Electron Transport and Dynamics in Magnetic and Superconducting Nanostructures

MAGNETRANS-UAM (INC REPORT 2009-2010)

Members:

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Head of the Group:	*Farkhad Aliev*
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	Arkadi Levanyuk (retired in 2009)
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	Antonio Lara (Collaboration Felllowship MEC 2010-2011)
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Former group members

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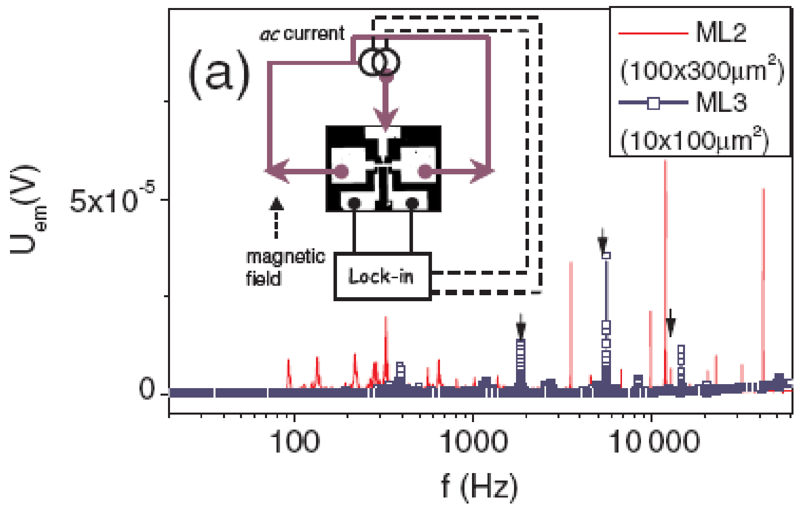
Juan F. Sierra -Since 2009 - posdoc with CEA- Grenoble, France

1.1 Magnetoelectronics and spintronics – electron transport and dynamics in magnetic multilayers

We observed unexpected resonant response in [Fe/Cr]10 multilayers epitaxially grown on MgO(100) substrates which exists only when both ac current and dc magnetic field are simultaneously applied. The magnitude of the resonances is determined by the multilayer magnetization proving their intrinsic character. The reduction of interface epitaxy leads to nonlinear dependence of the magnitude of resonances on the alternating current density. We speculate that the existence of the interface transition zone could facilitate the subatomic vibrations in thin metallic films and multilayers grown on bulk insulating substrates.

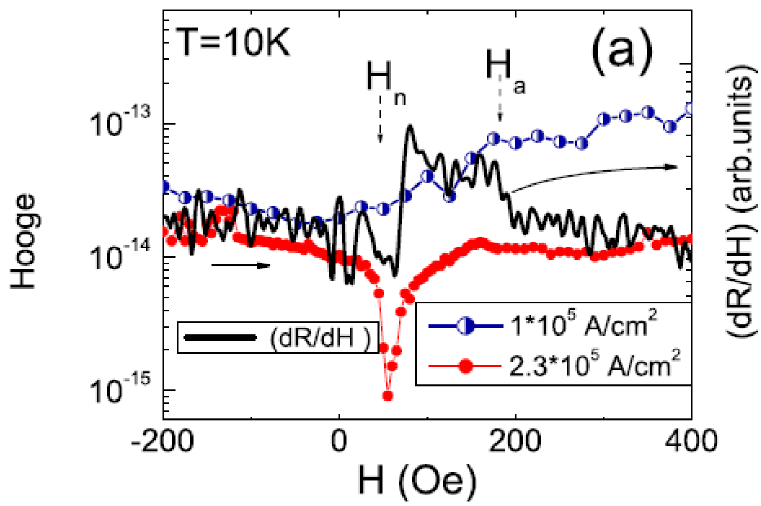


Frequency dependence of the voltage in 5 point geometry measured at 6 K for the in-plane field of 1T for two [Fe/Cr]10 on MgO multilayers with different dimensions. The inset sketches the five-probe measurement scheme.

F.G.Aliev, et al., Physical Review Letters **102**, 035503 (2009).

