CURRICULUM VITAE

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Professor of Research, Head of the Group on "*Nanomagnetism and Magnetization Processes*"

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1. Main Achievements

- President IEEE Magnetics Society (2017-8); President-Elect (2015-2016); Elected Secretary/Treasurer (2013-14); Elected AdCom Member (2010-12); Founder of IEEE MagSoc Spain Chapter (2007) http://www.ieeemagnetics.org/index.php?option=com_content&view=article&id=176&Itemid=90

- Salvador Velayos Award on Magnetism for his "*contributions to applied magnetism & magnetism internationalization activities*" (2017)

- Promotor of "Inniciative in Magnetism" at the ICMM/CSIC (2016) and of their Biannual Spring Meetings on Magnetism (2010)

- Visiting Professor to Hubei University, Wuhan, China (March 2016)

- International Head of the Laboratory Magnetic Sensors, Urals Federal University, UrFU, Yekaterinburg, Russia (2015-16) (funded by the UrFU and the Russian Federation) http://insma.urfu.ru/en/research/research-6

- Secretary Commission on Magnetism, Int. Union of Pure and Applied Physics, IUPAP (2011-14); Program Committee Chair, International Conference of Magnetism, ICM, Barcelona2015

- General Chair INTERMAG'08, Madrid, May 2008

- Manager of the Strategic Action on Nanoscience and Nanotechnology (Spain Ministry Science & Technology, 2004-9); Co-manager National Plan for Materials (2001-03); Member of the NMP Commission Spanish Delegation, FM7, Brussels (2007-10)

- Co-founder (2002), and President of Spanish Club of Magnetism, CEMAG (2006-8)

- Founder of the Group on "Nanomagnetism and Magnetization Processes" (2001)

- Director of Laboratory (Institute of Applied Magnetism, UCM-RENFE-CSIC, Madrid, 1992-2000)

- Professor of Research (Inst. Materials Science at Madrid, CSIC, 1996); Scientific Investigator (1989-96)

- Visiting Researcher to Max-Planck-Institute, Stuttgart, 1989 (Invited Max-Planck-Gesellschaft); to Univ. Sao Paulo, Brazil, 1989 (Invited Professor); to Univ. Santiago de Compostela, Spain, 1996 (Invited Professor)

- Postdoc stays: Max-Planck-Institute, Stuttgart, 1981-83 (Alexander von Humboldt Fellow); NATO Invited Researcher (Techniske Danmark Un., Lyngby, 1985)

- Associate Professor (Univ. Complutense, Madrid, 1985-89); Assistant Professor (1982-84); Post-graduate Assistant Professor (1975-80)

- Contracted Associated Professor (Univ. León, Spain, 1980-81)

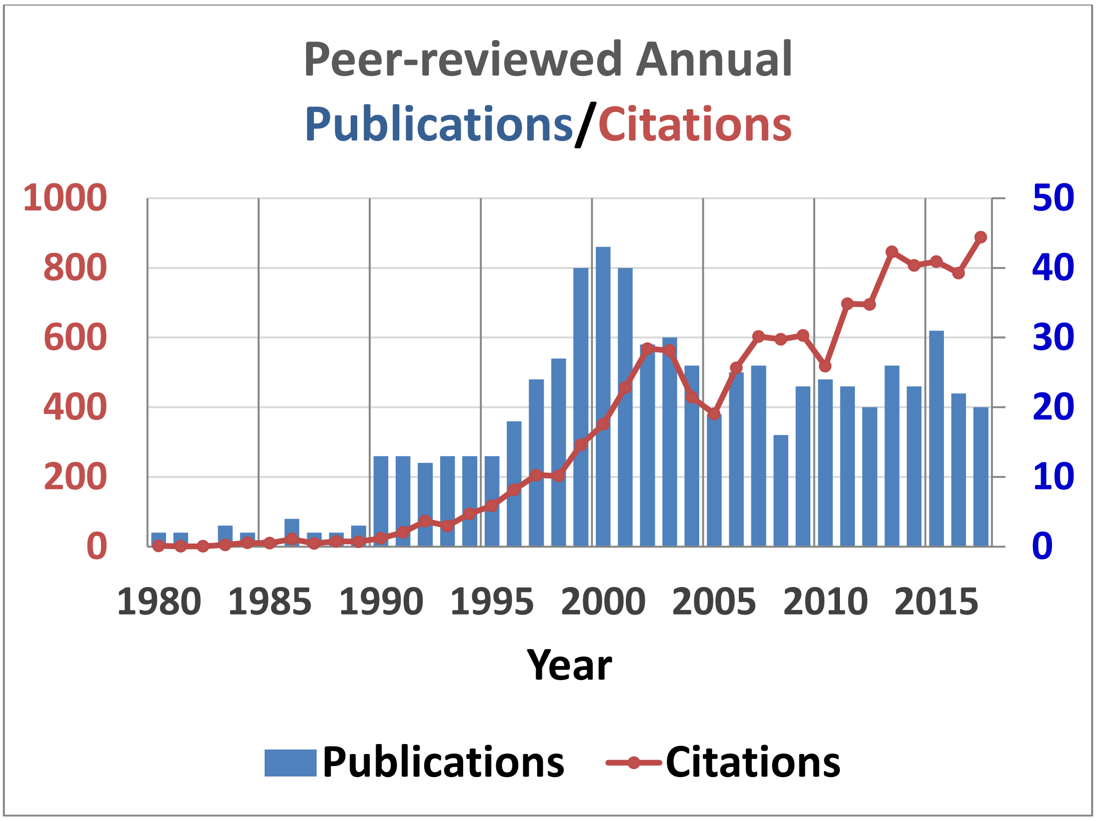
- Ph. D. (Physics) by Complutense University of Madrid (1980)

- IAESTE post-graduated grant (Koninklijke/Shell Lab., Amsterdam, 1974)

Expertise

Scientific: Nano and Micromagnetism; Nano and Microwires; Magnetic Domains and Walls; Magnetic Anisotropy; Amorphous & Nanocrystalline solids, Magnetostriction
Tecnological: Magnetic and Magnetoelastic Sensors; Giant Magneto-impedance

h impact factor: 52; 600 scientific publications with 13000 citations
Languages: Spanish (mother tongue), English, French and German



2. Scientific Interests

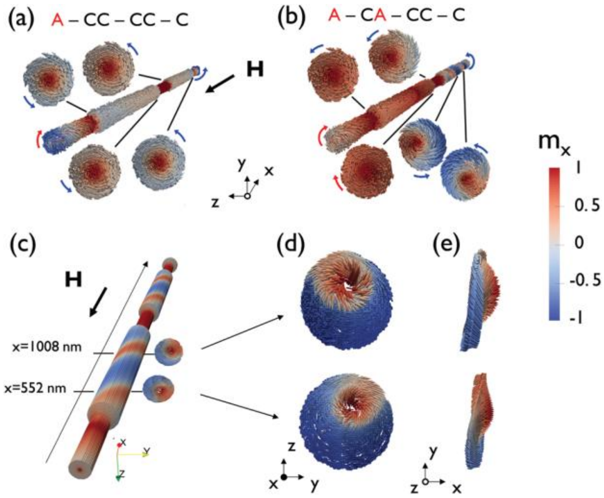
a) Magnetism of Cylindrical Nanowires

The most recent interest, along the last few years, addresses the magnetism of individual cylindrical magnetic nanowires after released from inside the template where they are electrolytically grown. The main challenges are related to their intrinsic geometry curvature at the nanoscale. It focuses particularly on the local magnetic moments distribution (magnetic domain structure) and the remagnetization process (mostly by domain wall motion).

The local domain structure is determined by the balance between shape and magnetocrystalline anisotropies. Fe and Ni rich alloy nanowires exhibit *bcc* or *fcc* cubic structure, and shape is the predominant anisotropy (as for Py). Co and Co-rich alloy nanowires show generally *hcp* symmetry that determines an effective magnetization easy axis at a given angle with the nanowire axis.

Experimental studies are performed on nanowires especially designed with modulations in diameter (notches, antinotches) or in composition (FM/FM or FM/Metal multilayer) intended for the controlled remagnetization through anisotropy modulations or for domain wall pinning. The micromagnetic modelling showed that remagnetization proceeds by the formation of vortex structures at the nanowire ends, followed by depinning and propagation of Bloch-point like wall or in combination with magnetization rotations depending on the specific anisotropy.

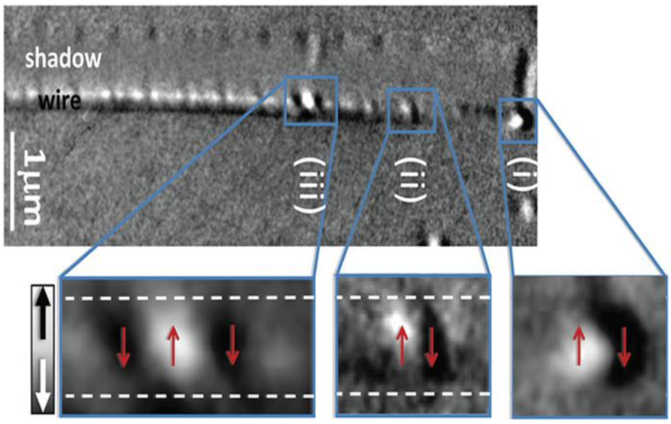
At remanence, depending on the energy balance, axial and vortex domains, have been experimentally imaged by advanced MFM (surface), as well as by PEEM-XMCD (surface and inner), and electron holography. Very recently, inner and surface transverse domains have been also imaged (PEEM). All these observations reflect the presence of the mentioned modulations. Complementary micromagnetic simulations are performed for the full understanding of observed remanence states. The presence of axial as well as either single or quite complex vortex structures are simulated that correlate with the experimental data. Quite recently, the presence of skyrmion tubes is confirmed in Co-rich nanowires with diameter modulations.



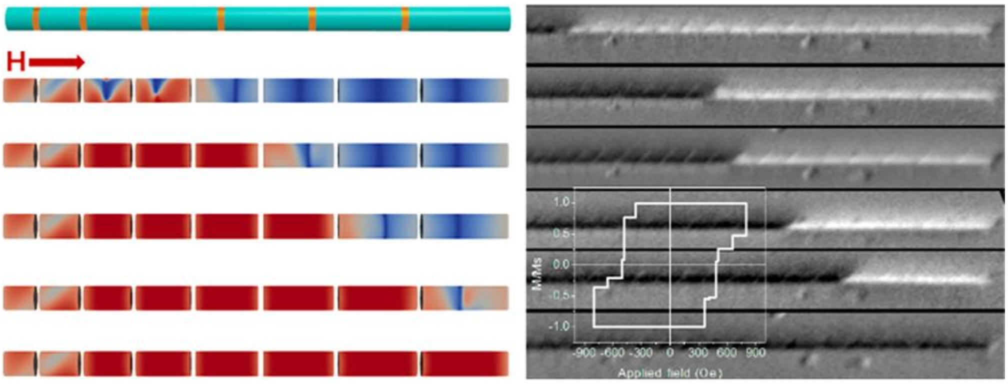
Simulated magnetization distribution in two-segment nanowires: Longitudinal magnetization component (a–b), Surface magnetization showing the magnetization spiral and the vortex/skyrmion magnetization structure (c), and views of cross sections showing the displaced skyrmion structure (d–e). (*J.A. Fernandez-Roldan et al. Nanoscale, 2018*)

Under applied axial field, experimental measurements have been obtained (hysteresis loops) by MOKE, MFM and PEEM showing the propagation of the domain wall or of the remagnetized local segments (for FM/Metal multilayer). Most recent data have allowed us to measure the magnetization ratchet in especially designed FM/Metal multilayer nanowires (submitted for publication).

