

# **ELECTRODEPOSITION OF COBALT NANODOTS**

**Dexter Nigos, Randy Dumas, Dr. Kai Liu**

University of California Davis  
One Shield Ave, Davis, CA 95616

## **Abstract:**

Arrays of Cobalt nanodots have been fabricated using a pulsed electrodeposition process. Tri-layer Cu/Co/Cu samples were used to prevent oxidation of the Co layer. Our dots have diameters of 200-400 nm and thickness of 20 - 100 nm. Magnetic properties of the dots were measured using Vibrating Sample Magnetometer (VSM). Measurements were made by applying a field both in plane and out of plane of our samples. The samples hysteresis loops are then analyzed and determined whether the loops show vortex state magnetic reversal.

## **Introduction:**

Over the past few years, there has been an increasing interest in studying magnetic materials on the submicron-scale level. From a scientific point of view, because of their extremely small size, nanostructured magnetic materials often possess different magnetic properties compared to their bulk counterparts. From a technological point of view, these new and enhanced properties lead to some potential applications. One application for these nanostructured magnetic materials is for patterned magnetic recording media. In a conventional hard disk, data is stored in small bit cell region. A standard bit cell contains 50-100 randomly ordered grains (Fig. 1). Currently, the ultimate goal is to create patterned single-grain size bit cell. These patterned single-grain size bit cell, or dots, can increase the bit cell density significantly thus allowing more storage space.

The characteristic length scale important in our system is the domain wall width. In large scales, magnetic materials often display complex multi-domain patterns during magnetic reversal. A system is large scale if its size is much bigger than the domain wall width (domain wall width  $\sim 60\text{nm}$ ). In a multi-domain phase (Fig. 2a), their magnetic reversal involves complex domain expansion and domain wall movement. As the size of the materials is significantly reduced ( $\sim$ domain wall width), simple patterns are formed. In single-domain phase (Fig. 2b),

magnetic reversal occurs when their magnetization rotates coherently. With the proper size and shape vortex phase magnetic reversal can occur (Fig. 2c). In comparison to multi-domain and single-domain magnetic reversal, vortex phase has a more interesting behavior. Vortex state magnetic reversal has abrupt changes in magnetization due to the nucleation and annihilation of the vortex from the dot. Another characteristic of a vortex state hysteresis loop is pinching type behavior near zero external field. The main goal of this experiment is to be able to fabricate circular cobalt nanodots with the proper thickness and identify vortices within the dots by studying their magnetic reversal using the VSM.

### **Fabrication:**

We begin the fabrication of the cobalt nanodots with a nuclepore track-etch membrane filter. This filter is made out of a polycarbonate film with sharply defined cylindrical pores. One side of the filter is then plated with copper. The copper is plated by sputtering. After one side of the polycarbonate filter has been plated with copper, electrodeposition process can then take place. Electrodeposition is a process of depositing materials from an electrolyte by the passage of electrical current. A schematic of a typical electrodeposition cell is shown in Fig. 3. With the plated filter, a small glass tube is placed on top. An o-ring is placed between the glass tube and the filter to create a seal. An electrolyte can then be poured inside the tube, followed by the reference electrode and counter electrode. For this experiment, our electrolyte consists of 50g/L of Cobalt (II) Sulfate Heptahydrate and 0.5g/L of Copper (II) Sulfate Pentahydrate. 40g/L of Boric Acid was used as a buffer for the solution to have a pH of about 3.8. When a small potential difference is applied between the counter and working electrode, cobalt and copper ions in the electrolyte will then migrate inside the cylindrical pores. The metal ions are then reduced and form our tri-layer sample. Our tri-layer samples are created using pulse-deposition process (Fig. 4). During this process, we periodically switched between 2 different plating potential values to allow alternating layer of sample to be deposited. During the deposition of cobalt, copper ions were also being deposited as an impurity. The amount of copper in our cobalt sample is negligible since the electrolyte we used had a very low concentration of copper. The capping layer of copper is necessary to prevent our cobalt dots from oxidation.

There were two ways we determined the dot thickness during the electrodeposition process. One is by monitoring how much charge was being transferred throughout the electrodeposition process. With the total number of coulombs transferred, we calculated the mass of cobalt deposited into the filter. At 100% efficiency of the electroplating we have 0.3054mg/Coulomb. The calculated mass of cobalt is related to the approximate thickness of the dots in our sample because we know the density of cobalt is 8.9 grams/cm<sup>3</sup>. Another way to determine the thickness of the dots is to measure the saturation magnetization of the sample using the VSM. With the measured magnetization of the sample, the volume of cobalt in the sample can then be calculated because we know the saturation magnetization of cobalt is 1400emu/cm<sup>3</sup>.

