Advances in Curvilinear Magnetism: Cylindrical Magnetic Nanowires

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Curvilinear geometry in magnetic nanostructures (e.g., nanohelices, nanotubes and nanowires or rolled-up flexible multilayers) originates unprecedented phenomena whose manipulation leads to a new generation of technology applications. Particularly, cylindrical magnetic nanowires represent a novel 3D alternative (skyrmion tubes, magnetochiral-induced asymmetry, Bloch-point walls) to planar 2D systems which most recent experimental advances are here reviewed.

Nanowires (Fe, Co, Ni and magnetic metallic alloys, 20-400nm in diameter and up to 50 μm long) are synthesized by controlled electrochemical route inside the self-assembled pores of alumina templaytes, a less-expensive technique allowing reliable systematic investigations. Magnetization configurations of these nanowires reflect the energy balance between crystal anisotropy and stray-fields. After a brief summary of properties of the nanowire arrays we will pay attention to individual cylindrical nanowires after released from the membrane.

Particular interest presents engineered nanowires with modulations in diameter or composition leading to multilayered systems with axial, transverse, vortex and more exotic magnetic configurations. Recent results in isolated nanowires have established their 3D magnetic character, conventionally taken as 1D. The reconstruction of 3D internal magnetic state is achieved by advanced microscopy techniques (e.g., Photo-Electron Emission and X-ray Transmission Electron Microscopies, with X-ray Magnetic Circular Dichroism), Vector-Field Electron Nanotomography, or Scanning Nitrogen-Vacancy Magnetometry resolving local magnetic inhomogeneities. Remagnetization proceeds by Bloch-point walls and complex rotational processes where modulations induce controlled domain wall pinning and effects like magnetization ratchet or skyrmions tubes. Under current pulses, walls are pushed to nanowire end but re-nucleated under thermal fluctuations when current is off. A wide spectrum of applications involving cylindrical nanowires is summarized: spintronics, robotics, magneto-thermoelectric effects, sensors, biomedicals, or microwave absorption.

The last part of the talk will be devoted to the advances involving magnetic microwires as this was the first topic of collaboration, by the beginning of the 90's, between the Technical Physical Institute, Iasi, and the ICMM/CSIC, Madrid.