Measuring the Anomalous Hall Effect on GdCo Nanodots

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Abstract

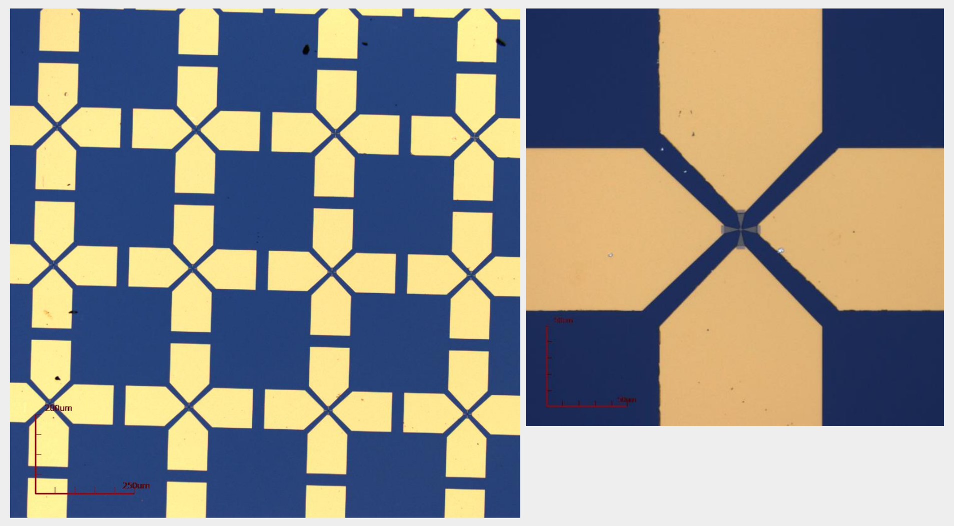
Until very recently, magnetic nanodots used in both magnetic logic and magnetic random access memory have required spin-polarized currents to transfer the angular momentum needed to switch the magnetization, and thereby switch the magnetic logic bit. This particular switching process, however, is limited to nanosecond or greater timescales – much too slow for future electronics. All-Optical Switching accomplishes this phenomenon 1000 times faster: at femtosecond timescales. Since the electronics of the future will be smaller in scale, it is also necessary to characterize the magnetization switching in small-scale devices. The switching is measured using nanodots arranged on anomalous Hall effect crossbars. Various anomalous Hall effect crossbar designs are examined and detection of single nanodot switching of the gadolinium cobalt (GdCo) nanodots is demonstrated. This work helps advance technology by helping to bring about ultrafast and energy efficient memory storage.

Motivation

Despite increasing demand for high speed computing, digital computing speeds have remained stagnant in recent years. This stagnation is due in part to limited progress in the logic on/off switching speeds. This project aims to bring research one step closer to faster computing by measuring electronic detection of nanomagnetic memory bits.

