Fabrication and metrology of novel magnetic tunnel junctions in the ultra-thin barrier limit

Within a broader program of exploring methods to fabricate structures with novel electronic properties at the nanometer scale, we are using highly charged ions (HCIs) to produce ensembles of nano-features within magnetic tunnel junctions (MTJ). Technologically, MTJs are a major component of magnetic random access memory (MRAM) architectures which are expected to eventually replace hard drives and are already standard components in automotive and aviation applications. A leading technical challenge is producing MTJs whose resistance-area (RA) product (two dimensional resistivity) fall in a range that allows for both high signal-to-noise, fast write times, and long lifetimes. Contemporary approaches have focused on producing MTJ layer structures with uniform RA products, whereas our approach is to produce a layer structure that is a superposition of high and low RA product regions, whose average RA product is determined by the relative density of each.

Our strategy is to irradiate high quality oxides with very dilute doses of highly charged ions (HCIs) that introduce local regions of thinned oxide at each individual ion's impact site. The HCI impact sites result in ultra-thin (< 1 nm) regions of the tunnel barrier, Characterization of these ultra-thin barrier has precipitated the development of new measurement and analytical techniques. In the regime where HCI irradiation has reduced the native RA product by many orders of magnitude, a negative resistance error common to all cross-wire devices has been discovered. Modeling and experimental work resulted in high accuracy correction to these deleterious effects, extended the meaningful range of measurements on crossed-wire devices to extremely small resistances.

To understand the magnetic switching behavior of these thin films, a new first-order reversal curve technique (FORC) has been demonstrated which reveals distribution of coercive and interaction fields properties of the magnetic domains. Shown in the figure is a FORC diagram that illustrates the density of magnetic domain switching as a function of the coercive and interaction fields within one of our MTJ structures. This technique is expected to provide new insight into a wide range of technologically important magnetic devices.

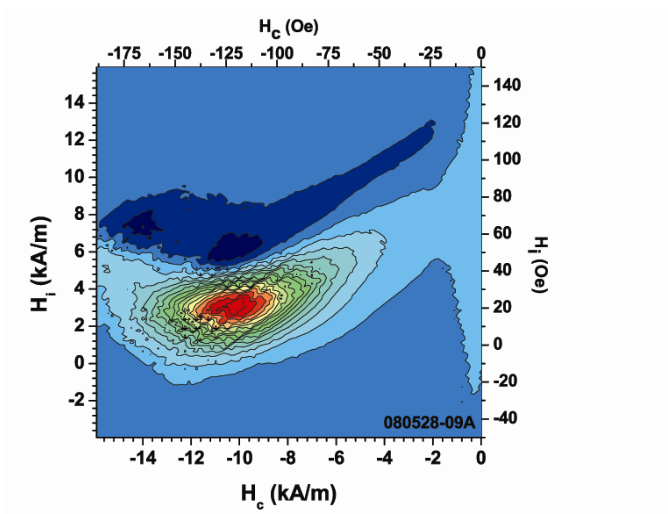

Figure 2.2: FORC diagram that shows the density of magnetic domain switching as a function of the coercive and interaction fields.

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