A deep knowledge of the magnetization reversal of individual nanowires is needed for full developments in logic devices, and advanced spintronics were the control over the domain wall motion is essential.



XMCD–PEEM image of a single FeCoCu nanowire with bamboo-like diameter modulations oriented perpendicular to the incident X-rays. The arrows indicate the local spin configuration, inner axial magnetization and vortex structures around the anti-notches are deduced *(C. Bran et al., J. Mater. Chem. C, 2016, 4, 978)*



The unidirectional motion of information carriers such as domain walls in magnetic nanostrips is a key feature for many future spintronic applications based on shift registers. This magnetic ratchet effect has so far been achieved in a limited number of complex nanomagnetic structures, for example, by lithographically engineered pinning sites. Here we report on a simple remagnetization ratchet originated in the asymmetric potential from the designed increasing lengths of magnetostatically coupled ferromagnetic segments in FeCo/Cu cylindrical nanowires. The magnetization reversal in neighboring segments propagates sequentially in steps starting from the shorter segments, irrespective of the applied field direction. This natural and efficient ratchet offers alternatives for the design of three-dimensional advanced storage and logic devices. (*C.Bran et al., Magnetization Ratchet in Cylindrical Nanowires, ACS Nano May2018)*

Key Publications.-

- C. Bran, E. Berganza, J.A. Fernandez-Roldan, E.M. Palmero, J. Meier, E. Calle, M. Jaafar, M. Foerster, L. Aballe, A. Fraile Rodriguez,, R.P. del Real, A. Asenjo, O. Chubykalo-Fesenko, and M. Vazquez
"Magnetization Ratchet in Cylindrical Nanowires",
ACS Nano May2018

- J.A. Fernandez-Roldan, R. Perez del Real, C. Bran, M. Vazquez and O. Chubykalo-Fesenko
"Magnetization pinning in modulated nanowires: from topological protection to the "corkscrew" mechanism"
(2018) Nanoscale, DOI: 10.1039/c8nr00024g

- Berganza, E., Jaafar, M., Bran, C., Fernández-Roldán, J.A., Chubykalo-Fesenko, O., Vázquez, M., Asenjo, A.
"Multisegmented Nanowires: A Step towards the Control of the Domain Wall Configuration"
(2017) Scientific Reports, 7 (1), art. no. 11576. DOI: 10.1038/s41598-017-11902-w

- Bran, C., Fernandez-Roldan, J.A., Palmero, E.M., Berganza, E., Guzman, J., Del Real, R.P., Asenjo, A., Fraile Rodríguez, A., Foerster, M., Aballe, L., Chubykalo-Fesenko, O., Vazquez, M.
"Direct observation of transverse and vortex metastable magnetic domains in cylindrical nanowires"
(2017) Physical Review B, 96 (12), art. no. 125415, . DOI: 10.1103/PhysRevB.96.125415

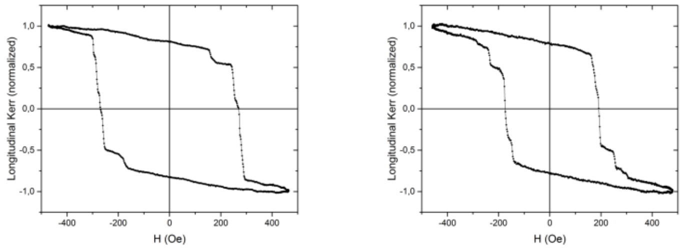
- Rotarescu, C., Moreno, R., Fernández-Roldan, J.A., Trabada, D.G., Nemes, N.M., Fehér, T., Bran, C., Vázquez, M., Chiriac, H., Lupu, N., Óvári, T.-A., Chubykalo-Fesenko, O.
"Effective anisotropies in magnetic nanowires using the torque method"
(2017) Journal of Magnetism and Magnetic Materials, 443, pp. 378-384. DOI: 10.1016/j.jmmm.2017.07.059

- Toscano, D., Leonel, S.A., Coura, P.Z., Sato, F., Costa, B.V., Vázquez, M.
"Magnetization reversal of the transverse domain wall confined between two clusters of magnetic impurities in a ferromagnetic planar nanowire"
(2016) Journal of Magnetism and Magnetic Materials, 419, pp. 37-42. DOI: 10.1016/j.jmmm.2016.05.107

- Rodríguez, L.A., Bran, C., Reyes, D., Berganza, E., Vázquez, M., Gatel, C., Snoeck, E., Asenjo, A.
"Quantitative Nanoscale Magnetic Study of Isolated Diameter-Modulated FeCoCu Nanowires"
(2016) ACS Nano, 10 (10), pp. 9669-9678. DOI: 10.1021/acsnano.6b05496

- Berganza, E., Bran, C., Jaafar, M., Vazquez, M., Asenjo, A.
"Domain wall pinning in FeCoCu bamboo-like nanowires"
(2016) Scientific Reports, 6, art. no. 29702, . DOI: 10.1038/srep29702

- Bran, C., Berganza, E., Palmero, E.M., Fernandez-Roldan, J.A., Del Real, R.P., Aballe, L., Foerster, M., Asenjo, A., Fraile Rodríguez, A., Vazquez, M.
"Spin configuration of cylindrical bamboo-like magnetic nanowires"
(2016) Journal of Materials Chemistry C, 4 (5), pp. 978-984. DOI: 10.1039/c5tc04194e

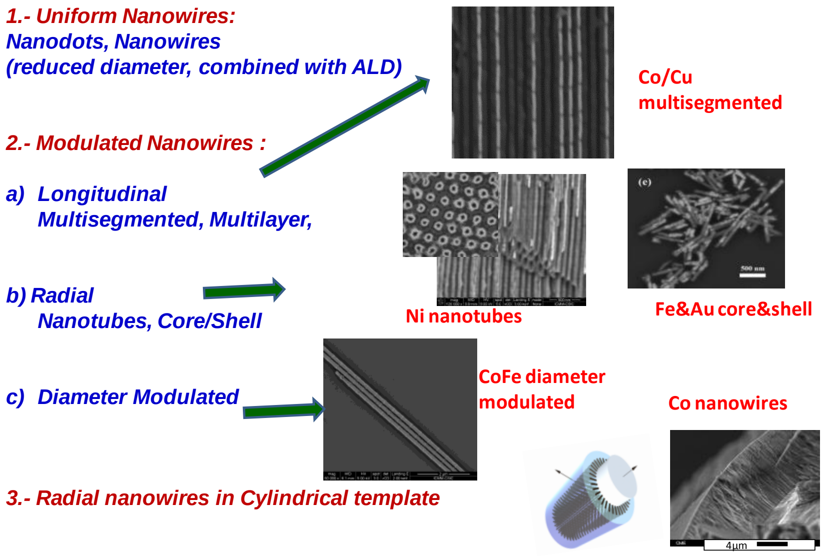


MOKE local hysteresis loops at different positions along a multisegmented FM/Metal individul nanowire denoting the propagation of a domain wall

b) Arrays of Nanowires, Magnetism & Functionalization

Cylindrical nanowires are grown by electrodeposition into self-assembled pores in alumina membranes as templates. These porous membranes are prepared by two-anodization process starting from Al foils or disks. The controlled synthesis process has been addressed in the last years, firstly on the anodization processes to achieve modulations of pores diameter through the so-called hard-soft anodization under careful control of voltage/current electrolysis. Subsequent procedures include the removal of non-oxidized Al bottom resulting in pores open by both ends of the membrane and the sputtering of noble metal thin film at one end.

Arrays of nanowires are then grown under controlled electrodeposition using a bath according to the desired magnetic alloy. Typical compositions include Fe, Co, Ni and their alloys, while diameter is tailored between 15 and 200 nm and length between 100 nm and 50 *m*m (with up to very high aspect ratio). The nanowires are arranged into a hexagonal array with micrometric size and lattice parameter that can be tailored between 30 and 500 nm.

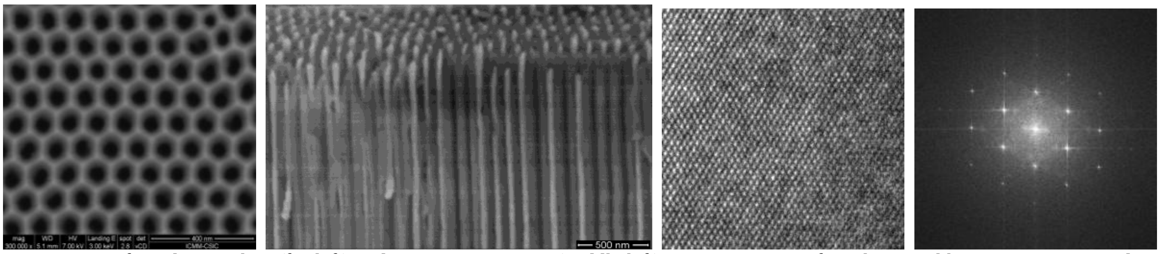


Different families of nanowires with cylindrical symmetry investigated

Of particular relevance is the case of segmented or multilayer nanowires prepared by single or double electrolythical bath. In this way, FM/FM multisegmented and FM/Metal multilayer nanowire arrays are obtained.

Arrays of nanowires with radial modulation of composition were also prepared, as for example FM nanotubes with controlled tube wall. Very challenging is on the other hand the synthesis of core/shell FM/FM bimagnetic nanowires. Magnetic Metal/Magnetic oxide core/shell bimagnetic nanowires can be also grown by suitable oxidation process. We were also able to synthesize radial nanowire arrays starting in a cylindrical configuration (Al rods).

Morphology and particularly crystalline structure are characteristics determined by different techniques as HRTEM, X-ray diffraction, SEM, or AFM.