Background

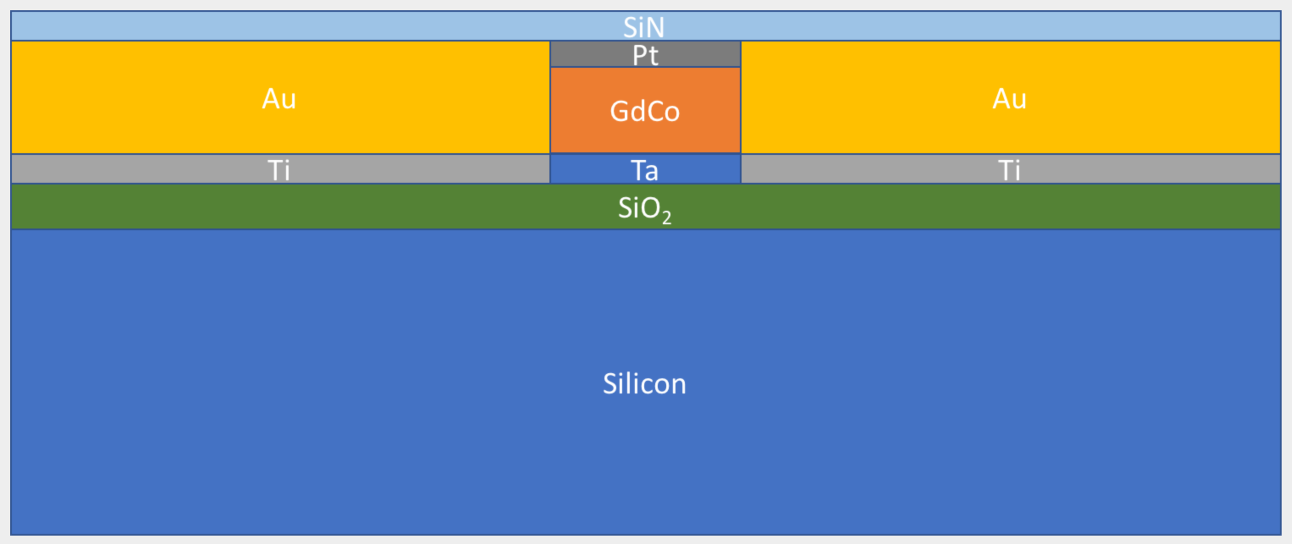
While the up or down magnetization state of most magnetic material is controlled only by a magnetic field, our magnetic material, GdCo, can have its magnetization reversed by a laser through All-Optical Switching. The anomalous Hall effect can be described as follows: Electrons flowing as current through this magnetic material will be randomly spin up or spin down. The magnetization of the material will alter the original spin direction of electrons with the opposite spin direction. There will be a build up on either side of the magnetic material of electrons with opposite spins. The side with less electrons serves as the reference to the other side, and a voltage can be measured across the material.

