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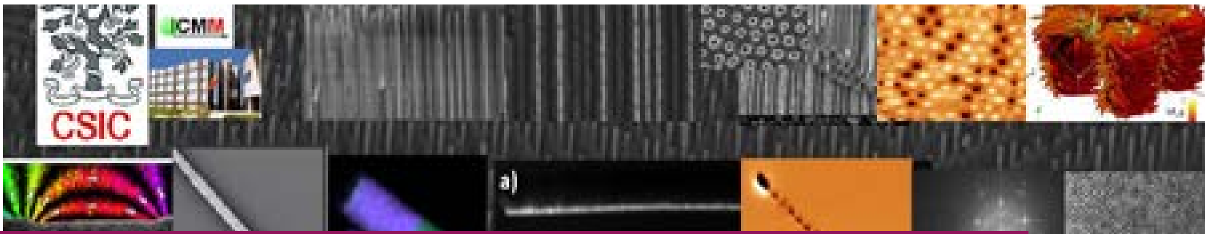

MaP Doctoral School | Science & Technology of the Small - Seminar

Cylindrical Micro- and Nanowires: From Curvature Effects on Magnetization to Sensing Applications

Prof. em. Manuel Vázquez, Spanish Council for Research (CSIC)

9 March 2023 | 15.00-16.00 | ETH Hönggerberg, HCI J 498

Research on curvature effects in magnetic nanostructures is attracting much interest as they offer novel alternatives to planar systems. In particular, the cylindrical geometry introduces significant singularities in the magnetic response of ferromagnetic wires just from their curvature, which primarily depends on their diameter, length, and aspect ratio. The main magnetic configurations include axial, transverse, and vortex (circular with a singularity at the axis). Microwires, 1 to 180 micrometer, are fabricated by in-rotating-water and by quenching and drawing ultrarapid solidification techniques. Micrometric-diameter amorphous wires with high magnetostriction re-magnetize through an ideal millimeter-long single domain wall propagating at kilometer-per-second speeds that results in a square hysteresis loop. Such bistable behavior and their magnetoelastic properties are the basis for various devices (e.g., field, stress and temperature sensors, electromagnetic shielding). On the other hand, ultrasoft non-magnetostrictive microwires are employed in very sensitive field sensors based on their Giant Magneto-Impedance, GMI, effect or in flux-gate magnetometers.

Nanowires (20 nm to 400 nm in diameter) present an outstanding behavior where the crystalline structure plays a major role in competition with shape anisotropy. Cylindrical nanowires are considered as scaffolds for advanced three-dimensional nanoarchitectures exploiting intrinsic curvature that introduces significant differences from planar-based nanotechnologies. They are proposed for novel sensor devices and magnets, and their interconnecting arrays are considered for energy devices or brain-inspired computing. An ultimate goal is currently the investigation of the magnetization reversal modes in individual nanowires by advanced techniques, e.g., X-ray magnetic circular dichroism (XMCD) coupled to photoemission electron microscopy (PEEM), magnetic force microscopy (MFM), magneto-optical Kerr effect (MOKE), electron holography, and micromagnetic simulations. They show axial, transverse, vortex, and more complex, exotic magnetic configurations and effects (e.g., magnetization ratchets, skyrmion tubes, helical vortices). The reversal nucleates at the nanowire ends involving singularities (e.g., Bloch-point walls) and at local transition regions (e.g., modulations in diameter and composition between segments of differently designed magnetic properties. Individual nanowires are currently used or proposed for biomedical applications, such as cancer treatment, magnetic resonance imaging (MRI) contrast agents, or in composites for their antimicrobial activity.

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