterns suitable for BPM magnetic recording at areal densities above 1 terabit/in^2. In addition, we will present a magneto-optical Kerr and magnetic force microscopy (MFM) study of the ultra-high density BPM media.

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[2] S. Y. Chow, P. R. Krauss, and P. Renstrom, "Imprint Lithography with 25-nanometer Resolution", *Science* **272**, 85 (1996)