Magnetic and superconductor nanostructures

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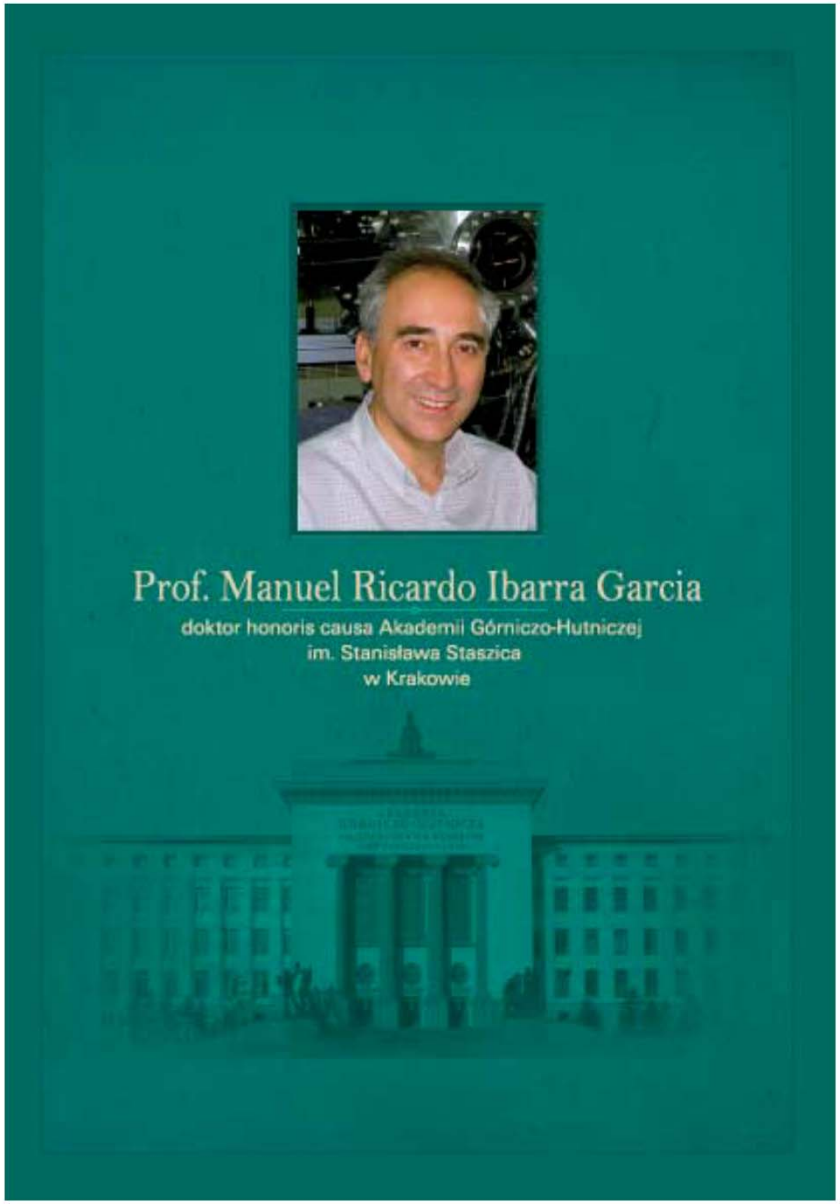
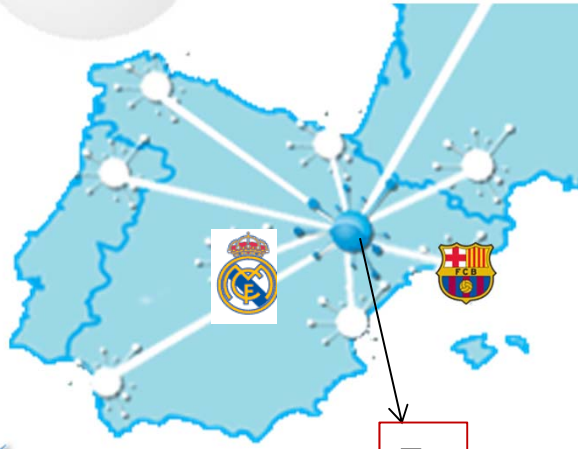
Universidad Zaragoza

AGH

LMA LABORATORIO DE MICROSCOPIAS AVANZADAS


Prof. Manuel Ricardo Ibarra Garcia
doktor honoris causa Akademii Górniczo-Hutniczej
im. Stanisława Staszica
w Krakowie

