Characterization of Ultrafast Switching Behavior with Scaling of GdCo Nanomagnetic Dots

Daisy O'Mahoney[1], Amal El- Ghazaly[2], Ph. D., Charles-Henri Lambert[2], Ph. D., P. Nigel Brown[3], and Jeffrey Bokor[2], Ph.D

[1]Santa Barbara City College, [2]Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, [3]Laney College

2017 Transfer-to-Excellence Research Experiences for Undergraduates Program (TTE REU Program)

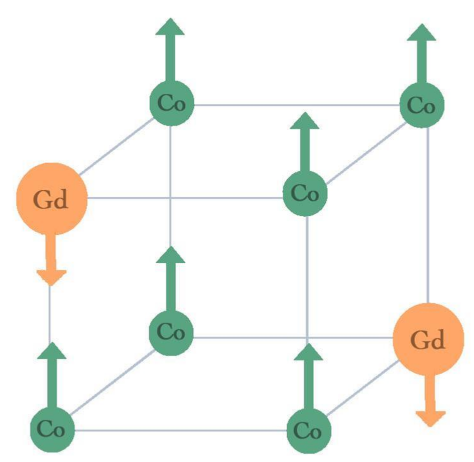
Abstract

This work aims to bring research closer to faster computing by characterizing the ultrafast femtosecond switching behavior of nanomagnetic GdCo memory bits without the use of spin-polarized currents, by using ultrafast optical laser pulses. While all-optical magnetization reversal was demonstrated in large GdFeCo magnetic dots using only linearly polarized light, it is important to characterize the switching behavior of these dots as they are scaled down dramatically in size. A Ti-Sapphire laser was directed at arrays of GdCo dots varying in diameter from 5µm to 50nm and was used to measure the all-optical switching, hysteresis loops, and time-domain switching behavior of these dots as a function of their size.

Background

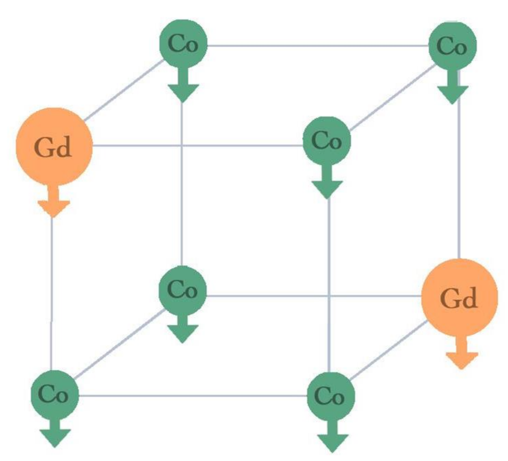
All-Optical Switching of GdCo

Before Laser Pulse



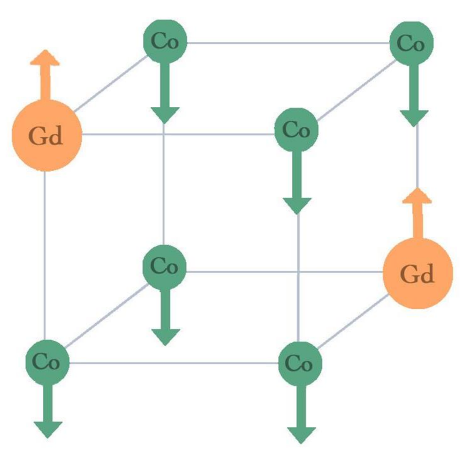
- GdCo is a ferrimagnet, where Gd and Co have magnetic poles that point in opposite directions.
- Because of this structure, it is able to reverse its poles without a magnetic field.

During Laser Pulse



- During the laser pulse, the Co demagnetizes first because of its smaller mass.
- It then aligns with the still magnetized Gd to create a transient ferromagnetic state.

