Magnetic Force Microscopy of Ferromagnetic Nanoparticles Formed in Al_2O_3 by Ion Implantation

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The production of nanoparticles with controlled size is of great technological interest. It leads to catalysts with improved properties, to semiconductor nanocrystals with size-tunable optical properties[1], and to ultra high density magnetic recording materials[2]. Adequate sizes and distribution of particles may also lead to interesting magnetic properties[3]. We have used ion implantation to produce nanoparticles of ferromagnetic materials in α-Al_2O_3. Ion energy, dose, and temperature during the implantation as well as post-implantation annealing are parameters that control the size and distribution of the particles[1]. Results obtained by Magnetic Force Microscopy (MFM) on Al_2O_3 implanted with Fe and with Fe plus Pt will be presented. They will be compared to high-resolution TEM images and to the implant profiles measured by Rutherford Backscattering Spectrometry (RBS).

Fe implanted α-Al_2O_3 (0001)

In the MFM experiments, the surface topography was obtained by scanning in the contact tapping mode with a magnetized tip. After each scan line, the oscillating tip was lifted above the surface to acquire the phase image. Fig. 1a shows the two images for Al_2O_3 before Fe implantation, and the phase image (right) is featureless. Fig. 1b is the images for α-Al_2O_3 (c-oriented) implanted with Fe and annealed at 1100^0C. The dark spots in the phase image correspond to magnetic Fe particles that are situated 200-400 nm below the surface.

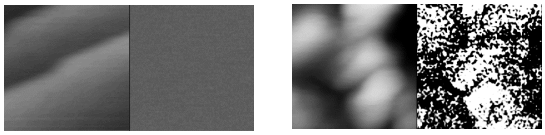

Fig.1a (0.5μm x 0.5μm) **Fig.1b** Fe Implanted Al_2O_3 350 keV,1E17 at cm^{-2},550^0C

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Fe + Pt implanted α-Al_2O_3 (0001)

FePt nanoparticles are known to exhibit a very high coercivity[2]. Fe and Pt were implanted into Al_2O_3 at energies chosen to give an overlap of the impurities profiles. The sample was imaged after annealing at 1100^0C during 2 hours with an Ar/4%H_2 flow and slow cooling. The post-implantation anneal is necessary to precipitate ferromagnetic FePt nanoparticles. Images of the sample were taken before and after magnetization in a magnetic field of 6.5 Tesla normal to the surface. The application of a strong magnetic field resulted in a better definition of the magnetic islands in the images. Fig.2 shows the topography and phase images of Fe+Pt implanted Al_2O_3 after magnetization. Analysis of the image indicates that more than 53% of the surveyed area is magnetic. The sample exhibits a high coercivity at room temperature (>1.5 Tesla). MFM results on FePt nanoparticles produced by a variety of conditions will be presented.

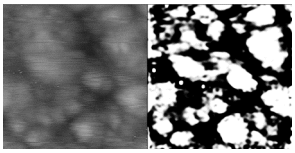

Fig 2 0.5 μm x 0.5 μm scans Topography (left) and Phase of Al_2O_3 implanted with Fe(350keV,1E17at.cm^{-2},550^0C) and Pt(910keV,8.2E16at.cm^{-2},500^0C).

References

[1] A. Meldrum, E. Sonder, R.A. Zuhr, I.M. Anderson, J.D. Budai, C.W. White, L.A. Boatner and D.O. Henderson, J. Mater. Res. Vol 14, No. 12, 4489-4502 (1999).
[2] Shouheng Sun, C.B. Murray, Dieter Weller, Liesl Folks and Andreas Moser, Science, Vol 287, 1989-1992, 17 March 2000.
[3] S. Honda, F.A. Modine, A. Meldrum, J.D. Budai, T.E. Haynes and L.A. Boatner, Appl. Phys. Lett., Vol 77, 711-713 (2000).