### **Magnetometry:**

Many samples of Cobalt dots with different diameters and thickness were prepared, with diameters of 200nm and 400nm and thickness of 20nm-100nm. Magnetic properties of the samples were measured with the VSM. The total area of our sample is about 1 cm<sup>2</sup>. It is necessary to measure stack of samples to obtain a sufficiently large signal. The stacked samples are then mounted to the VSM for measurements. Two different magnetic measurements were made. The first involved applying a field in the plane of the sample. The other measurement involved applying the field out of the plane of the sample. Hysteresis loops are then recorded and analyzed.

Our fabricated 200nm diameter with thickness from 20 - 100nm samples show no sign of vortex phase magnetic reversal properties (Fig 5). The hysteresis loops of the samples and the FORC measurements reveal single-domain magnetic reversal behavior. No abrupt changes in magnetization were discovered from the magnetic reversal of the samples. On all 200nm diameter samples, no pinch at near zero field were found either.

Instead of 200nm, we increased the diameter of our samples to 400nm and started our fabrication with very thin dots (thickness of dots is in the order of 10nm). One hysteresis loop of our 400nm samples shows an interesting small "pinch" near zero field (Fig. 6). Since this small "pinch" might be an indicative of having vortices within our dots further analysis was conducted. First

Order Reversal Curve (FORC) was used to further investigate the sample's magnetic properties. Unfortunately, our FORC measurements cannot conclude the existence of vortices within this particular sample.

**Conclusion:**

The arrays of cobalt nanodots with diameter of 200 and 400nm and thickness of 20-100nm were fabricated. Tri-layer of Copper-Cobalt-Copper samples were fabricated using pulse-deposition process to prevent oxidation. The magnetic reversal behavior of the dots was investigated using the Vibrating Sample Magnetometer. The First Order Reversal Curve (FORC) was used for further analysis of the magnetic behavior of our samples. As we increase the thickness from 20-90nm of our 200nm diameter samples, the hysteresis loops and FORC measurements showed characteristics of an array of single-domain particles. Furthermore, our 400nm diameter samples also showed characteristics of single-domain particles.