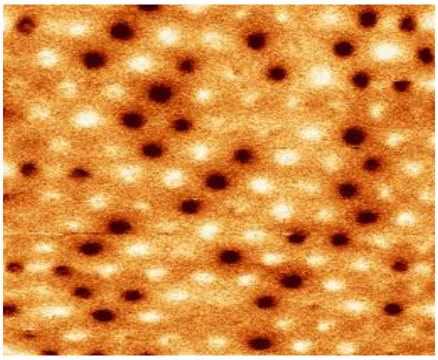
SEM images of anodic template (far left) and Co nanowire array(middle left). HRTEM image of single crystal hcp Co nanowire and its FFT

Studies are systematically performed to determine the magnetization process and the bulk response of the arrays, including the essential role played by the crystalline anisotropy of nanowires and the magnetostatic interactions between nanowires

A particular objective was to reach nanowire arrays with magnetically hard character. In this regard, CoFe alloys with the highest saturation magnetization (2.3 T) were considered. The inclusion of small amounts of other elements (i.e., Cu) resulted in very modest reduction of magnetization while increasing significantly their coercivity (0.5 T) and remanence (c. 0.9Ms) after suitable thermal treatments. Reasonable energy product values are still measured at high temperatures of about 500ºC. Most recent studies are focused towards the growth of ferri/antiferro magnetic caps at the ends of nanowires in order to magnetically couple with the main nanowire and enharden the remagnetization process.

The role of anisotropy was also clearly manifested in Co-rich nanowire arrays where the length and the diameter of nanowires determine the bulk magnetic response as a consequence of the different crystal symmetry of the transient initial and steady growing processes (*fcc* and *hcp*, respectively).

From the angular dependence of coercivity and remanence it is possible to determine through analythical calculations the preferred reversal mode, by propagation of either by vortex-like or transverse like mechanism of domain wall. The magnetostatic interactions have been also investigated making use of the First Order Reversal Curves, FORC.



Magnetic Force Microsciopy image of an arrays of Ni nanowires at remanence whose different (white/black) contrast denotes the opposite magnetization direction of individual nanowires (*A. Asenjo in Escrig et al. Phys. Rev. B75 (18), art. no. 184429 (2007)*)

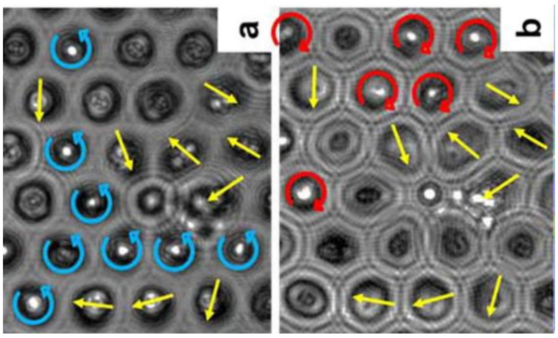
Interestingly, 3D nanopillar vortex array was determined for short (less than 100nm lenght) Co nanopillars. Moreover electron holography experiments showed the vortex or transverse closure structure at the ends of the nanowires. These data correlate with parallel imaging studies by MFM characterization of nanowire in the arrays where the nanowires ends show white or dark contrast denoting their dipolar character.

Fundamental studies were also performed in collaboration with other groups on spin waves modes. Configurational spin reorientation phase transition, or Ferromagnetic Resonance, as well as magneto-optical properties of Ni nanowire arrays.

Several kinds of functionalization of the nanowire arrays have been developed. One of them has been to use the template ordering to grow magneto-polymers (i.e., magnetic nanowire in PPMA composites) by replica-antireplica processes, or by magnetic nanoparticles into ordered polymers (see he figure below).

As another example, studies have been reported for Ni/Cu multilayer nanowires, where Ni short segments were isolated and employed as contrast agents in MRI. Fe/FeO core/shell nanowires were found of interest for biomedical and harsh environmental applications

Particularly interesting functionalization employing ordered porous Alumina templates is the growth of antidot thin films by sputtering onto the upper surface of the membrane. Several studies were performed, including MOKE and PEEM, to determine the formation of domains during the remagnetization. Single and bilayer antidot films were thus characterized.



Lorentz TEM images in over- (**a**) and under-focused (**b**) conditions of an array of Co nanowires 45 nm in diameter and 55-nm long at remanence. The arrows show the transverse direction and the clockwise (red) and anticlockwise (blue) rotation of NW magnetization *(Y.P. Ivanov, Y.P., Chuvilin et al. Scientific Reports, 6, art. no. 23844(2016))*

Key Publications

Synthesis & Structure & Role of Geometry

- I. Mínguez-Bacho,S. Rodríguez-López, A. Climent, D. Fichou, M. Vázquez, and M. Hernández-Vélez
Influence of Sulfur Incorporation into Nanoporous Anodic Alumina on the Volume Expansion and Self-Ordering Degree
(2015) J. Phys. Chem. C 119, 27392−27400 DOI: 10.1021/acs.jpcc.5b06928

- I. Mínguez-Bacho, S. Rodríguez-Lopez, A. Climent-Font, D. Fichou, M. Vazquez, M. Hernandez-Velez
Variation of the refractive index by means of sulfate anion incorporation into nanoporous anodic aluminum oxide films
(2016) Microporous and Mesoporous Materials 225, 192e197

- Fardi-Ilkhchy, A., Nasirpouri, F., Bran, C., Vázquez, M.
Compositionally graded Fe(1−x)-Pt(x) nanowires produced by alternating current electrodeposition into alumina templates
(2016) Journal of Solid State Chemistry, 244, pp. 35-44. DOI: 10.1016/j.jssc.2016.08.016

- Ovejero J.G., Bran C., Vilanova E., Kosel J., Morales M.P., Vazquez M.
Electrochemical synthesis of core-shell magnetic nanowires
(2015) Journal of Magnetism and Magnetic Materials, 389, pp. 144-147. DOI: 10.1016/j.jmmm.2015.04.059

- Proenca, M.P., Ventura, J., Sousa, C.T., Vazquez, M., Araujo, J.P.
Exchange bias, training effect, and bimodal distribution of blocking temperatures in electrodeposited core-shell nanotubes
(2013) Physical Review B - Condensed Matter and Materials Physics, 87 (13), art. no. 134404, . DOI: 10.1103/PhysRevB.87.134404

- Proenca, M.P., Sousa, C.T., Ventura, J., Vazquez, M., Araujo, J.P.
Distinguishing nanowire and nanotube formation by the deposition current transients

(2012) Nanoscale Research Letters, 7, . DOI: 10.1186/1556-276X-7-280

- Leitao, D.C., Apolinario, A., Sousa, C.T., Ventura, J., Sousa, J.B., Vazquez, M., Araujo, J.P.
Nanoscale topography: A tool to enhance pore order and pore size distribution in anodic aluminum oxide
(2011) Journal of Physical Chemistry C, 115 (17), pp. 8567-8572. Cited 31 times. DOI: 10.1021/jp202336j

- Escrig, J., Altbir, D., Jaafar, M., Navas, D., Asenjo, A., Vázquez, M.
Remanence of Ni nanowire arrays: Influence of size and labyrinth magnetic structure
(2007) Physical Review B - Condensed Matter and Materials Physics, 75 (18), art. no. 184429, . DOI: 10.1103/PhysRevB.75.184429

- Pirota, K.R., Vazquez, M.
Arrays of electroplated multilayered Co/Cu nanowires with controlled magnetic anisotropy
(2005) Advanced Engineering Materials, 7 (12), pp. 1111-1113. C. DOI: 10.1002/adem.200500162

- Vázquez, M., Pirota, K., Torrejón, J., Navas, D., Hernández-Vélez, M.
Magnetic behaviour of densely packed hexagonal arrays of Ni nanowires: Influence of geometric characteristics
(2005) Journal of Magnetism and Magnetic Materials, 294 (2), pp. 174-181. DOI: 10.1016/j.jmmm.2005.03.032

- Vázquez, M., Hernández-Vélez, M., Pirota, K., Asenjo, A., Navas, D., Velázquez, J., Vargas, P., Ramos, C.
Arrays of Ni nanowires in alumina membranes: Magnetic properties and spatial ordering
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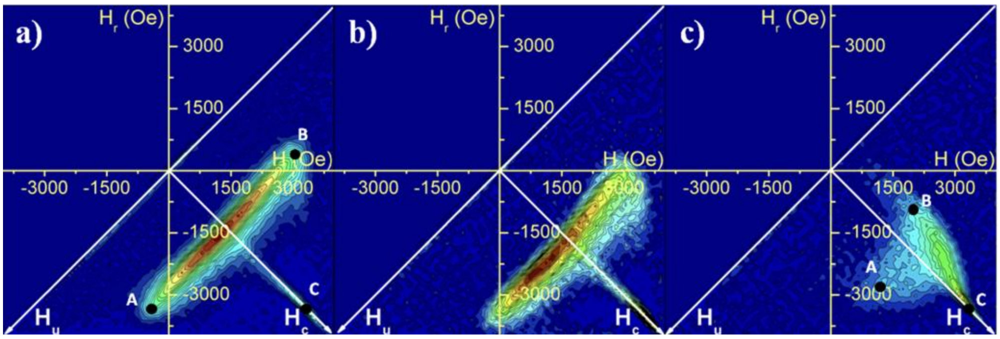

FORC distributions for FeCo/Cu multilayer nanowire arrays as afunction of the Cu layer thicknesses for the same FeCo segment thickness ([FeCoCu (300 nm) / Cu(x)]$_{10}$): (a) x=7 nm, (b) x=15 nm and (c) x=40 nm (*E. Palmero et al. Nanotechnology 27 (2016) 435705*).