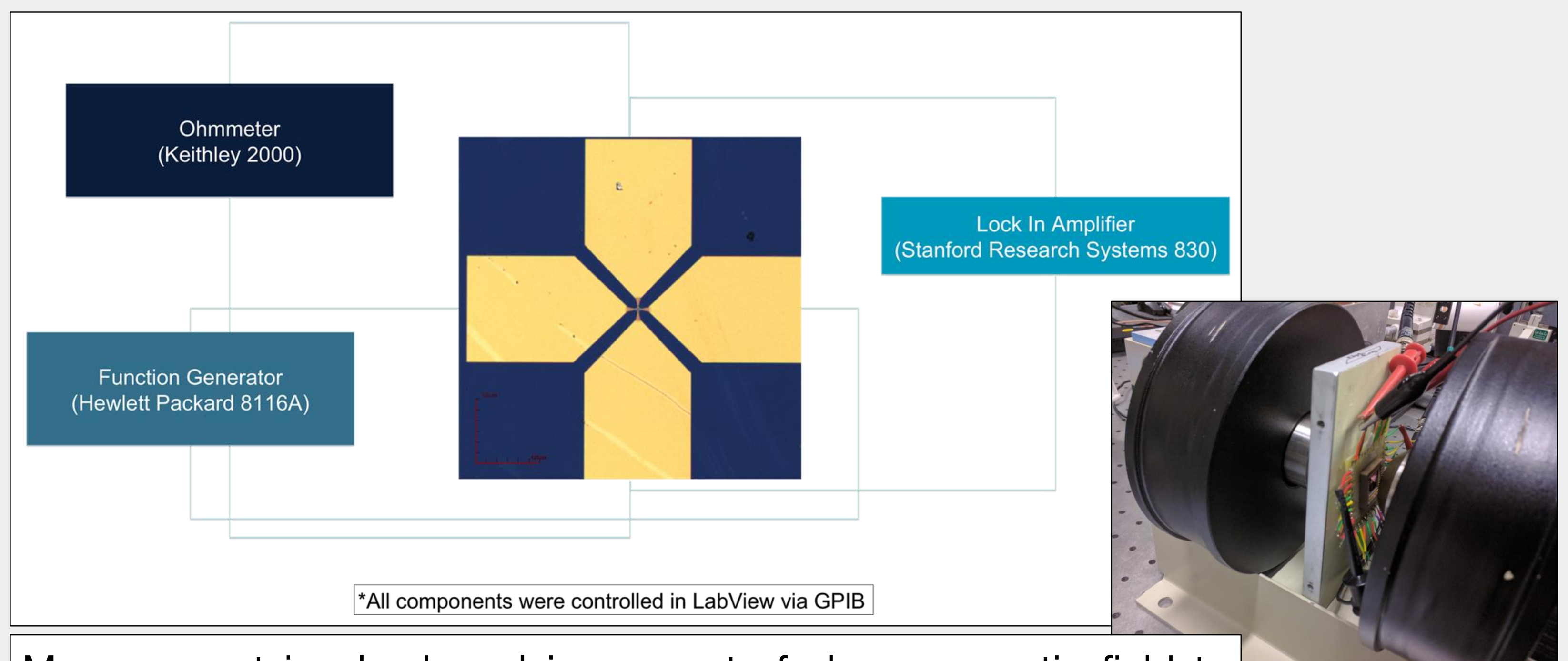


Left: Section of samples with magnetic crossbars
Right: A close-up of a single device with magnetic crossbars

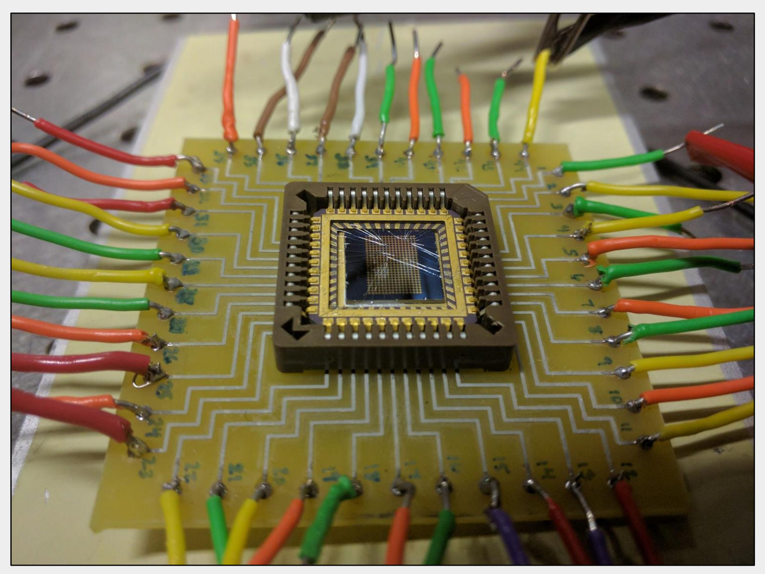
Methods

The samples were fabricated on a silicon substrate with 100 nm of SiO_2 over which the crossbars were patterned. The figure on the right shows a cross section of the material stack with the gold crossbars on both sides and the magnetic nanodot stack in the center. In the magnetic topology, the crossbars are also magnetic and only the contact pads are gold.