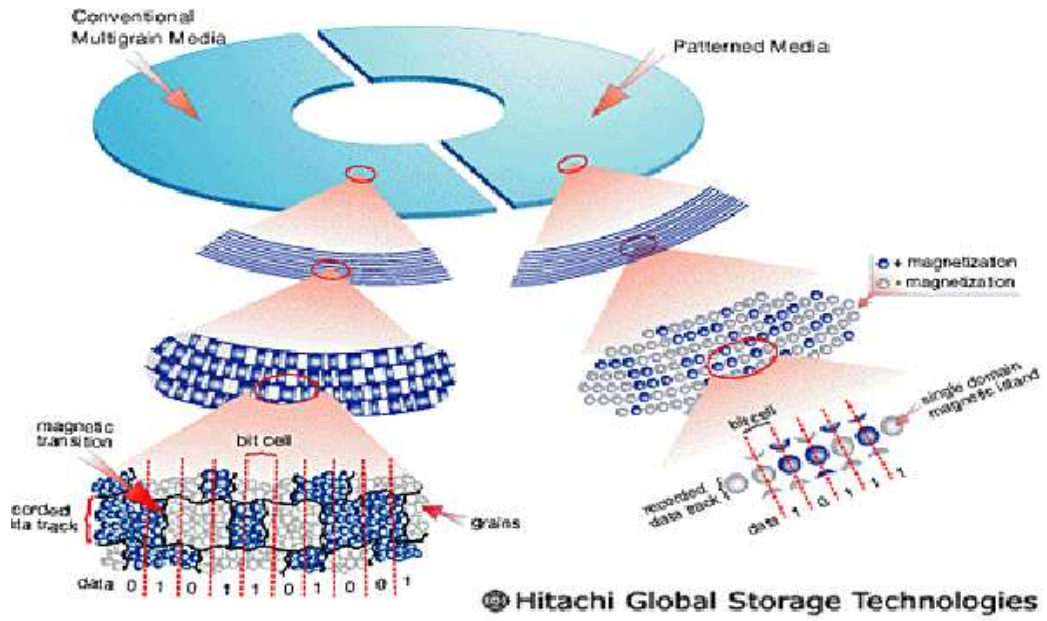


Fig. 1: Conventional Multigrain VS Patterned Media

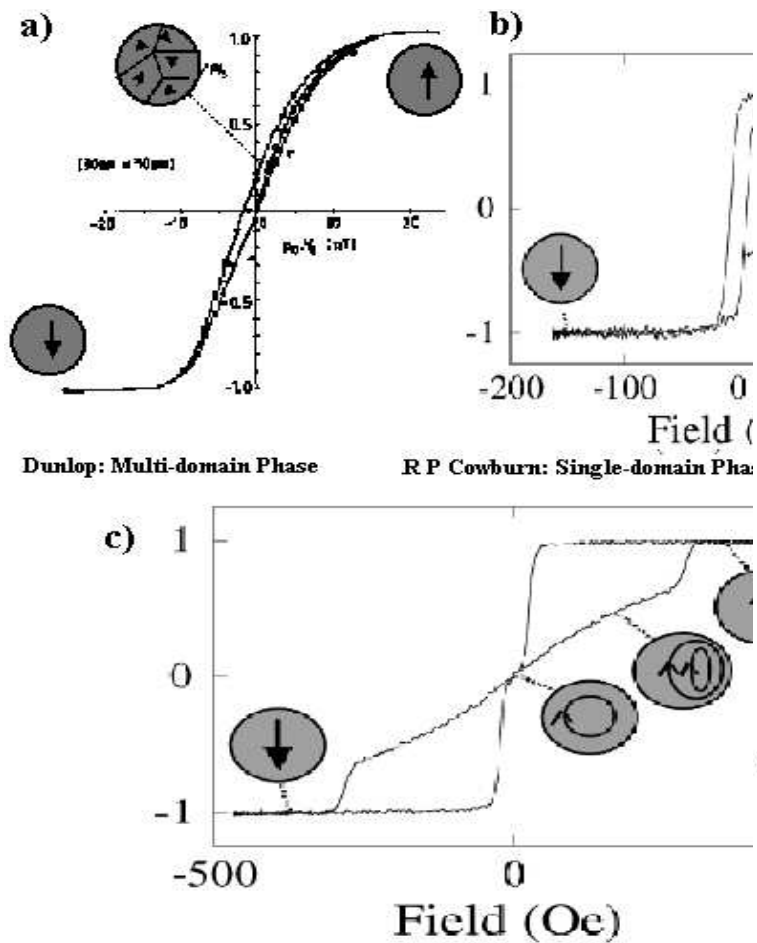


Fig. 2: a) Multi-Domain Phase, b) Single-Domain Phase

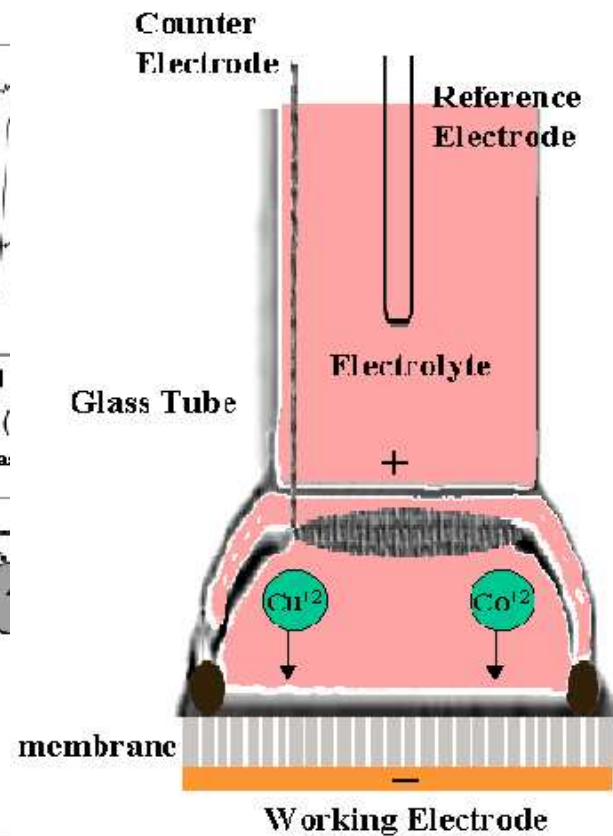


Fig. 3: Electrodeposition Cell