1.2 Anomalous low-frequency noise in synthetic antiferromagnets: Possible evidence of current-induced domain-wall motion

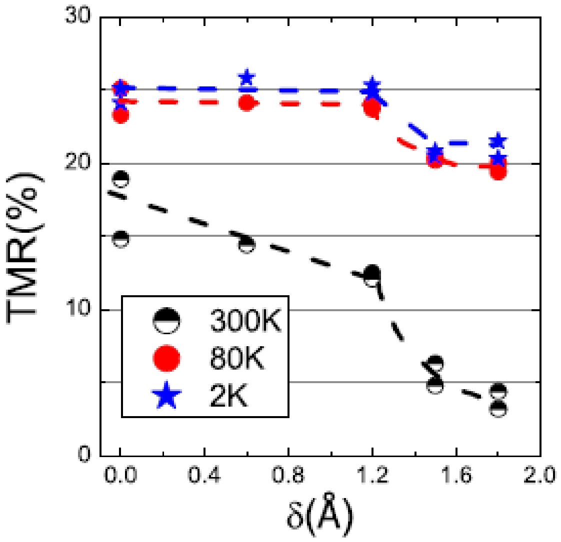
We investigate current-driven magnetization dynamics in synthetic [Fe/Cr]10 multilayer antiferromagnets by using low-frequency voltage noise measurements. We observe suppression of the noise above a critical current density of about 2 105 A/cm2. Theoretical estimates suggest that this effect may be attributed to current induced motion of domain walls in the antiferromagnet. The observed critical current density is about one order of magnitude smaller than for ferromagnetic systems. Our results are relevant for applications of antiferromagnetic metal spintronics in, e.g., magnetic memory storage technology.



Dependence of the Hooge factor on the magnetic field for Fe/Cr MML obtained from noise measurements at T=10 K with two different applied current densities. For comparison, the solid line shows the absolute values of the derivative dR/dH. The vertical arrows mark the regions of nucleation and annihilation of the domain walls determined from low field magnetoresistance measurements.

D. Herranz, et al., Physical Review **B79**, 134423(2009).

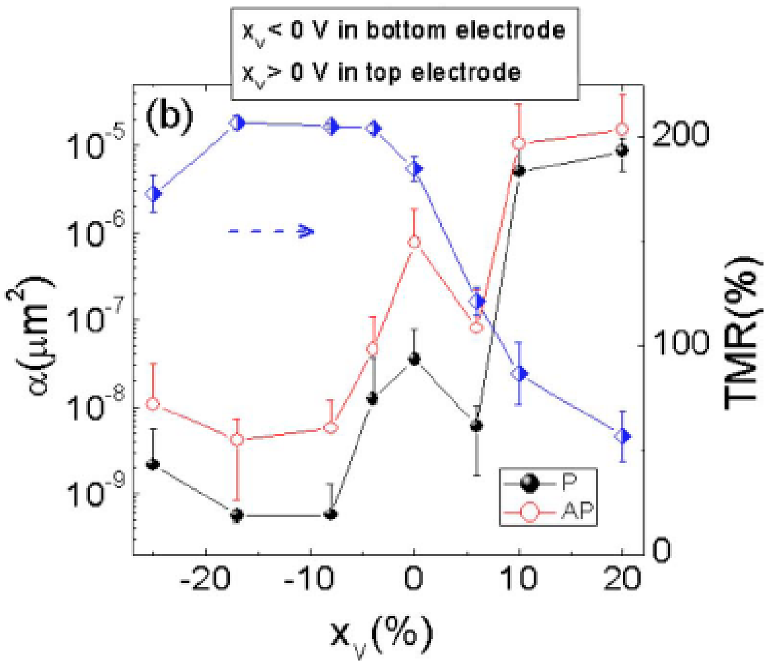
1.3 Conductance in Co/Al2O3/ <Si>Al2O3/ permalloy with asymmetrically doped barrier



Dependence of the tunneling magnetoresistance on the silicon thickness at three different temperatures. While presence of silicon reduces significantly the polarization at room temperature, decreasing the value of the TMR ratio, for temperatures below 80K the presence of the silicon layer seems not to affect the spin polarization, for thickness below 1.2 Å.