Magnetization Process, Anisotropy, Interactions

- F Z Wang, R Salikhov, M Spasova, S Liébana-Viñas, C Bran, Yu-Shen Chen, M Vazquez, M Farle, and U Wiedwald
Doubling of the magnetic energy product in ferromagnetic nanowires at ambient temperature by capping their tips with an antiferromagnet
Nanotechnology 28 (2017) 295402

- Ivanov, Y.P., Chuvilin, A., Vivas, L.G., Kosel, J., Chubykalo-Fesenko, O., Vázquez, M.
Single crystalline cylindrical nanowires-toward dense 3D arrays of magnetic vortices
(2016) Scientific Reports, 6, art. no. 23844, . DOI: 10.1038/srep23844

- Arshad, M.S., Proenca, M.P., Trafela, S., Neu, V., Wolff, U., Stienen, S., Vazquez, M., Kobe, S., Rožman, K.Ž.
The role of the crystal orientation (c-axis) on switching field distribution and the magnetic domain configuration in electrodeposited hcp Co-Pt nanowires
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- Bran, C., Espejo, A.P., Palmero, E.M., Escrig, J., Vázquez, M.
Angular dependence of coercivity with temperature in Co-based nanowires
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Spin Waves Modes in Cobalt Nanowires Arrays
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Toward Rare-Earth-Free Permanent Magnets: A Combinatorial Approach Exploiting the Possibilities of Modeling, Shape Anisotropy in Elongated Nanoparticles, and Combinatorial Thin-Film Approach
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Magnetization reversal dependence on effective magnetic anisotropy in electroplated Co-Cu nanowire arrays

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Correlation between structure and magnetic properties in CoxFe100-x nanowires: The roles of composition and wire diameter
(2015) Journal of Physics D: Applied Physics, 48 (14), art. no. 145304, . DOI: 10.1088/0022-3727/48/14/145304

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Magnetic behavior of NiCu nanowire arrays: Compositional, geometry and temperature dependence
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Structural and magnetic characterization of as-prepared and annealed FeCoCu nanowire arrays in ordered anodic aluminum oxide templates
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Structural and magnetic characterization of FeCoCu/Cu multilayer nanowire arrays
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Magnetic reversal modes in cylindrical nanowires
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Magnetic structure of a single-crystal hcp electrodeposited cobalt nanowire
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Magnetic anisotropy in ordered textured Co nanowires
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Magnetic anisotropy in CoNi nanowire arrays: Analytical calculations and experiments
(2012) Physical Review B - Condensed Matter and Materials Physics, 85 (3), art. no. 035439, . DOI: 10.1103/PhysRevB.85.035439

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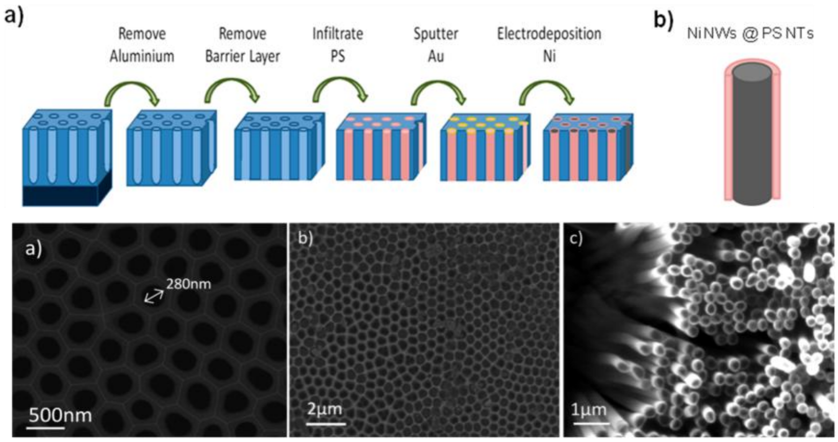

Top view SEM images of AAO membrane with average pore diameter of 280 nm and interdistance between pores of 420 nm (a), polystyrene nanotubes embedded into AAO membrane (b), and polystyrene nanotubes out of AAO membrane (c).

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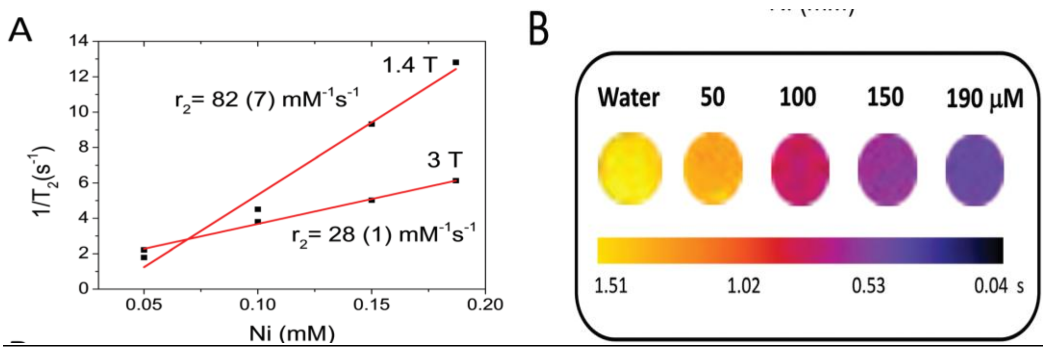

Individual Ni segments out of Ni/Cu nanowires as contrast agents for MRI imaging: Transversal relaxivity (r_2) of a water solution of PAA-coated Ni nanowires at 1.41 T and 3 T at 37 1C (A); and T_2 map of PAA-coated Ni nanowires acquired at 3 T and 37 1C (*M. Bañobre-López et al., Journal of Materials Chemistry B, 5 (18) (2017) pp. 3338-3347*)

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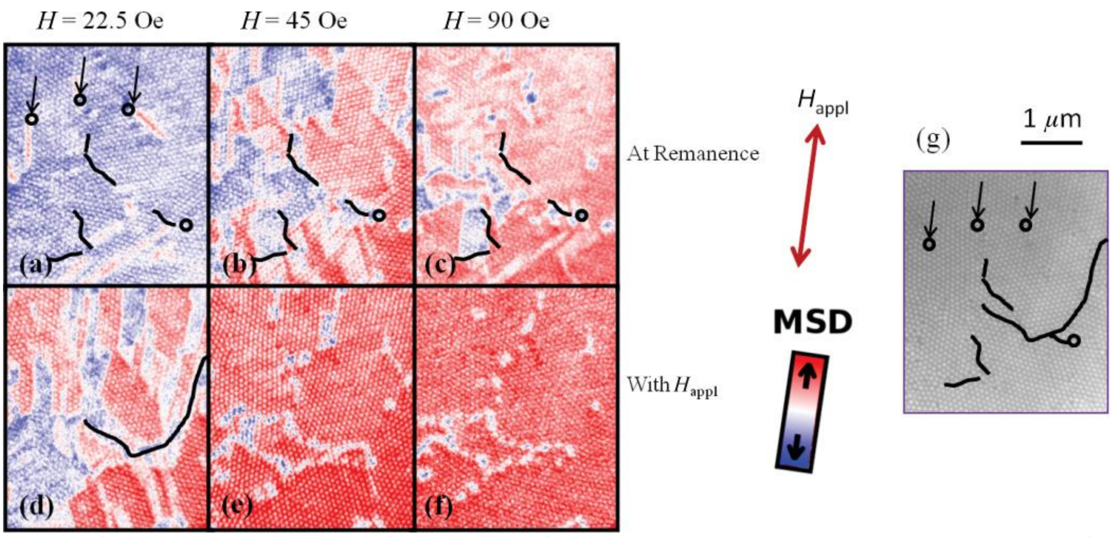

XMCD images of the magnetic domain structure of a Py antidot thin film grown on alumina template (a)–(c) at remanence and (d)–(f) under the applied field, and (g) XPEEM image denoting the geometric domains, with indication of some dislocations and punctual defects (*K.J. Merazzo et al. Phys. Rev B 85, 184427 (2012)*)

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Magnetic force microscopy study of dense stripe domains in Fe-B/Co-Si-B multilayers and the evolution under an external applied field
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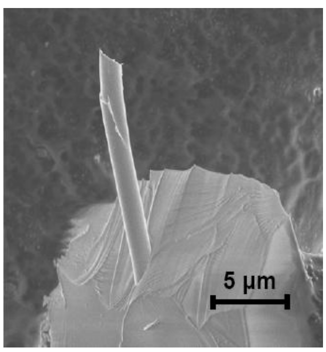
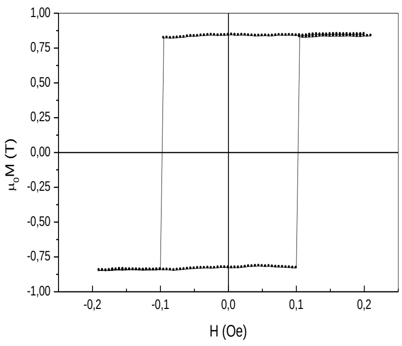
c) Magnetic Microwires

Amorphous metallic alloys are prepared by rapid solidification techniques. At the ICMM/CSIC laboratories we have three casting units operational for ribbons (50 mm thick), in-rotating-water quenching (120 mm diameter wires) and glass-coating quenching (glass-coated microwires, 1 to 30 μm diameter for the metallic core and 5-10 μm glass thickness). Amorphous structure, and its characteristics soft magnetic behaviour, is ensured by the rapid solidification process, so that, magnetic response is mainly determined by the strong mechanical stresses coupled to magnetostriction. General composition is FeCoSiB where the relative content Fe/Co determines the sign of magnetostriction (positive for Fe, and negative for Co).

Most relevant features are: i) Magnetic bistability (remagnetization between two stable remanent states showing a squared hysteresis loop), ii) Giant Magnetoimpedance (large change of impedance of a metallic conductor at the presence of a given static field). Other achievements by the group include: Bimagnetic microwires and Sensor Application. Previous studies included also Magnetostriction & Induced Anisotropies & Nanocrystalline Alloys.



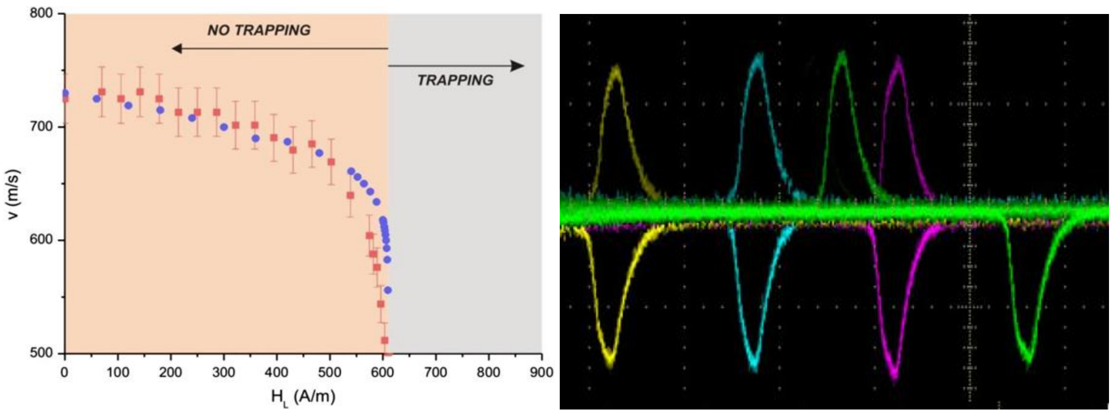


Glass-coating cast unit during the quenching fabrication (left); FeSiB glass-coated (center) and its bistable loop (right)

c.1) Magnetic Bistability & Single Domain Wall Remagnetization in Microwires

Magnetostrictive microwires show a squared hysteresis loop when axially magnetized. Such bistable behaviour, with a single giant Barkhausen jump, is originated by the propagation of a single domain wall, and it appears spontaneously in Fe rich microwires with large positive magnetostriction (30 ppm) where its coupling with strong mechanical (quenching, drawing and glass-induced) stresses of fabrication determine an axial magnetization easy direction.

