Application of Gettering Layers for Low Temperature Conversion of Magnetic Oxides into Ferromagnetic Metals in Thin Films, Multilayers, and Nanostructured Arrays

Wenlan Qiu, Long Chang, Dmitri Litvinov
University of Houston, Houston, TX 77004
wqiu@uh.edu

Nanoscale patterning of magnetic metals and their alloys remains a significant challenge due to the lack of reactive-ion etching (RIE) chemistries producing volatile compounds of magnetic elements[1,2]. Patterning is typically achieved either via a lift-off process, ion milling or wet etching, all facing fabrication issues such as fencing, shadowing, edge damage, and redeposition[2,3]. Alternatively, electrochemical deposition may circumvent these issues, but is difficult to make complex structures, i.e., Co/Pd or Co/Pt multilayers, and CoCrPtX alloys[3], which are widely studied to be the potential candidates for magnetic recording media with areal density beyond 1 Tb/in^2.

This work demonstrates conversion of nonmagnetic cobalt oxide (CoO) into ferromagnetic cobalt (Co) in thin films, multilayers, and nanostructured arrays by low temperature annealing in the presence of tantalum (Ta) gettering layers. Thin film of CoO sandwiched between Ta seed and capping layers can be effectively reduced to Co thin film by annealing at 200 ˚C, as showed in Figure 1, whereas CoO does not exhibit ferromagnetic properties at room temperature and is stable at up to 400 ˚C[4]. The CoO reduction, $5CoO + 2Ta = 5Co + Ta_2O_5$ (−1.15kJ/g), is attributed to the thermodynamically driven gettering of oxygen by Ta, which is confirmed by XPS spectra in Figure 2. Likewise, annealing at 200 ˚C of a nonmagnetic $[CoO/Pd]_{10}$ results in the conversion into a magnetic $[Co/Pd]_{10}$ with perpendicular anisotropy. Figure 3 compares the switching field of $[Co/Pd]_{10}$ and a set of annealed $[CoO/Pd]_{10}$ that are pattened into 200 nm squares.

A nanopatterning approach is introduced where CoO/Pd multilayer is locally reduced into Co/Pd multilayer to achieve magnetic nanostructured array in the presence of Ta islands. Schematic diagram of this scheme and the experimental result are presented in Figure 4. This technique can potentially be adapted to other systems for which thermodynamically favorable combination of oxide and gettering layers can be identified.

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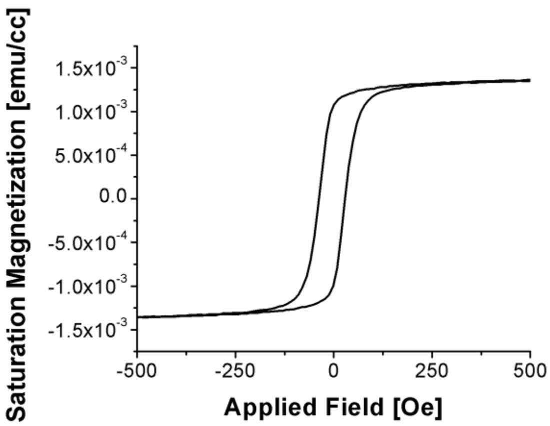

Figure 1: Hysteresis loop of annealed Ta/CoO/Ta

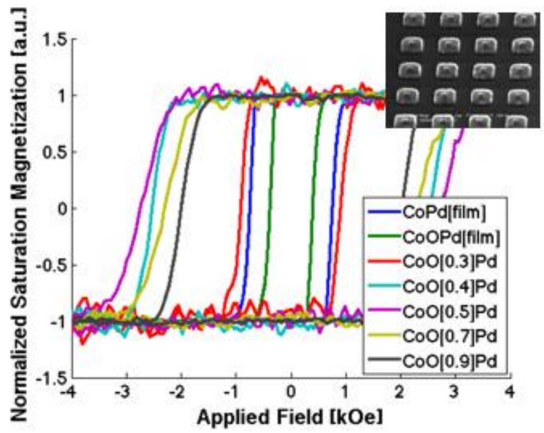

Figure 3: Comparison of switching filed properties of annealed $[CoO/Pd]_{10}$ thin films