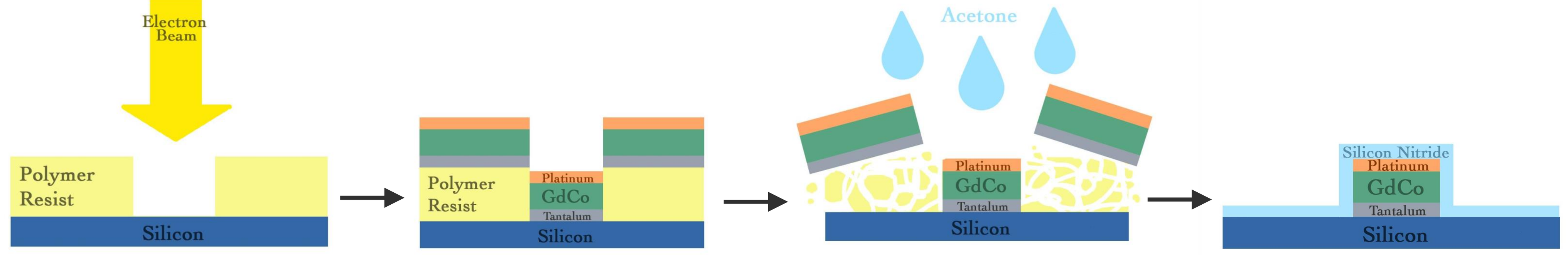
After Laser Pulse



- After the pulse, the Gd demagnetizes and, because it wants to have its pole in the opposite direction of the Co, it switches direction.
- At this point, the net magnetic direction has been reversed.

Methods

Lift-off Fabrication Process



- Silicon wafer is covered with polymer resist
- The resist is etched using electron beam

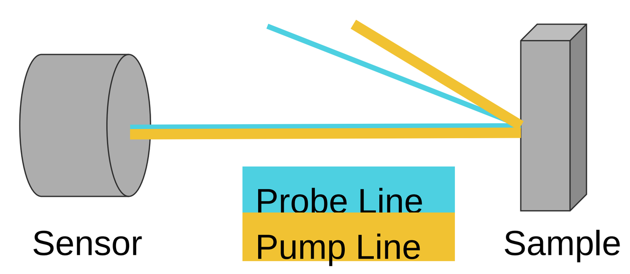
- Tantalum is deposited
- $Gd_{21}Co_{79}$ is grown using sputtering process
- Platinum is added to prevent oxidation

- Resist is removed using acetone, leaving dot pattern

- Dots are then covered with a thin layer of Silicon Nitride to prevent oxidation along the sides

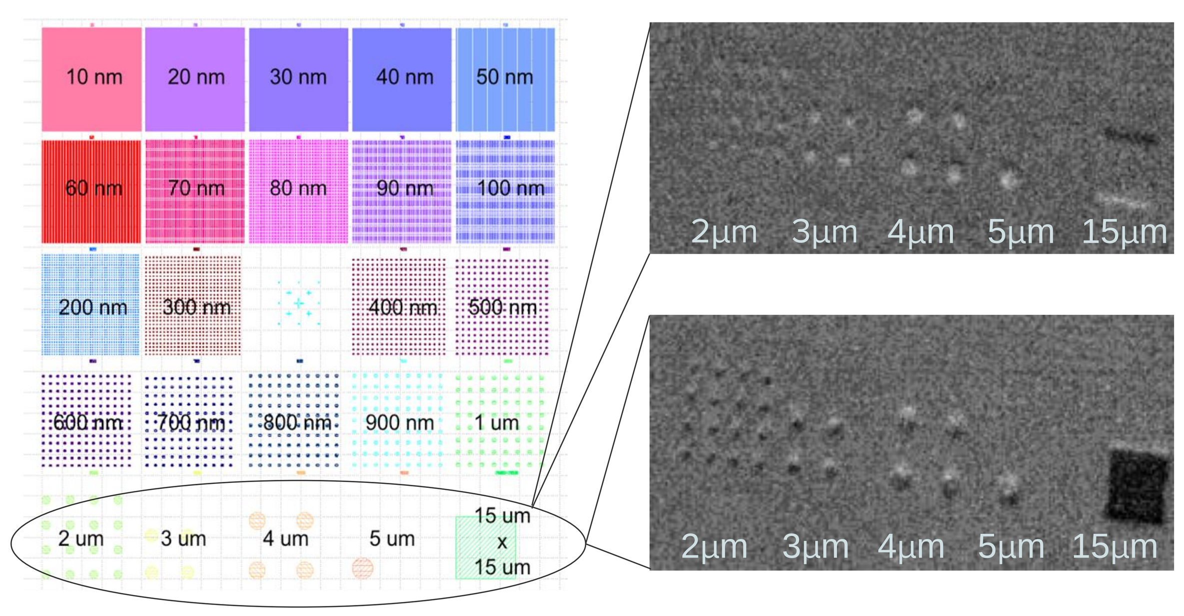
Testing with Laser Magneto-Optic Kerr Effect (MOKE)