Most relevant studies along have been devoted to the reversal by motion of a single DW that represents an ideal case for fundamental static and dynamic studies. As it has been demonstrated years ago, at remanence there is a nearly single axial domain with closure structures at both ends. Reduced local net magnetization is observed by MOKE at both ends. Under the application of a homogeneous axial field, at a critical value (0.1 to 5 Oe) a domain wall depins from one of the ends and propagates along the whole microwire to reach the opposite end. The position, motion direction and the speed of the wall is experimentally determined with the help of few tiny pick coils to be in the range 0.5 to few km/s.



Left.- Domain wall velocity in a FeSiB microwire is tuned in with a local field, H_L, antiparallel to the homogeneous drive field originating the wall motion. For a given local field, 610 A/m, it gets trapped. Experimental and calculated data of DWSt speed are included *(M. Vazquez et al. Phys. Rev. Letters, 108 (3), art. no. 037201 (2012))*Right.- Sequences of induced signals at the pickup coils numbered (yellow, blue, pink, green), under rightward (bottom peaks) and leftward (upper peaks) applied field of amplitude 392 A/m. Note the presence of two domain walls moving in opposite directions (*A. Jimenez et al. European Phys. Journal B, 86 (3), art. no. 113 (2013)*)

In a series of articles we investigated the motion equation of the wall considering the damping from structural defects and the interaction with amorphous relaxation effects. The temperature dependence of switching field allowed additional information about structure defects. More recently we have focused towards the controlled motion of the DW. The DW nucleates at the largest “defect” which is the end of the microwire, however, it can be nucleated somewhere else under the action of local reverse magnetic field supplied by a tiny coil. In this way, it was possible to move and to stop at will the position and the velocity by applying local field parallel/antiparallel to the main homogeneous exciting field. Moreover, several domain walls can be nucleated and move (when in opposition, they collapse and annihilate). Current challenge is the generation of a train of domain walls moving at unison. Further, the electromotive force induced at the ends of the microwire upon the flowing of a small ac current through the wire gives us an additional hint of the shape and motion conditions for the wall. Such control of the DW motion is thought to be much relevant for the development of magnetic sensors and particularly for logic devices

<u>Key Publications.-</u>

- Klein, P., Onufer, J., Ziman, J., Badini-Confalonieri, G.A., Vazquez, M., Varga, R.

Effect of Annealing on Domain Wall Mass in Amorphous FeCoMoB Microwires(2017) IEEE Transactions on Magnetics, 53 (11), art. no. 7894167, . DOI: 10.1109/TMAG.2017.2692253

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Enhancing the velocity of the single domain wall by current annealing in nanocrystalline FeCoMoB microwires
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(2014) Journal of Magnetism and Magnetic Materials, 358-359, pp. 198-203. DOI: 10.1016/j.jmmm.2014.01.068

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Stable and fast domain wall dynamics in nanocrystalline magnetic microwire
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Local magnetization profile and geometry magnetization effects in microwires as determined by magneto-optical Kerr effect
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- Vázquez, M., Basheed, G.A., Infante, G., Del Real, R.P.
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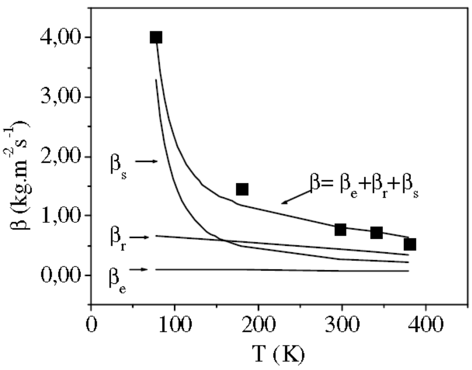
Influence of the sample length on the switching process of magnetostrictive amorphous wire
(1992) Journal of Magnetism and Magnetic Materials, 103 (1-2), pp. 117-125. DOI: 10.1016/0304-8853(92)90244-I



Temperature dependence of the domain wall damping β: experimental (square points) and calculated. Eddy current contribution, β_e, spin-relaxation damping coefficient, β_r, and structural relaxation wall damping β_s (R. *Varga et al., Phys. Rev. Letters, 94 (1), art. no. 017201, (2005).*

c.2) Giant Magnetoimpedance, GMI, and High-frequency absorption, FMR

The giant magnetoimpedance was rediscovered in 1994 in soft amorphous alloys (i.e., in-water-quenched microwires) and consists of the very large change of impedance, both real and imaginary parts, of a metallic conductor at the presence of static magnetic field. In fact, to measure the impedance, a small AC current of high frequency flows along the conductor. If the frequency is high enough, the current flows just near the surface down to the skin-effect depth. The real advantage is provided by ultra-soft conductors like the amorphous alloys where the static field changes the permeability of the sample and consequently the skin depth and the impedance finally. In ultrasoft microwires changes of permeability occur at small field and consequently they can be used as field sensors in the low-field region. It is particularly large effect in near vanishing magnetostriction alloys (i.e., CoFe based). Most original work was performed along the 90's decade to determine the full understanding of GMI and the optimal parameters like amplitude and frequency of AC current, the most suitable susceptibility characteristics of various materials (i.e, optimal response is obtained in amorphous wires and ribbons while amorphous thin films somehow gives a more limited response). For example, microwires with axial magnetization easy axis (Fe-base) show so-labelled single-peak GMI with a maximum at zero applied field. In turn, alloys with perpendicular easy axis (Co-base) exhibit two-peak behaviour with maximum GMI at the transverse anisotropy field.

The maximum GMI response is in the radio frequency range and up to few GHz depending on the composition and geometry. However, quite interesting is the response in the microwave frequency range (few GHz) where resonant absorption and FMR phenomena take place. That behaviour was originally exploited in the former USSR for the development of antiradar screens by embedding small microwire pieces in polymeric films and paintings.

Key Publications.

- El Kammouni, R., Kurlyandskaya, G.V., Vázquez, M., Volchkov, S.O.
Magnetic properties and magnetoimpedance of short CuBe/CoFeNi electroplated microtubes
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LC and ferromagnetic resonance in soft/hard magnetic microwires(2015) Journal of Magnetism and Magnetic Materials, 395, pp. 196-198. DOI: 10.1016/j.jmmm.2015.05.030

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(2014) Applied Physics Letters, 105 (10), art. no. 102409, . DOI: 10.1063/1.4895708

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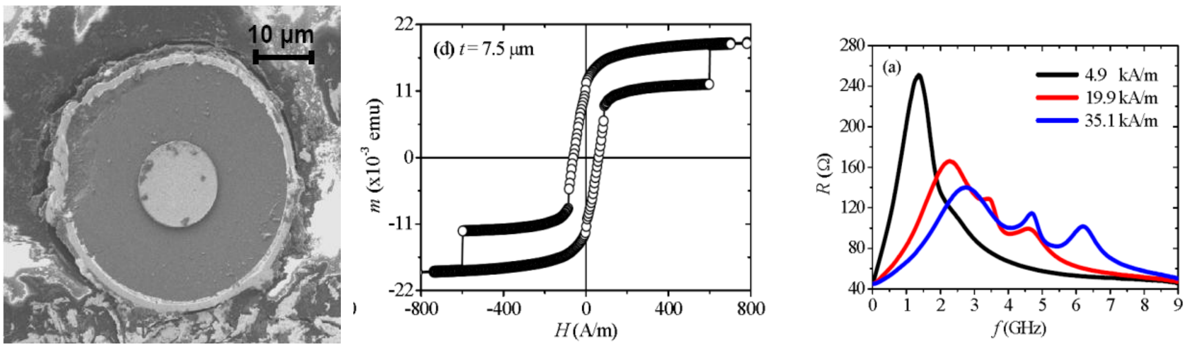


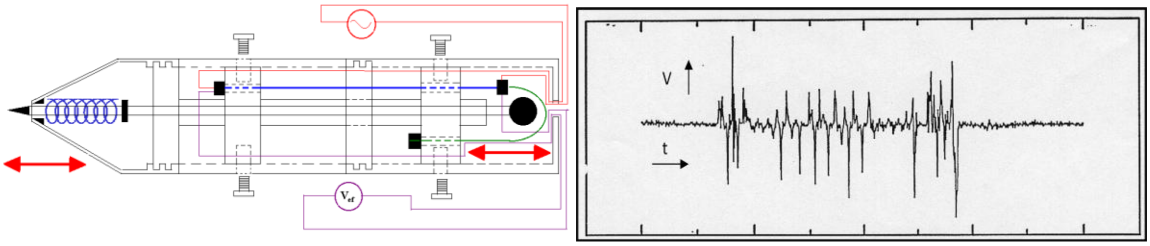
FeSiB/CoNi bimagnetic microwire (left); hysteresis loop of a soft/ultrasoft FeSiB/NiFe bimagnetic wire (center) and the impedance spectrum with static field as the parameter for a CoFeSiB/NiFe microwire (right) (*G. Infante PhD, 2010*)

c.3) Bimagnetic microwires and sensor applications

The group introduced by the beginning of 2000's the so-called bimagnetic of biphase microwires employing combined rapid solidification-sputtering-electrodeposition. In this way it was possible to grow an external magnetic micro or nanotube with different magnetic character as compared to the core of the precursor glass-coated microwire. Original work was performed in soft/soft, soft/hard and hard/soft bimagnetic wires. Particular emphasis was made to determine the extent of magnetoelastic and magnetostatic interactions between phases. Important is the case of soft/hard microwire after magnetic saturation followed by low-field magnetization since the soft core undergoes a magnetostatic shift similar to exchange bias.

Microwave absorption and FMR determination has been systematically performed in these bimagnetic wires where specific absorption phenomena are identified specially in soft/soft microwires.

All these effects namely, magnetic bistability and GMI are being currently employed in a number of sensor devices where specific microwires are designed and fabricated as particular sensing elements. In this way, a number of patents have been filed, and applied developments are currently in progress.



Magnetoelastic Signature device (pen) for signature identification and authentication and magnetoelastic signature (right) using GMI effect glass-coated microwire as sensing element (Patented).

