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Differences between in-plane and out-of-plane magnetoresistance: a texture or finite-size effect?

M. L. Sartorelli(1)*, E. R. Spada(1), A. S. da Rocha(1), L. M. da Silva(2), F. C. G. Gandra(2), A. P. Guimarães(3) and J. P. Sinnecker(3)

(1) Departamento de Física/Universidade Federal de Santa Catarina, Caixa Postal 476, CEP 88040-900, Florianópolis – SC, Brazil. e-mail: sart@fisica.ufsc.br
(2) IFGW, Unicamp, Caixa Postal 6165, CEP13083-970, Campinas – SP, Brazil
(3) CBPF, R. Dr. Xavier Sigaud, 150, CEP 22290-180, Rio de Janeiro – RJ, Brazil. E-mail: sinnecker@cbpf.br
* Corresponding author.

Abstract – Magnetoresistance measurements performed on textured cobalt continuous thin films and in antidot structures, with the applied field aligned either parallel, transverse (in-plane) or polar (out-of-plane) to the current direction, demonstrate that the geometrical size-effect previously observed in thin films is mainly caused by diffusive scattering at boundaries.

The spin-orbit interaction in ferromagnetic materials causes an increase in the scattering of electrons that move along the local magnetization direction as compared to those that move perpendicular to it. The magnitude of this effect is evaluated by the anisotropic magnetoresistance (AMR) ratio, defined as $(\rho_{//}-\rho_{\perp})/\rho_{//}$, in which $\rho_{//}$ and $\rho_{\perp}$ are the resistivities with the magnetization parallel and perpendicular to the current direction. In thin films, however, the AMR ratios measured at technical saturation, in transversal and polar configurations (i.e., when $\rho_{\perp}$ is measured with the magnetic field applied parallel or perpendicular to the film plane, respectively) are not equivalent, being the latter the highest. The origin of this effect, known as the geometrical size effect (GSE) is still not clarified and two different hypotheses emerged to explain it. The first one relates the effect to diffusive scattering of the majority spin electrons at the outer boundaries [1], whereas the second relates the effect to *sd*-scattering of the minority spins due to a film texture [2].

In order to clarify this point, highly textured cobalt deposits were electrodeposited on (100) n-type silicon in two different geometries: continuous thin films and antidot structures (Fig. 1) obtained by nanosphere lithography [3]. Thickness of thin films varied between 20 nm and 300 nm. The Co antidot structures were prepared from monolayered colloidal masks made with polystyrene (PS) spheres with diameters of 175 and 330 nm, whose interstices were filled with cobalt up to a thickness of 150 nm. Magnetoresistance measurements were performed at 300 K in a PPMS system, using an *ac*-bridge method at constant frequency with the magnetic field applied parallel to the current (ρ_L) as well as in transversal (ρ_T) and polar (ρ_P) configurations (Fig. 2).

Co electrodeposits are polycrystalline and X-ray diffraction indicates a mixture of fcc and hcp with a hcp (001) texture normal to the plane. Magnetoresistance measurements show that, at technical saturation, the ratio $(\rho_L-\rho_P)/(\rho_L-\rho_T)$ is close to 1 for the antidot structure, whereas it amounts to more than 2.5 for a continuous film of same thickness, indicating that the GSE stems from diffusive scattering at boundaries.

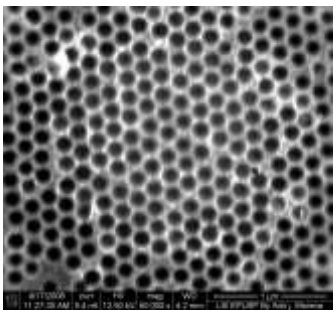

Figure 1: Co antidot structure made with PS spheres with a diameter of 175 nm.

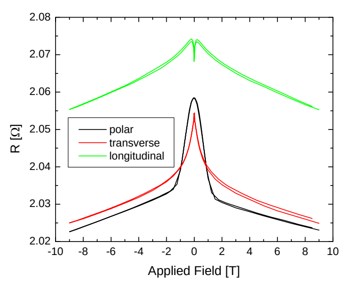

Figure 2: Magnetoresistance of Co antidot structure.

References

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