R. Guerrero, et al., Physical Review **B81**, 014404 (2010).

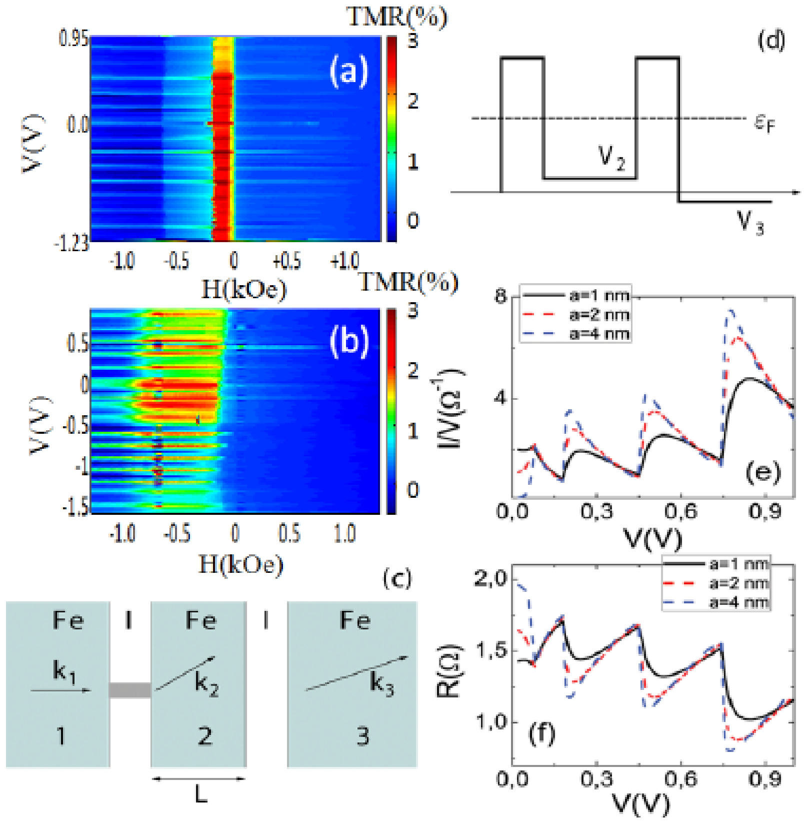
1.4 Strongly suppressed 1/f noise and enhanced magnetoresistance in epitaxial Fe–V/MgO/Fe magnetic tunnel junctions



Alloying Fe electrodes with V, through reduced FeV/MgO interface mismatch in epitaxial magnetic tunnel junctions with MgO barriers, notably suppresses both nonmagnetic parallel and magnetic antiparallel state 1/f noise and enhances tunneling magnetoresistance. We attribute the enhanced TMR and suppressed 1/f noise to strongly reduced misfit and dislocation densit.