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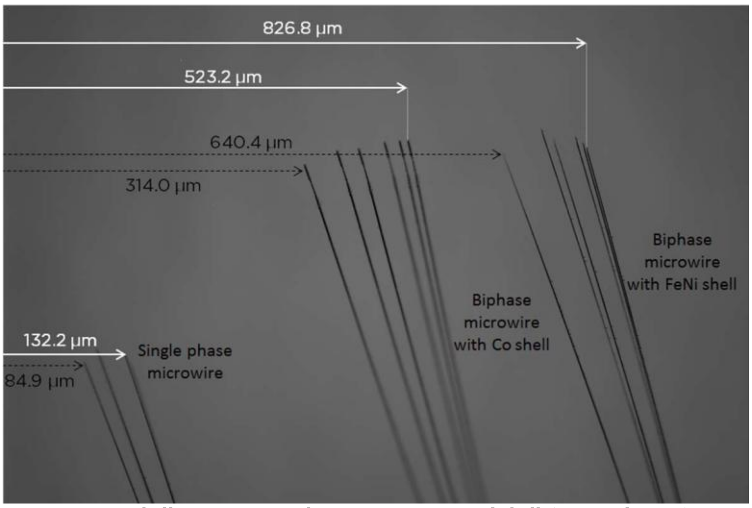

Micro-actuator based on bimagnetic core/shell microwires with asymmetric external shell (Patented, 2017). Image showing the bending under increasing applied field of the single-phase FeSiB (left), and biphase microwires with Co (middle) and FeNi (right) external shell.

c.4) Magnetostriction & Induced Anisotropies & Nanocrystalline Alloys

Investigations on amorphous alloys started during the 80's and continued later in the 90's not only on amorphous wires but also on amorphous ribbons. Interest at the time was focused on intrinsic stress distribution and on magnetostriction. Very fine magnetostriction measurements were performed (modified small-angle-magnetization-rotation method) in vanishing-magnetostriction ribbons (CoFe-based) as a function of the measuring temperature. It was found particularly the crossing zero-magnetostriction in CoFe- based alloys at given temperature below the Curie point. That was interpreted as originated from the different temperature dependence of single-ion and two-ion anisotropy mechanisms. Also, the critical exponent for the magnetostriction was introduced and correlated with the other critical exponents for magnetization and susceptibility.

An important aspect was the induction of magnetic anisotropies by free thermal treatments or at the presence of magnetic field or mechanical stresses. That way enabled the induction of axia, transverse and helical anisotropies. Quite interestingly, studies on the nanocrystallization process in FeSiBCuNb alloys were performed. The microstructural changes of the amorphous state were correlated to the magnetic response so that, ultrasoft character was observed before the nucleation of small hard grains.

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4. Main Scientific Projects

- “Design of magnetic nanowires for green technologies” MAT2016-76824-C3-1-R, MINEC (2017-19), IPs: A. Asenjo, R.Perez,

- “Magnetic Nanowires and their 3D arrays for advanced technlogies”, MAT2013-48054-C2-1; MINECO; 2014- 2016; IPs: Manuel Vázquez and Agustina Asenjo

- “Rare Earth Free Permanent Magnets (REFREEPERMAG)”, FP7NMP.2011. 2.2-4; European Union, 2012- 2015 IPs: D. Niarchos (NCRS, Athens), M. Vázquez (ICMM/CSIC), Univ. Duisburg-Essen (M. Farle), Techn. Un. Vienna (J. Fidler), Uppsala Uni. (O. Erikson), Ruhr-Universitaet Bochum, Leibniz-Institut fuer Festkoerper-und Werkstofforschung Dresden (S. Faehler), Comm. Energie Atomique (F. Ott), Un. Toulouse (G. Viau), Magnetfabrik Bonn, Wittenstein Cyber Motor, Un Delaware, USA (G. Hadjipanayis).

- *"Ordered arrays of nanodots and antidots: magnetization and transport", MAT2010-20798-C05-01; MCINN; 2011- 2014; IP: Manuel Vázquez*

- "New Frontiers in fundamental and applied nanomagnetism". NANOFRONTMAG-CM (S2013/MIT-2850) CAM: 2014-2018; IPs: R. Miranda (IMDEA), M. Vazquez (ICMM/CSIC)

- *"Integrated Lab-On-Chip Platforms for Medical Diagnostics" EUI2008-00120; Programa Internacionalización Investigacion Hispano-Portugués; 2008- 2011; IPs: P. Freitas, R. Ibarra, M. Vázquez (ICMM).*

- "Magnetic nanoparticles combined with submicron bubbles for oncologing imaging" NANOMAGDYE, FP7-NMP-2007-SMALL-1; European Union;; IPs: G. Pourroy (CNRS, Grenoble), M. Vázquez (ICMM), I. Bernhard (Saarland Univ.), P. Chirco (Softech Techn & Res. Italy), P. Vertesy (Hungarian Ac. Sc.) 2008- 2012

- *"Magnetotransport in micro and nanowires" MAT2007-65420-C02-01; MCINN, 2008- 2011; IP: M. Vázquez;*

- "Ordered arrays of nanowires, nanotubes and antidots" 2010CL0018; Bilateral Project ICMM/CSIC and Univ. Santiago, Chile; 2011-2012; IPs: D. Altbir and M. Vázquez

- *"Magnetic Nanostructures for Data Storage"; MISTI Global Seed Fund, MIT-Spain; 2009- 2011; IPs: C. Ross (MIT); M. Vázquez (ICMM/CSIC)/F. Castaño (UPV)*

- "FMR studies in magnetic wires"; Bilateral Spanish-Czech action; 2009- 2011; IPs: M. Vazquez and L. Kraus.

- *"Magnetic Nanoparticles and Nanostructures: from spintronics to biomedicine" NANOBIOMAGNET(S2009/MAT-1726); CAM; 2009-2012; IPs: R. Miranda, IMDEA, ICMM, M. Vázquez;*

- "The study of high frequency behavior of magnetic nanostructures" PCI2006-A7-0694; ICMM/CSIC- Un. Tangier, Marocco; 2008- 2011; IPs: M. Vazquez and M.R. Brittel;

- *"Magnetotransport properties in micro and nanowires", Min Ed. Sc. MAT2007-6542-C2-01 IP MVazquez, 2007-2010*

- "Ordered magnetic nanostructures for applications in optomagnetic biosensors" PIE CSIC project. ICMM/IMM/IIQA/ICMAB, IP: (ICMM) M Vazquez, G. Armelles, P. Marco, 2005-07.

- *"Magnetic domain analysis and magnetization process of micro and nanowires" Spain-Germany Bilateral agreement IP: R. Schaefer (IFW, Dresden) and M Vazquez (ICMM), 2005-06.*

- "Template assisted gowth of magnetic nanostructures from chemical solutions" PIE CSIC project ICMAB/CNM/ICMM, IP (ICMM) M Vazquez, X. Obradors, X. Borrisé, 2005-07.

- *"High frequency behavior of arrays of micro and nanowires" Japan-Span bilateral program, Tohoku Un. (M. Yamaguchi) and CSIC (M Vazquez), 2005*

- "Ferromagnetic nanowire arrays" Funded by Regional Government of Madrid GRMAT/0423-2004, IP: MVazquez, 2005

- *"Evaluation of magnetic properties of nanocrystalline magnetic materials" Bilateral Spain-Poland program, Cestochowa Inst Power Engeenering (J. Sczyglowsky) ICMM (MVazquez), 2004-05.*

- "Uni and bidimensional self-assembled magnetic nanosystems" Min. Es. Science, MAT2004-00150, IP MVazquez, 2005-07.

- *"Giant Magnetoimpedance in magnetic microwires" Funded by CSIC-CONACYTAgreement, UNAM-Mexico (R. Valenzuela) and ICMM-CSIC (MVazquez) 2004-5*

- "Magnetstrictive bi-layers for multifunctional sensor famiygjlies" EU-Growth GRD1-2001-40725, IP: H. Pfützner (Techn. Un. Vienna), M Vazquez (CSIC), Cardiff Un. (T. Moses), Fiat (J.Chiricco), ELCAT (Germany).

- *"Magnetism in low dimensions, relaxation and anisotropy" Funded by FONDECYT 2002 (Chile). IP: P. Vargas (Un. F. Sta. María, Valparaiso), M. Vázquez (ICMM/CSIC), M. Knobel (Un. Campinas, Brasil). 2002-2003.*

- "Nanohilos magnéticos" Funded by AECI/CONACYT. IP: M. Vázquez (ICMM), M. Tovar (CA. Bariloche, Argentina). 2001-2002.

- *"The nature of disperse (second) phase and the dynamic properties in ultrasoft magnetic alloys" Foreign Affairs Minst. PI: M. Vázquez & A. Lovas (Hungary Ac. Sciences) 2001-2003.*

- "Magnetoimpedance and absorption in soft ferrites and amorphous alloys" Agreement CSIC/CONACYT. PI: Vázquez (CSIC) and R. Valenzuela (CONACYT, UNAM-Mexico). 1999-2000

- *"Preparation, Magnetic Properties and Applications of amorphous microwires" Spain-Romania Bilateral agreement, PI.: M. Vázquez (CSIC) and H. Chiriac (Inst. Phys. Iasi, Romania). 1996-1997, 1999-2001*

- "New sensing elements for magnetic recording: Nanowires and characterization by MFM" Regional Governm. Madrid, CAM (07N/0033/1998). Diciembre 1998 / Diciembre 2000

- *"Artificial Magnetic Nanoestructures design, preparation, magnetic characterization and applications" CICYT MAT98-0965-C04-C01. PI: M. Vázquez (Coordinator, ICMM), J.J. de Miguel (UAM), P. Crespo (IMA), y F. Cebollada (UPM). Octubre 1998 / Octubre 2001*

- "Electrical and Magnetic properties of materials" EU (Programa ALFA Europeo-Latinoamericano). PI: J.Irvine (Coordinador, Univ. St. Andrews), G.Pourroy (Univ. Strassbourg), M.Vázquez (IMA), R.Valenzuela (UNAM), J.Gonzalez (Univ. P. Vasco), A.Guimaraes (Univ. R. Janeiro), Univ. Aveiro y Univ. Monterrey. 1998.

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- *"Magnetism of multiphase systems" Spain Minst. Science and Education CICYT (MAT95-0273). Jul.95-Jun.98.*

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- *"Amorphous and nanocrystalline alloys" Programa de Cooperación Iberoamericana (ICI). PI: M.Vázquez (IMA) and H.Sirkin (Univ. Buenos Aires). Ene.1995-Dic. 1996.*

- "Multiphase Magnetic systems" Spain-Germany Integrated Action. PI: H.Kronmüller (MPI, Stuttgart) and M.Vázquez (ICMM, Madrid). Enero 1995- Diciembre 1997.

- *"Vibrating Sample Magnetometry" Infraestructure Min. Ed. Science, CICYT. 1994.*

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- *"Optimized soft magnetic materials: microwires and nanocrystalline alloys" Spain. Min. Sc. Educ. C.I.C.Y.T (MAT/ 92-0156). Junio 1992- Mayo 1995).*

- "Preparation and structural and magnetic characterisation of amorphous wires". British-Spanish Integrated Actions. PI: H.A. Davies (Univ. de Sheffield) and M. Vázquez (ICMM). Abril 1992- Marzo 1993.

- *"Correlation between microstructure and magnetization processes in soft/hard magnetic materials" Germany-Spain Integrated Actions. PI: H. Kronmüller (M.P.I. Stuttgart) y M. Vázquez (I.C.M.M.). En. 1991- Dic. 1993.*

- "Fabrication, magnetic characterization and microstructure modifications in amorphous alloys of technological relevance" Sp. Misn. Sc. Educ. CICYT (MAT89-0508). Nov. 1989- Oct.1992.

