Susceptibility Analysis of Patterned Magnetic Thin Films

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Ferromagnetic materials are in widespread use as transducers and field sensors in hard disk drives. These materials in particular are useful because of their ease of magnetization, or equivalently, their high susceptibility. This susceptibility is related to the formation of magnetic domains, or areas where all the individual atomic dipoles are aligned. Magnetic moments in these domains tend to act together, allowing a much greater response to applied fields. By patterning magnetic materials, we can make higher resolution sensors because of the reduced area it measures. However, patterning the material tends to reduce the sensitivity to applied fields and alter the magnetic domain patterns.

To investigate the susceptibility over a range of sizes, we patterned rectangles of varying dimensions using the material CoZrTaTb with a thickness of 400 nm. Using standard photolithography techniques and etching, we patterned areas of magnetic material with lengths and widths between 3-10 µm with the easy axis along one of these dimensions. Figure 1 illustrates a small part of one array.

In addition to making these patterned films, we engaged in modeling of these devices and were able to make predictions about the domain patterns we would observe as well as the susceptibility and resonant frequency of these devices. Figure 2 shows an example of a calculated domain configuration called a “four-domain” pattern.

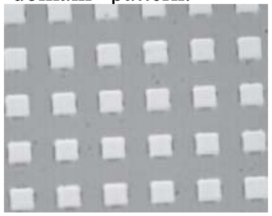

Figure 1: Optical image of array of 5 um squares of CoZrTaTb spaced 5 um apart.

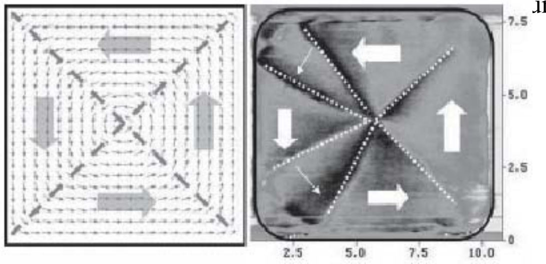

Figure 2: Ideal “four-domain” pattern for a square magnetic film and MFM image of actual film.

Magnetic force microscope (MFM) imaging of the sample showed a domain pattern close to what was predicted through modeling. We expect a “four-domain” model shown in Figure 2; the adjacent MFM image shows that the sample is mostly in the expected configuration. Figure 3 shows the saturating field for square devices as a function of side length and direction of applied field. There is a slight gap between the measured curves due to the direction of the applied field. If we are magnetizing along the easy axis, the sample will have a lower saturating fields than if we magnetized along the hard axis. When simulating these devices, we produce a curve of similar shape. However, the simulated fields are off by roughly a factor of two. We attribute this discrepancy to any number of factors, including rounding of corners in the devices, interactions between the devices, possible variation in thickness, the formation of “tulip” patterns due to defects in the devices, and uncertainty in material parameters. We see in Figure 4 that the rounding can be significant and may be enough to cause a noticable drop in the susceptability.

When measuring the samples in the network analyzer, we observed no resonant frequencies below 3 GHz, the frequency limit of the current equipment. This agrees with our calculated frequencies of resonance which are all greater than 3 GHz for the geometries of our devices. However, more testing is needed to determine the validity of the actual values of the resonant frequency.

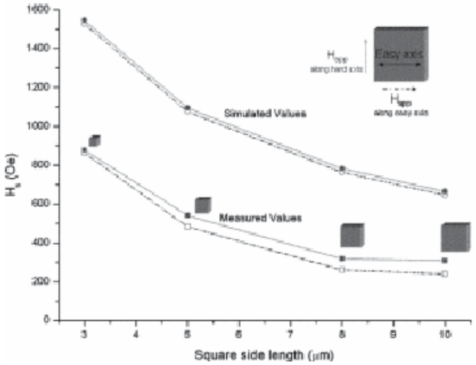

Figure 3: Graph of simulated and measured saturating fields for 400 nm thick squares of CoZrTaTb.

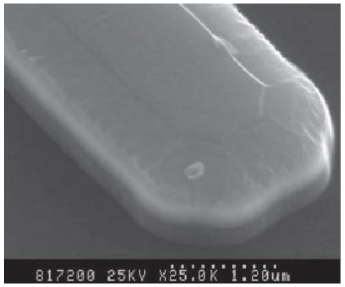

Figure 4: SEM image of rounded edges on an 8um by 3um rectangular pattern CoZrTaTb film..