Co and Co-Pt Nanoparticles Formed in Silica by Ion Implantation

A. E. Malik[a,b], K. Belay[b], D. J. Llewellyn[b,d], W.D. Hutchison[a], K. Nishmura[c] and R. Elliman[b]

[a] *School of Physical, Environmental and Mathematical Sciences, The University of New South Wales at ADFA, Canberra ACT 2600.*

[b] *Electronic Materials Engineering Department, Research School of Physics and Engineering, Australian National University, Canberra, ACT 0200, Australia.*

[c] *Graduate School of Science and Engineering, University of Toyama, Toyama, Japan.*

[b, d] *Centre for Advanced Microscopy, Australian National University, Canberra, ACT 0200, Australia.*

Corresponding author: Email aem109@anu.edu.au

Abstract: Nanoparticles of metallic cobalt and cobalt-platinum alloy have been synthesised via ion implantation and thermal annealing. The size and spatial distributions of the resulting nanoparticles were investigated as a function of annealing temperature, for temperatures up to 900°C, and correlated with their magnetic properties.

1 Introduction: Co-Pt nanoparticles are of particular interest for ultra-high-density magnetic recording media and have been produced by a range of thin film deposition techniques [4-5] (e.g. molecular beam epitaxy, electron beam evaporation, electron deposition etc) due to their magneto crystalline anisotropy, chemical stability and high Curie temperature [6]. Recent studies have investigated the synthesis of cobalt nanoparticles in silica by ion implantation [1-3] but few have investigated the magnetic properties of such particles or their alloys. In this study we report the synthesis of Co and Co-Pt alloy nanoparticles and the effect of alloying and processing on their magnetic properties.

2 Experimental: Si wafers with a 100nm thick, thermally grown SiO_2 surface layer were implanted with 50 keV Co ions or 100 keV Pt ions with fluences of 6×10^{16} ions/cm^2, or for the Co-Pt alloy, sequentially implanted with Co and then Pt ions each with a fluence of 3×10^{16} ions/cm^2. According to the Monte-Carlo ion-range simulation code SRIM 2007 [7], the average range of both Co and Pt ions in SiO_2 is ~43 nm for the above mentioned energies.

The implanted samples were annealed separately at 500°C, 700°C, 900°C for 1 hour to study the effect of annealing temperature on the size and distribution of nanoparticles, which were determined from transmission electron microscopy of sample cross-sections.

3 Results and Discussion: Fig. 1 shows the TEM images of the Co-implanted sample as a function of annealing temperature. At low temperatures the nucleation and growth of nanoparticles is limited by the lack of diffusion and only small particles are observed, concentrated at the projected range of implanted cobalt distribution. As the annealing temperature increases, the size of the nanoparticles increases and some long-range transport of Co is observed. This is illustrated in Figs. 1b and 1c for samples annealed at 700°C and 900°C, respectively. During

978-1-4244-7333-5/10/$26.00 ©2010 IEEE

annealing at 900°C cobalt atoms easily diffuse to the surface and SiO_2/Si interface forming a bimodal or trimodal depth distribution as shown in fig. 1c.

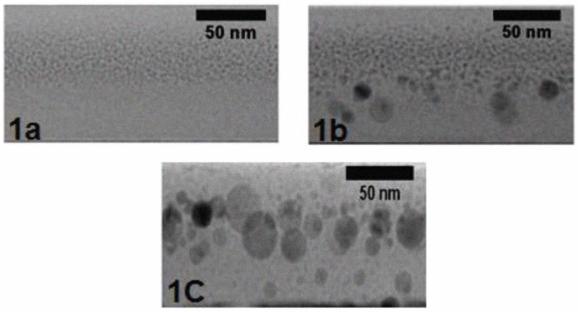

Fig. 1 Cross-sectional TEM images of Co implanted samples annealed at 500°C (1a), 700°C (1b) and 900°C (1c) for one hour.

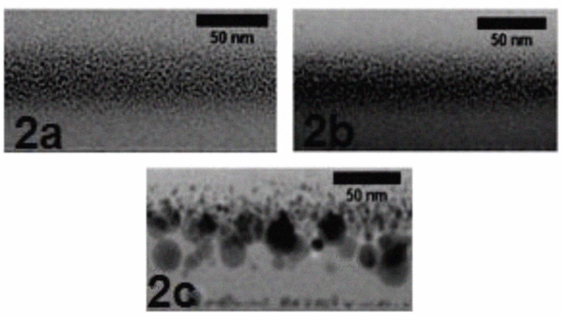

Fig. 2 Cross-sectional TEM images of Co-Pt implanted samples annealed at 500°C (1a), 700°C (1b) and 900°C (1c) for one hour.

The evolution of nanoparticles in samples implanted with Co and Pt is shown in Fig. 2. Alloying of Co and Pt leads to smaller particles on average than for the equivalent total fluence of Co-only due to the low diffusivity of Pt in SiO_2.

Magnetic characterisation of these samples was carried out with a maximum applied field of ±10000 Oe using a super conducting quantum interference device (SQUID) in hysteresis mode. The effect of size of nanoparticles and their type (i.e. metallic or alloy) on magnetization was observed. It was found that the CoPt alloy show an enhanced magnetic character in all the cases studied. Due to the addition of Pt to Co increased coercivity of the CoPt sample annealed at all the temperatures.

References:

[1] Gilliot M, En Naciri A, Johann L, Stoquert J P, Grob J J and Muller D 2007 *J. Appl. Phys.* **101** 014319.

[2] Orleans C D, Cerruti C, Estournes C, Grob C J J, Guille J L, Haas F, Muller D, Richard
Plouet M and Stoquert J P 2003 *Nucl. Inst. Methods Phys. B* **209** 316.

[3] Mettei G, Maurizio C, de Julian C F, Mazzoldi P, Battaglin G, Canton P, Cattaruzza E, and Scian C 2006 *Nucl. Inst. Methods Phys. B* **250** 206.

[4] Ferrate F, Liveri V. T, 2005 Coll. Surf. A **259** 7.

[5] Yuan F. T, Chang H. W, Liao W. M, Hsiao S. N, Chen S. K, Yao Y. D, **2007** Appl. Phys. 101 09K526.

[6] Vlasova N. I, Kandaurova G. S and Shchegoleva N. N, 2000 J. Magn. Magn. Mater. **222** 138.

[7] Ziegler F, Biersack J P, Littmark U 1985 *The Stopping and Range of Ions in Solids*, (New-York: Pergamon) http://www.srim.org/.