5. PhD Supervision

- David González "Plantillas nanostructuradas por impresión y anodización para el crecimiento de redes ordenadas de nanohilos y nanotiras de Co" Univ. Autónoma de Madrid, co-Supervisors: M. Vazquez and D. Navas, 2017

- Alejandro Jimenez "Movimiento controlado de paredes magnéticas en microhilos biestables" Univ Autónoma de Madrid, Supervisor: M Vazquez, 2017

- Ester M. Palmero "Magnetization processes of magnetic modulated nanowires" Autonomous Univ. Madrid, Co-supervisors: M. Vazquez, R. Perez and C. Bran, 2016

- Rhimou El Kammouni "Single and biphase magnetic microwires: Microwave behavior and temperature dependence" Uni. Autónoma Madrid, Supervisor: MVazquez, 2014

- Mariana P. Proença, "Magnetism at the Nanoscale: Nanoparticles, Nanowires, Nanotubes and their Ordered Arrays " Porto University, Co-supervisors: J. P. E. de Araújo,, M. Vázquez and J. O. Ventura, 2013

- Karla J. Merazzo "Ordered magnetic anidot arrays" Autonomous Univ. Madrid, Supervisor: M. Vazquez, 2012

- Diana P. Leitao "On the magnetic and structural properties of Co and Co-based nanowire arrays" Porto University, Portugal, Co-supervising: JP Araujo and M Vazquez, 2012

- Ignacio Minguez " Nanostructures fabrication: Porous anodic alumina and ZnO nanorods" Autonomous Univ. Madrid, co-Supervisors: M. Hernandez-Velez and M. Vazquez, 2012

- Laura G. Vivas "On the magnetic and structural properties of Co and Co-based nanowire arrays" Autonomous Univ. Madrid, Supervisor: M. Vazquez, 2012

- German Infante "Propiedades magnéticas y de Transporte en nuevos microhilos mono y bifásicos" Autonomous Univ. Madrid, Supervisor: M Vazquez, 2010

.- Wagner O. da Rosa "Nanostructuras magnéticas ordenadas sobre alúmina anodizada" Universidad Autónoma de Mdrid, Co- Superviors: M Vazquez and A. Asenjo, 2009

- Ruy Sanz "Nanostricturas ordenadas basadas en TiO2 y ZnO obtenidas mediante irradiación iónica" Universidad Autónoma de Madrid, Co-Supervisors: M. Hernandez-Velez and M. Vazquez, 2009.

- Jacob Torrejon “Estudiodel acoplamiento magnetoelastico y magnetoestático en microsistemas magnéticos multifásicos” Universidad Autónoma de Madrid, Supervisor: M Vazquez, 2009

- Pedro Mendoza de Zelis “Mecanismos de inversion de imanacion en aleaciones amorfas“, University of La Plata, Argentina. Co-supervisor Q. Sánchez, M. Vazquez. 2007

- Davas Navas “Preparación y Propiedades Magneticas de arrays de nanohilos magnéticos en membranas porosas”, Autonomous Univ. Madrid, Supervisor M Vazquez, 2006

- Karin García “Proceso de inversion de la imanación, y su dinámica en microhilos magneticos biestables”, Universidad Complutense de Madrid. Supervisor M Vazquez. 2006.

- Carlos Luna “Preparación y Propiedades Magneticas de nanopartículas de CoNi”, Universidad Autónoma de Madrid. Co-supervisors: J.C. Serna and M. Vazquez, 2006.

- Pedro Agudo “Influencia de pequeños contenidos de Ni y Cr en el comportamiento magnético y propiedades de corrosión de aleaciones nanocristalinas”, Universidad Complutense. Supervisor: M Vazquez, 2005

- Yin-Feng Li “Propiedades dinámicas de imanación y efecto de magnetoimpedancia gigante en hilos magnéticos”, Universidad Complutense. Supervisor: M. Vazquez, 2003.

- Leonor Pascual “Propiedades magnéticas lineales y circulares de los hilos amorfos”, Universidad Complutense, co-Supervisors: D.X Chen and M Vazquez 2003

- David García “Anisotropías magnéticas en películas delgadas y multicapas ferromagnético/ferromagnético fabricadas por pulverización catódica”, Universidad Complutense de Madrid, Supervisor: M Vazquez, 2000

- Juan Manuel García Beneytez “Magnetismo y propiedades de transporte en Microhilos Metálicos”, Universidad Complutense de Madrid, Supervisor M Vazquez, 2.000

- José Miguel García “Nanohilos Magéticos preparados por electrodeposición y caracterizado mediante Microscopía de Fuerzas Magnéticas”, Universidad Complutense de Madrid, Supervisor M Vazquez, 1999

- Hector García Miquel”Caracterización de las propiedades magnéticas de vidrios metálicos en forma de microhilos, de composición FeCoSiB” Universidad Politécnica de Valencia, co-Supervising: M Vazquez and J.M. Andrés, 1999

- Javier Moya “Aleaciones nanocristalinas: propiedades magneticas blandas, propiedades mecanicas, y aplicaciones” Universidad de Buenos Aires, co-Supervising: H. Sirkin and M. Vazquez, 1999

- Julián Velázquez Cano "Anisotropia Magnetoelástica en hilos amorfos inducida durante su proceso de Fabricación" Universidad Complutense, co-Supervising: A. Hernando and M. Vazquez, 1995

- Pilar Marín Palacios "Evolución de las propiedades magnéticas durante el proceso de nanocristalización de hilos amorfos de composición FeSiBCuNb" Universidad Complutense, Supervisor: M. Vazquez, 1995.

- Cristina Gomez Polo "Magnetismo de hilos amorfos: comportamiento biestable y relajación estructural" Universidad Complutense, Supervisor: M Vazquez, 1992.

- Julián González Estévez "Anisotropías magnéticas inducidas en vidrios metálicos recocidos por corrientes eléctricas" Universidad del Pais Vasco, co-Supervising: JM Barandiarán and M Vazquez, 1987

- Cristina Nuñez de Villavicencio "Medida directa de la magnetostricción en aleaciones amorfas ricas en Co: Variación con la temperatura y exponente crítico" Universidad Complutense, Supervisor: M Vazquez, 1987.

6. Main Technological Projects

- “Development of a new technology for the application in wireless battery charging in the range of 20-150 kHz” MINECO (RTC-2016-4820-4), Consortium: PREMO-ANDALTEC-CSIC-UPM, PI. (CSIC) R. Perez, M. Vazquez

- *“EM protection of electrical bundles to fast EM transients”; EADS France; 2013-2016; IP: R. Pérez, M.Vazquez (ICMM/CSIC)*

- “Magnetic microwires for various sensor devices” Universidad Publica de Navarra, 2013-2014; IPs: M. Vazquez (CSIC) & C. Gomez-Polo (UnPub Navarra)

- *“Displacement and Position sensing using magnetic microwires materials” Micro-Epsilon Messtechnik GmbH, Ortenburg, Germany; 2011; IPs: M. Vazquez and T. Wisspeittner;*

- “Dynamics of domain wall motion in micro and nanowires”; ICMM/CSIC and IBM, Almaden Research Centre; 2010-2014; IPs: S.S.K. Parkin and M. Vazquez.

- *“Hilos submicrometricos para generador eléctrico, purificación de aguas y sensor medioambiental” PLE2009-0057; MICINN; 2009-2012; IPs: M. Vazquez (CSIC), K. Mohri (Nagoya Industrial Research Inst., NISRI)*

- “Magnetic microwires rapidly solidified for sensing applications” Contract Publ. Univ. Navarra (C. Gomez-Polo) and ICMM/CSIC (M Vazquez), 2008-2011

- *“Microwires as sensing elements for low-noise sensors”, contract Quantec, Geotech (Montreal, Canada) R. Bazinet and ICMM/CSIC, M. Vazquez, 2007-08*

- “Fabrication and development of micron-size glass-coated microwires as sensing elements for magneto-impedance devices” contract Aichi-Toyota Japan (Y. Honkura) and ICMM/CSIC (M Vazquez) 2005-06.

- *“Magnetoelastic signature: Development of magnetoelastic sensos for identification and authentification of signature employing magnetic microwires as sensing elements” Min. Ed. Science, Project PETRI 95-0594-OP Company Micromag and ICMM/CSIC IP ICMM: M. Vázquez. 2002-2003.*

- “Magnetic wires for absorption screens”, Spain Space Agency INTA/IMA. IP: M. Vazquez, 1998- 1999.

- *“Antiradar absorption screens” Spain. Min. Sc. Educ., PETRI 95-0339-OP IMA/ Minist. Defense, TPYCEA., IP (IMA): M. Vazquez, 1999 –2001*

- "Magnetic fields by high voltaje power lines" General Attorney Justice Minstr. of Madrid. IP: M. Vazquez, 1997.

- *"Battery charge by magnetic induction” Tutoring J.M. Garcia grant VOLKSWAGEN-CSIC. 1996-8*

- Magnetic properties of soft ferrites” Hispafer (Philips Components), IMA and Farmacyc Fac., UCM. IP(IMA): M.Vazquez, 1996.

- *“Soft magnetic materials by metallurgical techniques" IMA & Barcelona Univ. PI: M.Vazquez (IMA) and N. Clavaguera, 1995*

- "Amorphous microwires as absorption materials of electromagnetic radiation” Spain Minst. Defense, program: COINCIDENTE, IMA and TPYCEA. IP(IMA): M.Vazquez, 1995.

- *“Magnetic integrated circuits MAGIC”, GAME program PI: IMA, Alcatel-Sesa, Philips, Univ. Politécnica de Madrid & Universidad de Oviedo. IP(IMA): M.Vazquez, 1994-1996.*

- Spin-off promotor of company "Vidrios Metálicos S.A." for the development of prototypes based in magnetic properties of amorphous alloys. Jan. 1987.

7. Patents

- M. Vazquez, R. ElKammouni, V. Rodionova, N. Perov, K. Chichay, I. Baraban
“Microactuator based on bimagnetic coated core/shell microwires with asymmetric external shell and the use of it”
Co-ownership CSIC/Fed.Un. Baltic, Europe/Russia patent EP17382418.6

- M. Vazquez and V. Kolesar
“Procedure & apparatus to measure DC-field based on magnetostrictive effect in magnetic wires.
Co-owbership CSIC/Slovak Techn. Bratislava Uni. EP15195921

- M. Vazquez and V. Kolesar
“Temperature sensor for electromechanical systems and its fabrication procedure“
Co-owbership CSIC/Slovak Techn. Bratislava Uni., Sp. Patent P2014/31530

- R. Perez, M. Vazquez, E. Palmero, A. Asenjo and C. Bran
“Sensors based on disks with magnetic nanowires”
CSIC, Sp.Patent P2014/31005

- M. Vazquez, G. Badini-Confalonieri, G. Infante, M. Butta and P. Ripka
“Bimetallic magnetic wires with helical anisotropy”,
Co-ownership CSIC/Czech Techn. Prag Un., Sp. Patent PES2009/070417.