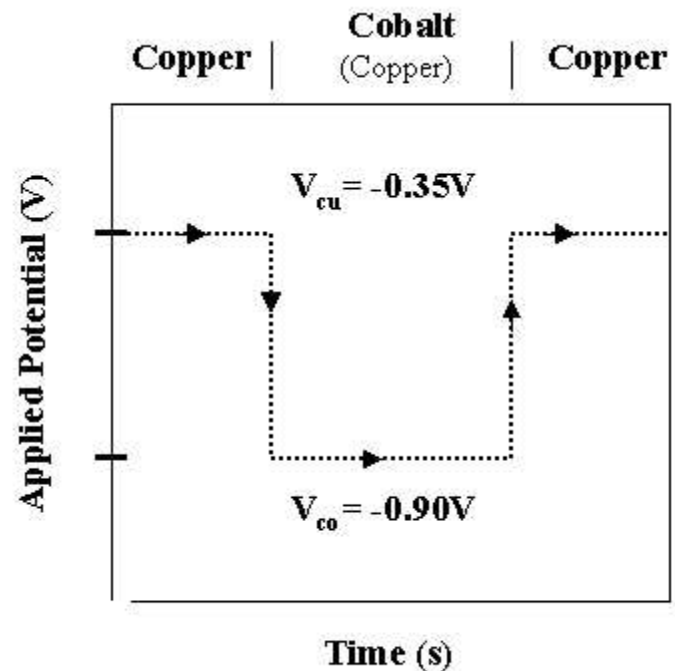


Fig. 4 Pulse-Deposition Process

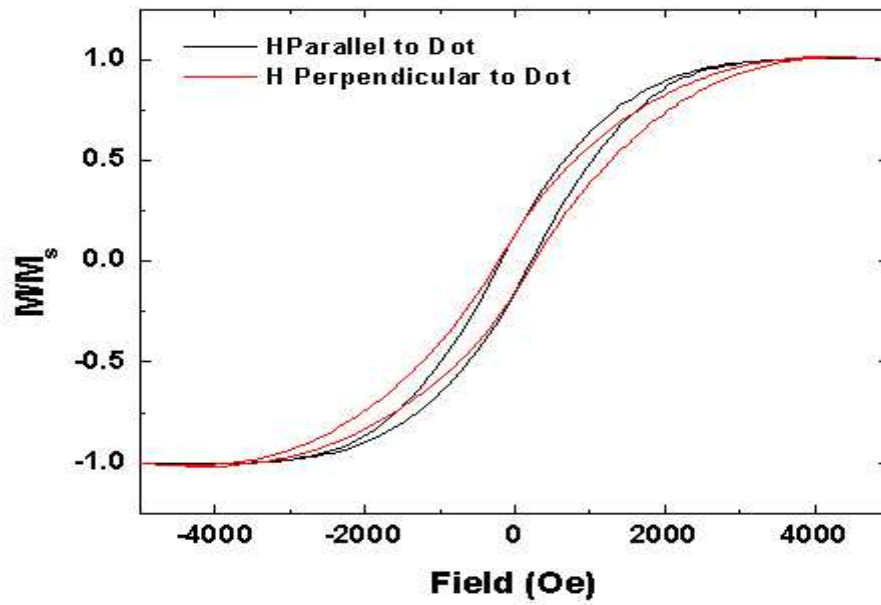


Fig. 5 Hysteresis Loop Cobalt Nanodots

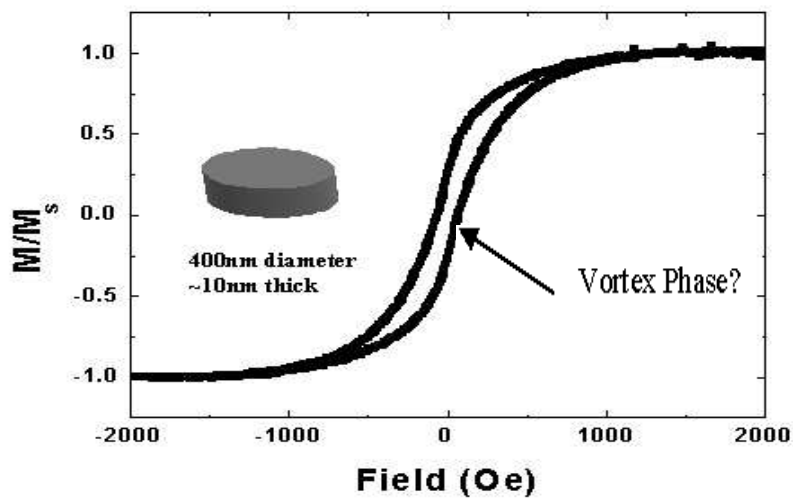


Fig. 6 Minor Pinch at Near Zero Field