D. Herranz, et al., Applied Physics Letters **96**, 202501 (2010).

1.5 Tunneling in Double Barrier Junctions with ‘‘Hot Spots’’

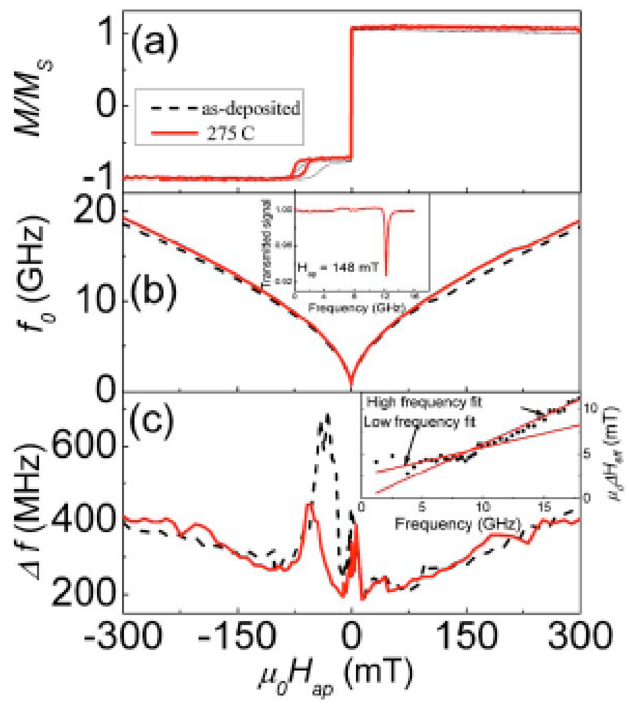


3D plot with magnetic field along x, bias voltage along y, and TMR along z directions. Panel (a) corresponds to magnetic field along the HA and (b) along IA. (c) Schematic presentation of the model with a single spot and (d) the corresponding energy profile. (e) Calculated conductance (I=V) for DMTJ with a single spot in P state for different spot dimensions. (f) R versus V for DMTJ with multiple spots in the P state for different average spot dimensions

D. Herranz, et al., Physical Review Letters **105**, 047207 (2010)

2.1 Magnetization dynamics in magnetic tunnel junctions with different annealing

The broadband ferromagnetic resonance (FMR) linewidth of the free layer of magnetic tunnel junctions is used as a simple diagnostic of the quality of the magnetic structure. The FMR linewidth increases near the field regions of free layer reversal and pinned layer reversal, and this increase correlates with an increase in magnetic hysteresis in unpatterned films, low-frequency noise in patterned devices, and previous observations of magnetic domain ripple by use of Lorentz microscopy. Post-annealing changes the free layer FMR linewidth, indicating that considerable magnetic disorder, originating in the exchange-biased pinned layer, is transferred to the free layer.

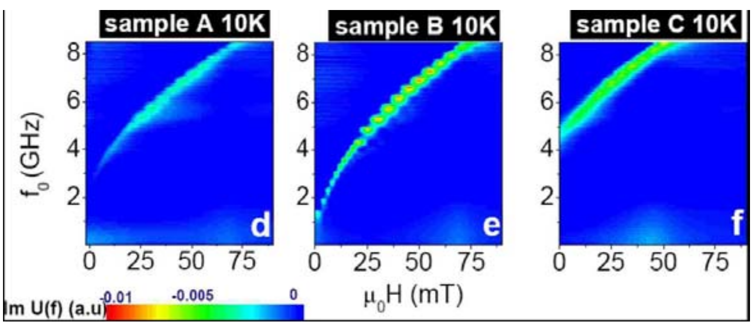


3D plot with magnetic field along x, bias voltage along y, and TMR along z directions. Panel (a) corresponds to magnetic field along the HA and (b) along IA. (c) Schematic presentation of the model with a single spot and (d) the corresponding energy profile. (e) Calculated conductance (I=V) for DMTJ with a single spot in P state for different spot dimensions. (f) R versus V for DMTJ with multiple spots in the P state for different average spot dimensions.

J.Sierra, et al., Applied Physics Letters **94**, 012506 (2009).