- Samples were tested using MOKE, which reads the change in the probe laser after interacting with the laser.
- To find switching field, an alternating magnetic field was applied to sample and Laser MOKE was used to graph it.
- For all optical switching, Laser MOKE was used to look at the sample before and after a single pulse from the pump.



Results

All-Optical Switching



All-optical switching observed on dots from 5 µm to 200 nm

However, 200 nm dots had a nickel impurity which caused a two-step switch

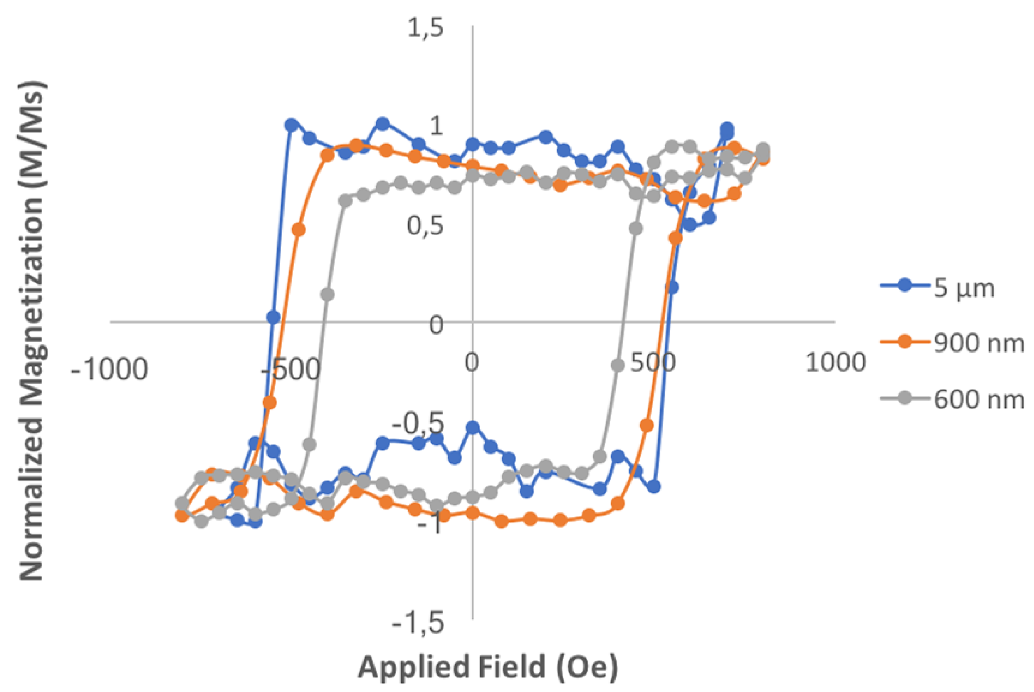
Usable $Gd_{21}Co_{79}$ dots without the impurity were only fabricated down to 500 nm