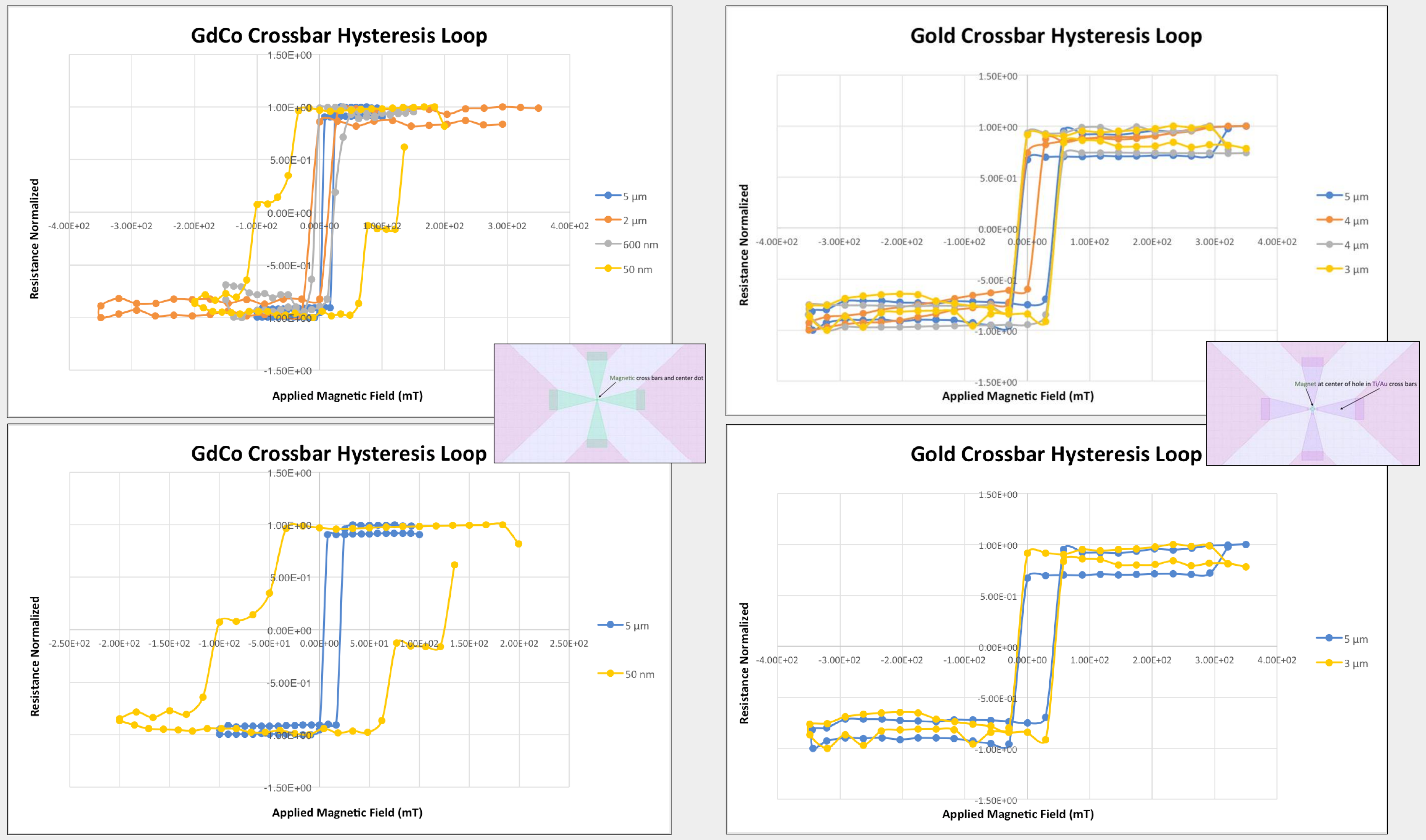


Measurement involved applying an out-of-plane magnetic field to the nanodot using Hemholtz coils while resistance of the crossbar was measured. Instruments applied current to one pair of crossbars. Voltage was measured across the other pair.



The chip was wirebonded into a package for PCB-level testing using the measurement setup illustrated on the left.

Results



The top graphs show a compilation of all measurements taken for the samples with magnetic and metallic crossbars. The bottom graphs show only the largest and smallest samples that were measured with each topology to show the difference in switching fields as dot size scales.

Next Steps

These experiments showed promising results for reliably switching and measuring switching in gadolinium cobalt nanodots through the use of Hemholtz coils to switch the magnetization of these nanodots. Following these experiments, it will be necessary to demonstrate magnetization switching optically using a laser. Research is already being done to reliably switch nanodots with a laser. The incorporation with this project would be measuring the resistance levels before and after the laser switches the polarity of the nanodots.

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