2.2 Temperature dependent dynamic and static magnetic response in magnetic tunnel junctions with Permalloy layers

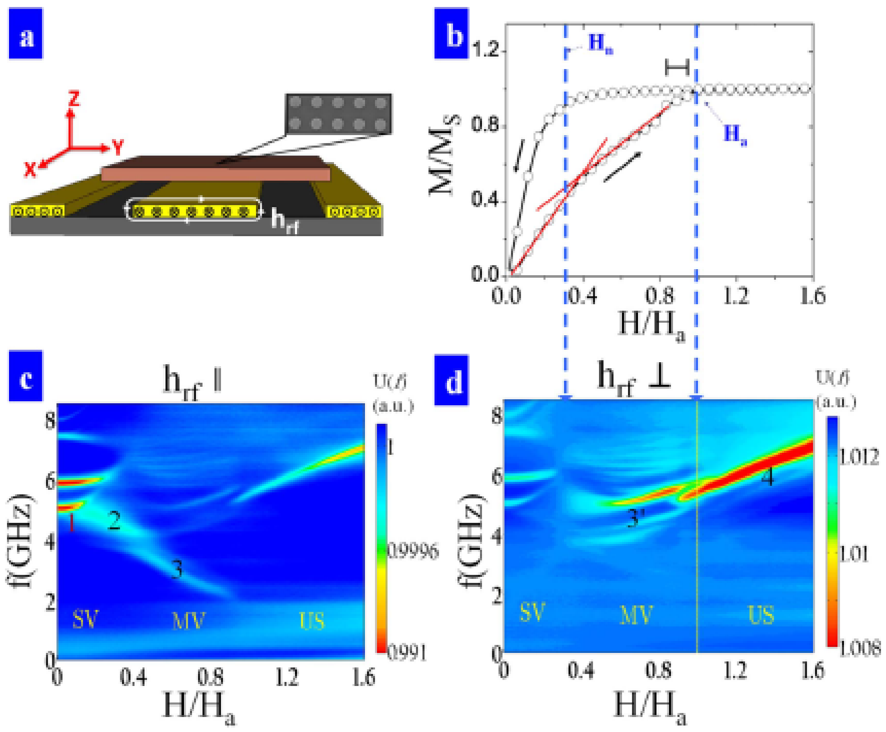
Ferromagnetic resonance and static magnetic properties of CoFe/Al2O3 /CoFe/Py and CoFe/Al2O3 /CoFeB/Py magnetic tunnel junctions and of 25 nm thick single-layer Permalloy films have been studied as a function of temperature down to 2 K. The temperature dependence of the ferromagnetic resonance excited in the Py layers in magnetic tunnel junctions shows "kneelike" enhancement of the resonance frequency accompanied by an anomaly in the magnetization near 60 K. We attribute the anomalous static and dynamic magnetic response at low temperatures to interface stress induced magnetic reorientation transition at the Py interface which could be influenced by dipolar soft-hard layer coupling through the Al2O3 barrier.



J. Sierra, et al., Appl. Phys. Lett. 93, 172510 (2008)

2.3 Spin waves in circular soft magnetic dots at the crossover between vortex and single domain state

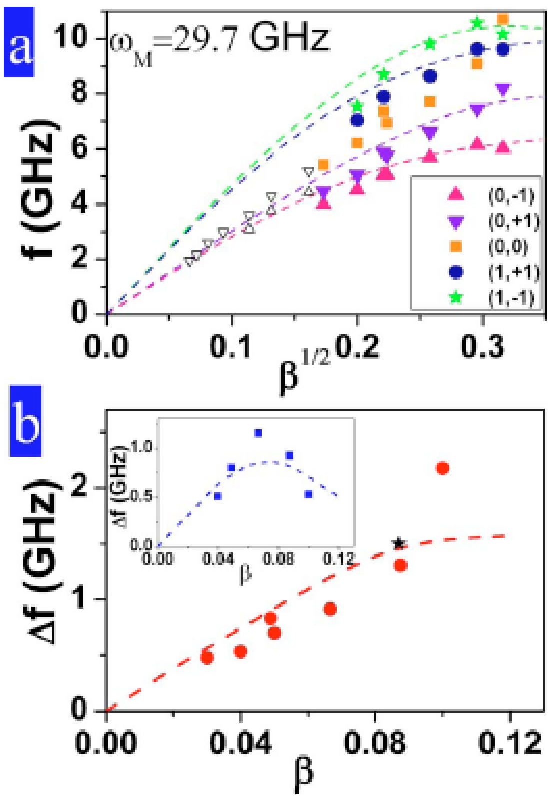
Spin waves in circular soft magnetic dots at the crossover between vortex and single domain state. We report on linear spin dynamics in the vortex state of Permalloy cylindrical dots subjected to an in-plane bias magnetic field. We demonstrate experimentally by a broadband ferromagnetic resonance technique and by simulations that breaking the cylindrical symmetry of the magnetic vortex gradually changes and suppresses the azimuthal spin eigenmodes below the vortex nucleation field and leads further to the appearance of new eigenmodes. The parallel microwave field pumping is shown to be a unique tool to observe spin excitation modes localized near the strongly shifted vortex core for the bias field between the vortex nucleation and annihilation fields. Meanwhile, the perpendicular field pumping, which excites the spin waves throughout the entire dot, reveals a crossover between two dynamic vortex regimes near the nucleation field.



