COLOQUIO DE FÍSICA – 50 AÑOS DEPARTAMENTO DE FÍSICA

Superconducting Vortex-Antivortex formation in Nb based Superconductor/Ferromagnet thin film heterostructures by Low Temperature Magnetic Force Microscopy

Profesora ANNAMARIA CUCOLO
Universidad de Salerno, Italia

Martes, 1 de Octubre de 2013
Lugar: Auditorio CALIMA
Hora: 4:00 p.m.

Superconducting Vortex-Antivortex formation in Nb based Superconductor/Ferromagnet thin film heterostructures by Low Temperature Magnetic Force Microscopy

A. M. Cucolo[1,2]

C. Di Giorgio[1], F. Bobba[1,2], A. Scarfato[1,2], M. Iavarone[2,3,4], G. Karapetrov[3], V. Novosad[3], V. Yefremenko[3]

[1]. "E.R. Caianiello" Physics Department and NANOMATES, Research Centre for nanomaterials and nanotechnology, University of Salerno, Fisciano (SA), Italy.

[2]. CNR-SPIN Salerno, Fisciano (SA), Italy.

[3]. Materials Science Division, Argonne National Laboratory, Argonne, IL, United States.

[4]. Physics Department, Temple University, Philadelphia, PA, United States.

We used low temperature Magnetic Force Microscopy to investigate the vortex dynamics in Superconductor/Ferromagnet (SC/FM) thin film heterostructures realized by Py/Nb thin film bilayers. Indeed, by tuning the magnetic state of the ferromagnet new physical phenomena can be observed associated with the interaction between the Abrikosov vortex lattice in the Nb layer and the periodic, stripe-like Py magnetic domains. The analysis of the different behaviors of these systems is of great importance for applications allowing to predict and control the electronic properties of the SC/FM hybrids.

In our samples, Nb thickness (d_s)varied in the range of 100÷360 nm and Py thickness (d_{Py}) in the range 1÷4 μm. To ensure that the FM and SC layers were only magnetically coupled, during fabrication, a 10 nm SiO_2 was deposited on top of the Py film. The samples behavior above and below the Nb superconducting critical temperature were analyzed by means of an cryogenic Scanning Force Microscope. Low temperature MFM allowed us to collect the topographic and magnetic force gradient maps in the same area of the sample. We used commercial micro-fabricated Si cantilevers with magnetic coating (Veeco MESP LM) and resonance frequency f_o of about 75 kHz. The magnetic moment of the tip was $0.3 \cdot 10^{-16}$ Am^2 and the coercivity <3 10^4 A/m. Before measuring, the tip was magnetized in the upward direction and several images of the same area were acquired at different tip-sample heights varying in the range of 50÷280 nm.

In our experiments a variety of different behaviors were observed, depending on the intensity of the out of plane magnetization component M_0 of the Py layer as well as on the interrelations among some "geometrical" parameters of the hybrids, i.e., the Nb penetration depth λ_L and thickness d_s and the Py stripes half period width w. When $w > \lambda_L$, in zero external applied field, depending on d_s, the samples showed "spontaneous" Vortices-Antivortices (V-AV) formation, in a chain-like configuration along the magnetic stripes due to the alternating out of plane component M_0 of the Py stray field. We have analyzed the observed experimental results within a theoretical model which deal with M_0 intensity threshold causing spontaneous V-AV formation [4].

[1] M.Iavarone, A. Scarfato, F. Bobba, M.Longobardi, S.A. Moore, G. Karapetrov, V. Yefremenko, V. Novosad, A.M. Cucolo, *Vortex confinement in planar Superconductor/Ferromagnet hybrid structures*, IEEE Magnetics Society 48, 11 (2012)

[2]A.M. Cucolo, A. Scarfato, M.Iavarone, M.Longobardi, F. Bobba, G. Karapetrov, V. Novosad, V. Yefremenko, *Visualizing vortex dynamics in Py/Nb thin film hybrids by Low Temperature Magnetic Force Microscopy*, Jurnal of Superconductivity and Novel Magnetism, 25, 2167-2171 (2012)

[3] M.Iavarone, A. Scarfato, F. Bobba, M.Longobardi, G. Karapetrov, V. Yefremenko, V. Novosad, V. Yefremenko, F. Giubileo, A.M. Cucolo, *Imaging the spontaneous formation of vortex-antivortex pairs in planar superconductor/ferromagnet hybrid structures*, Phys. Rev. B 84, 024506 (2011)

[4] R. Laiho, E. Lahderanta, E.B. Sonin, and K.B. Traito, *Penetration of vortices into the ferromagnet/type II superconductor bilayer*, Phys. Rev. B 67, 144522 (2003)