Hysteresis Measurements

Normalized magnetic hysteresis loops of 5 µm, 1 µm, and 600 nm diameter dots of $Gd_{21}Co_{79}$ – all dots successfully achieved all-optical switching

For dots from 5 µm to 500 nm, switching field remained relatively constant

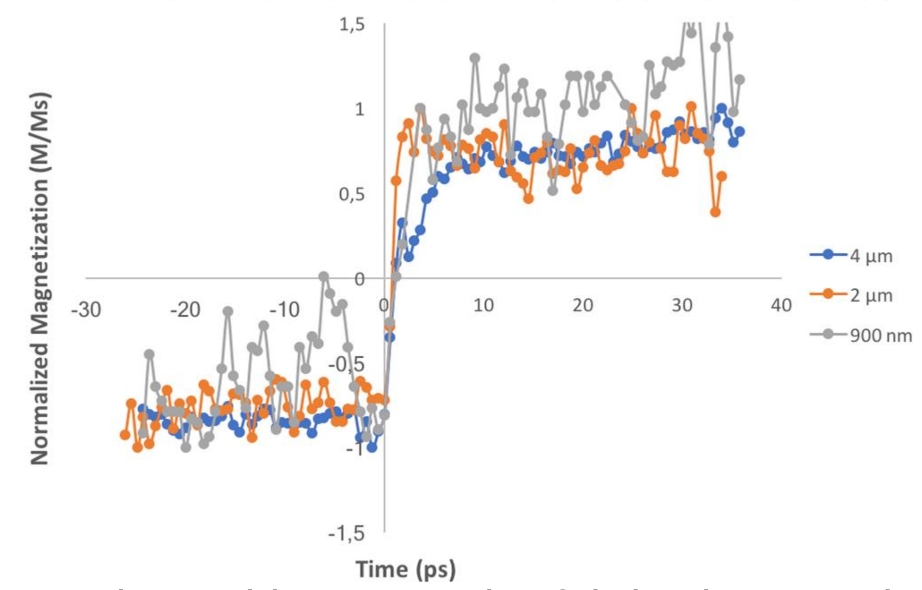
Dots below 500 nm were in-plane



Future Research

Preliminary time-resolved measurements of all-optical switching were taken for dots 5µm to 800 nm. However, more measurements of smaller dots need to be taken before any conclusions can be drawn.

Time-Resolved Measurements



- To continue this research, fabrication needs to be improved to create smaller usable dots.
- Hysteresis, all-optical switching, and time-resolved measurements should be taken of dots as they are scaled down from 200 nm.

Conclusions

Originally, GdFeCo was being studied as a potential material for magnetic memory, but our findings show that GdCo is also a viable material that can switch all-optically and is easier to fabricate due to Cobalt's tendency to grow out-of-plane, which ensures perpendicular anisotropy of the dots. As dots were scaled down, the switching field remained constant for sizes down to 500 nm, which allowed us to predict that this trend should continue as dots are scaled smaller. All-optical switching also continued as dots were scaled down to 200 nm, which suggests that size does not affect this material's ability to switch all-optically.

Acknowledgements

I would like to thank the National Science Foundation, the University of California, Berkeley, and the Center for Energy Efficient Electronics Science for funding and making this research possible. I would also like to thank Amal El-Ghazaly, Nigel Brown, Jon Gorchon, Charles-Henri Lambert, and Professor Jeffrey Bokor, and all of my fellow summer 2017 REU interns. I would finally like to thank Raeanne Napoleon for always inspiring and encouraging me in my pursuit of higher education in the sciences.

Contact Information

Email:
daisyaomahoney@gmail.com
Phone:
(805) 680-5734

Support Information
This work was funded by National Science Foundation Award ECCS-0939514 & ECCS-1461157