F.G.Aliev, et al., Physical Review **B79**, 174433 (2009)

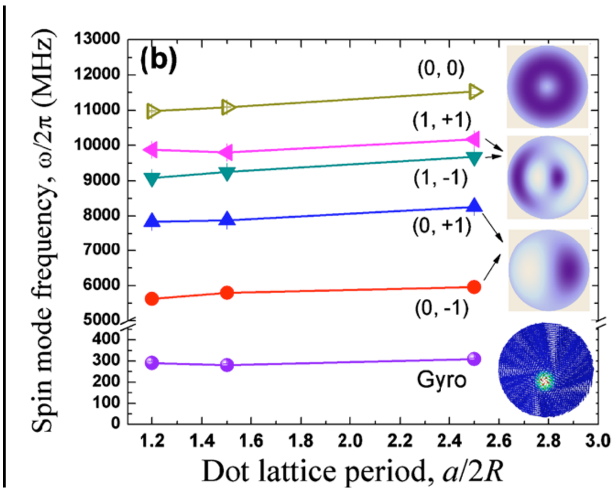
2.4 Precise probing spin wave mode frequencies in the vortex state of circular magnetic dots

We report on detailed broadband ferromagnetic resonance measurements of azimuthal and radial spin wave excitations in circular Permalloy dots in the vortex ground state.



A. Awad, et al., Applied Physics Letters **96**, 012503 (2010)

2.5 **Spin excitation frequencies in magnetostatically coupled arrays of vortex state circular Permalloy dots**

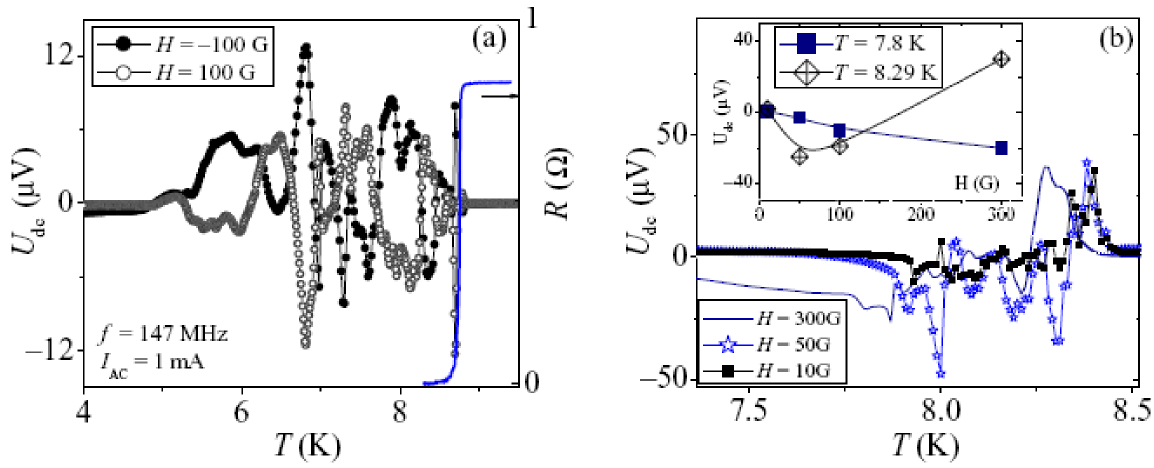


Zero in-plane bias field response of the three arrays of Py dots with different interdot separations, d=200, 500, and 1500 nm. The detected spin excitation frequencies labeled by the mode indices n,m vs the interdot separation.

A. Awad, et al., Appl. Phys. Lett. 97, 132501 (2010)

3. Current rectification by superconducting films without apparent asymmetry

Unusual dc electric fields induced by a high frequency alternating current in superconducting Nb films under a perpendicular magnetic field



100 nm Nb film: Measured dc voltage transversal to the applied ac current, as a function of temperature, with two applied magnetic fields of opposite polarity: ±100G (±0.01 T).

F.G.Aliev, et al., New Journal of Physics **11** (2009) 063033.

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