Nanotechnology Highlight

Making Nanoscale Magnetic Elements for Magnetic Random Access Memories

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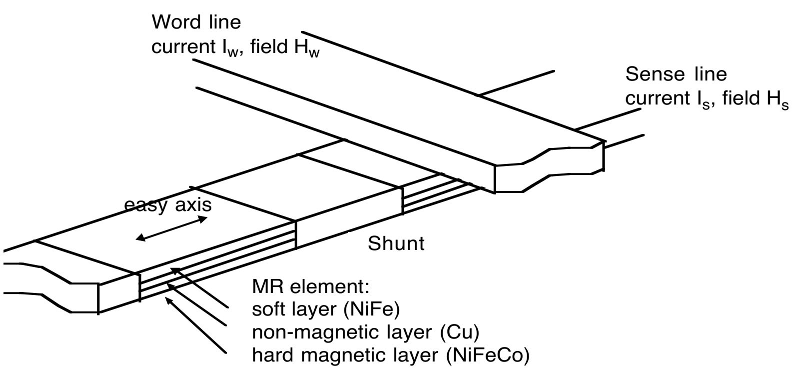
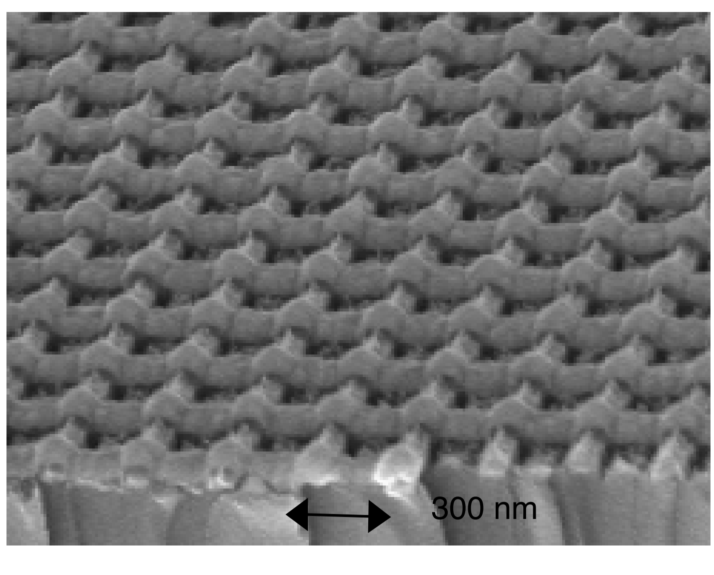
MRAMs are solid-state non-volatile magnetic storage devices in which each bit of data is stored an a small magnetoresistive element. A typical magnetoresistive (MR) element consists of two different magnetic layers, for instance Cobalt and Permalloy (a nickel-iron alloy). Each element can store one bit of data, depending on the magnetic orientation of the cobalt layer. These devices are competitors to the well-known silicon memory chips used in every computer, but they are superior in one important way: the data remain stored in the MRAM chip even when the power is switched off, so do not need to be reloaded like the data in a semiconductor memory. This makes MRAMs an attractive alternative for applications such as low power portable electronics and satellites.



Schematic of MRAM structure, which consists of an array of parallel sense lines and parallel word lines. The MR elements are connected in series. Magnetic fields generated by currents passed simultaneously through a sense line and a word line write the element at the intersection of the two lines. To read, resistance changes in the sense line caused by a smaller wordline current are measured.

The key part of the MRAM device is the MR element. To make a successful device, the field needed to reverse the magnetization of both the Cobalt and the Permalloy layers must be controlled. However, these fields depend on the shape and size of the MR element, and its internal structure. Commercial MRAM devices incorporate MR elements of a few microns in size, which limits the amount of data that can be stored on one chip. However, during this NSF-funded project, we have developed methods for making very small MR elements, with dimensions of order 0.1 micron, using an unusual fabrication technique known as interference lithography. We have shown how the magnetic behavior of the elements depends on their shape and size, and have developed MRAM prototypes with cell sizes of 0.3 microns. This research could be useful in the next generation of high-capacity MRAM devices.



A prototype MRAM device. The horizontal lines are the word lines, while the lines running nearly vertically are the sense lines. At each intersection there is a 100nm x 150 nm MR element. The cell size is 300 nm x 400 nm.