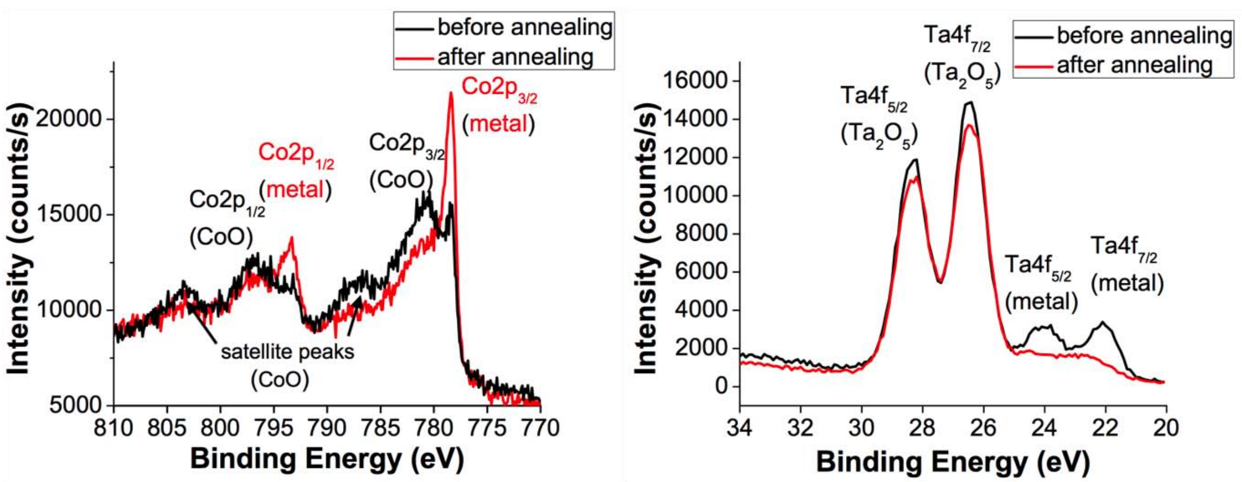

Figure 2: XPS spectra of Co and Ta positions indicating the redox reaction during annealing

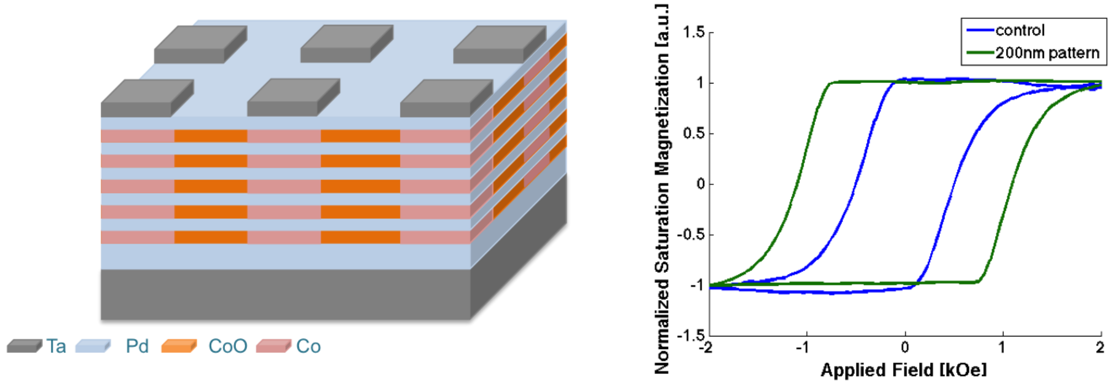

Figure 4: Proposed nanoscale patterning scheme and experimental result