- M. Vazquez, G. Badini-Confalonieri, C. Gomez-Polo, J. Perez de Landazabal, J. Recarte, V. Sanchez
“Ferromagnetic wires with shape memory”,
Co-owbership CSIC/Un. Publica Navarra, PCT/ES2008/070034.

- M. Vazquez, K. Pirota, G. Badini-Confalonieri, J. Torrejon and H. Pfüztner
“Multifunctional sensor based on magnetic microwires”
Co-ownership CSIC/Techn Un. Vienna, Patent PCT/ES2006/070173

- V. Larin, A. Torkunov, L. Panina, D. Mapps, A. Zhukov, J. Gonzalez, M. Vázquez, A. Hernando
"Micro wires and a process for their preparation”

- C. Tyren, A. Hernando, M. Vázquez and C. Quiñones
“Wireless Stress Antenna”
UK Patent

- F. Castaño, M. Vázquez, A. Hernando
“Viscosimetro basado en la rotación macroscópica de hilos inducida por campo magnético”

- A. Hernando, M. Vázquez, P. Marín, E. Fraga, P. Agudo, D.X. Chen y J. Llorente
"Dispositivo magnético electrónico para control de sistemas de proteccion perimetral"
P9901732

- M. Vázquez, A. Hernando, J.J. Freijo, C. Gómez-Polo y J.M. Barandiarán
"Dispositivo para la deteccion de la posicion de un piston neumático"
P9900237

- M. Vázquez, A. Hernando, P. Marín, A. Zhukov, V. Larin, A. Torkunov y A. Antonenko
"Producción de microhilos magnéticos de elevada susceptibilidad"

- M. Vázquez, A. Hernando, J. Arcas y C. Gómez
"Sensor de corriente crítica basado en el efecto Matteucci"
P9602271

- A. Hernando, A. Zhukov, M. Vázquez, V. Larin, A. Torkunov y A. Antonenko
" Método de codificación y marcado magnético de objetos"
P9601993

- M. Vázquez, J.M. Garcia Beneytez y A.Zhukov
" Dispositivo magnetoelastico para la identificacion y autentificación de firmas",
P 9600172

- M. Vázquez, A. Hernando y R. Valenzuela
"Dispositivo para la medida de corrientes continuas",
P 9502081

- M. Vázquez, A. Hernando y R. Valenzuela
"Dispositivo magnético de detección y control de elementos móviles",
P 9501232

- E. Fraga, G. Rivero, J.M. Barandiarán, M. Vázquez y A.Hernando
"Dispositivo eléctrico y electrónico de seguridad para vallas" ,
P 9302583

- M. Vázquez, G. Rivero, J. M. Barandiarán y A. Hernando
"Sensor de detección de ejes móviles en vias de ferrocarril"
P9001345

- M. Vázquez, G. Rivero, J. M. Barandiarán y A. Hernando
"Sensor de campo magnético",
P9001344

- M. Vázquez, G. Rivero, J. M. Barandiarán y A. Hernando
"Sensor de campos magnéticos que utiliza como sensor un hilo amorfo ferromagnético con anisotropia helicoidal" ,
P 9001343

- M.Vázquez, G. Rivero, J. M. Barandiarán y A. Hernando
"Sistemas de seguridad para vallas alámbricas",
P 8903270 (Comercialized).

- A. Mitra, M. Vázquez, G. Rivero, J.M. Barandiarán y A. Hernando
"Sensor de fuerza o tensión mecánica",
P 8903269

8. Conferences (only chairing/organization)

- Program Chair, ICM'2015, Barcelona
- Chair Intermag Europe 2008, Madrid
- Co-chair Symposium "Soft Magnetic Materials". JEMS, Grenoble, 2001.
- Chair Int. Workshop on Magnetic Wires. San Sebastian, Spain 2001.
- Co-chair Symposium "Ferromagnetic Materials". Spring Meeting MRS. San Francisco, 2001.
- Co-Promotor of European Magnetic Sensors and Applications, EMSA, series of Conferences, Athens, 1994
- Secretary "Soft Magnetic Materials'9" Conf. El Escorial, 1989.
- Secretary "Intern. Symp. on Magnetic Properties of Amorphous Metals" Benalmádena, Spain, 1987

8a) Selected Invited Talks to Conferences and Schools

- Cali School on Magnetism, Colombia, 2018
- *Advances in Magnetics, AIM 2018, La Thuile, Italy*

- Carnegie Mellon Uni., Pittsburgh, 2017
- *18th Int. Symposium on Electromagnetics, ISEM 2017, Chamonix, France*
- Intern. Baltic Conf. on Magnetism, IBCM 2017, Kaliningrad, Russia
- Annual Meeting, Italy Chapter, Messina
- *VI Euro-Asian Symposium MagnTrends, Eastmag 2016, Krasnoiarsk, Russia*
- 16th Czech and Slovak Conf. on Magnetism, Kosiçe, 2016
- Course Magnetism, Univ. Wuhan Hubei, China
- Advances in Magnetics'16, Bormio, Italy
- Int. Worksh. Magn. Nano. Magnets., IWMNM, Meersburg, Germany, 2015
- Recent Trends in Physics, ICRTP, Indore, India, 2016
- Amophous Nanocrystaline Magnetic Materials Conf, ANMM'2015, Iasi, Romania
- *ISMANAM'2015, Paris*
- Int. Workshop Magnetic Wires, Ordizia, Spain, 2015
- Summer school, NanoSciences, Ile-de-France, Etiolles, France, 2015
- Russian School, Urals Federal Univ. Yekaterinburg, 2014
- Int. Works. Novel Trends in Ferroics Phys. St. Petersburg, 2014
- MISM Conf., Moscow, 2014
- *INTERMAG 2014, Dresden, 2014*
- DICNMA 2013, S.Sebastian, 2013
- *EINC2013, Easter Island, Chile 2013*
- Spring School Magn. Materials & Applications, BCMaterials, Bilbao. 2013
- X LAW3M, Buenos Aires, 2013.
- II Brazilian Works. Magnetism & Dynamics, Natal, Brazil 2012
- *ICAUMS2012, Nara, Japan, 2012*
- *Joint Int. Magn. Symp., JEMS, Parma, 2012*
- Baltic School Sol. State & Magn., Kaliningrad, 2012
- *Adv. Electromagn. Symp., AES, Paris, 2012*
- 5th Int. Worksh. ANMM, Iasi, 2011.
- National Meeting NSC Taiwan, Hsinchu, 2011.
- 3rd Works. Chile-Mexico, Los Andes, 2011.
- *TMS Conf., San Diego, 2011*
- 3rd International Conference on Advanced Nano Materials, ANM 2010. Agadir, Morocco, 2010
- LAW3M, Manizales, Colombia, 2010
- UIMP, La Coruña, 2010
- *8th EMSA Conf. Bodrum, Turkey 2010*
- III Int. Conf. Quantum, Nano and Micro Technologies, Cancun, Mexico 2009
- *Self-organised Nanomagnets, Aussois, France Abr.2009*
- Int. Work. Non-crystalline Solids, Porto, 2008
- MISM, Moscow 2008
- *Soft Magnetic Materials Conf., SMM'18 Cardiff. Sept. 2007*
- Latin Amer. Workshop MMM. Rio de Janeiro 2007
- Int. Workshop non-crystalline solids. Gijon, Spain 2006
- LAW3M. Reñaca. Chile. Dic. 2005
- *Soft Magnetic Mat. Conf. Bratislava, 2005*
- ISEM Bad Gastein, Austria, 2005
- *90ª Reunion Nacional de Física. La Plata. Argentina. 2005*
- Int. Workshop Nanomagnetism ans Applications. La Habana. Nov. 2004
- At the Fontiers of the Condensed Matter school, Buenos Aires 2004
- *Joint European Magnetic Symposia. Dresden 2004*
- Meeting British Magnetic Society. Cardiff 2003
- Soft Magnetic materials Conf. Düsseldorf, 2003
- Int. Workshop Amorphous and Nanocrystalline Materials. Iasi. Romania, 2003
- Latin American workshop on magn. Magnetic materials. Chihuahua, 2003
- Int. WorkshopNon-crystalline solids. Méjico, 2003
- VI Congreso nacional de Materiales. Madrid, 2002
- *Int. Symp. Electromagnetics, ISEF Cracow. Sept. 2001*
- V Latin-Amer. Workshop, Bariloche, Argentina 2001
- International Symposium on Advanced Magnetic Materials. San Sebastian. 2000
- *ICM'2000 Conf. Recife, Brazil 2000*
- *Früjahr Tagung der Deutsche Physicalische Gesellschaft. Regensburg, 2000*
- *Opening ceremony Chungnam Univ. Center. Kyonjyu. 1999*
- *MISM international symposium devoted to E. Kondorskii, Moscow 1999*
- *Inten. Workshop on Amorphous wires, Films & Micromagnetic Sensor". Nagoya Mayo 1999.*
- *18th Ann. Conf. Prop.&Appl. Magnetic materials. Chicago Abril 1999.*
- 1998 Pulver Metallurgy World Congress. Granada, 1998
- IV Latin-American Workshop on MMM. Sao Paulo. Brasil. Julio 1998
- Texture and Properties Magnetics Int. Conf. Yekaterinburg, 1997
- Summer School UCM. El Escorial. Agosto 1997.
- *Université Schneider du Magnétisme" Groupe Schneider, Grenoble. Abril 1997.*
- I Escuela Iberoamericana de Magnetismo" UNAM (Mexico). Abril 1997.
- V Reunión Nacional de Materiales. Cádiz, Spain 1996
- *EMSA Conf. Iasi, Romania, 1996*
- *Corea Int. Conf. KIST, Seoul 1996*
- *Soft Magnetic Materials (SMM) Conf. Krakow, 1995*
- ISMANAM Conf. Grenoble, 1994.
- *Intern. Workshop on Rapidly Quenched Magnetic Wire and Applications, Albuquerque (New Mexico) 1994.*

- *European Magnetic Materials (EMMA) Conf., Kosice, Slovak Rep. 1993*
- International Workshop on Magnetism, Magnetic Materials and Applications. Univ La Habana, Cuba, 1991
- Scool on Ciencia y Tecnología de Materiales " Organized Inst. C. Materiales de Madrid. Madrid 1990
- III Escuela Ibérica de Magnetismo y Materiales Magnéticos ". G.E.F.E.S. Jaca 1989
- Course on Magnetic Properties of Amorphous Alloys, Depart. Física. Univ. de Sao Paulo, Brazil 1989
- Curso Internacional sobre Materiales Magnéticos " Centro Internacional de Física. Bogotá, 1988