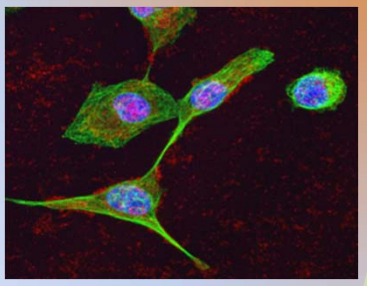
Institute of Nanoscience of Aragón



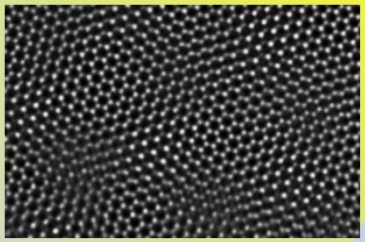
ZARAGOZA

RESEARCH AREAS

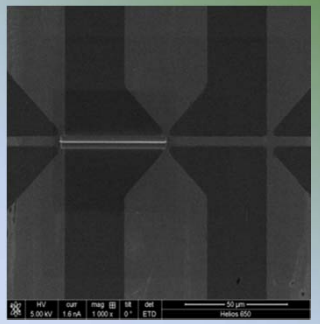
NANOBIOMEDICINE



NANOMATERIALS



NANO PHYSICS.



LMA

LABORATORIO DE MICROSCOPIAS AVANZADAS

Magnetic and superconducting nanostructures

SCANNING PROBE METHODS (SPM)

ULTRA HIGH RESOLUTION (UHRTEM)

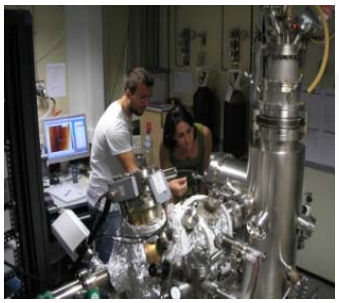
SAMPLE PREPARATION

LMA
LABORATORIO DE MICROSCOPIAS AVANZADAS

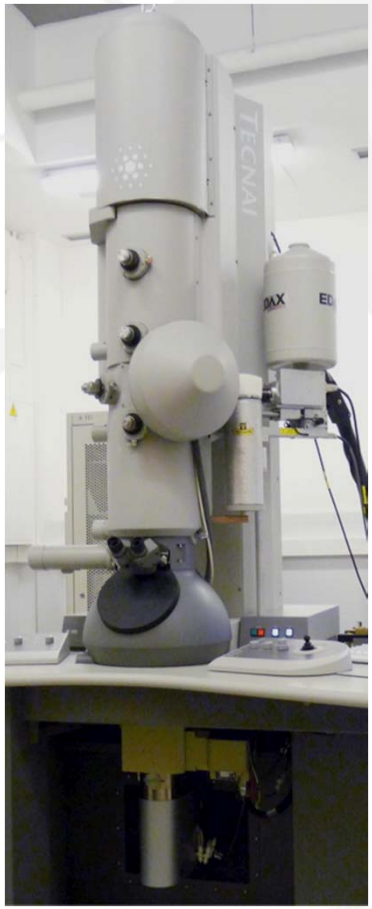
HIGH RESOLUCIÓN (HRTEM)

MICROSTRUCTURE SPECTROSCOPY

DUAL BEAM FIB_e



HRTEM FACILITIES



Tecnai F30
- Schottky-FEG
- EELS
- EDX
- Lorentz lens

Titan low-base 60-300KV
- Probe Cs-corrected
- Monochromator
- X-FEG
- EELS
- EDX

Titan high-base 60-300KV
- Image Cs-corrected
- Schottky-FEG
- Biprism
- EELS
- EDX

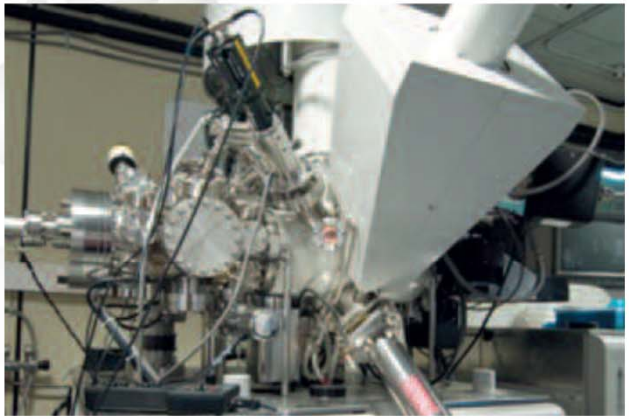
CLEAN ROOM & DUAL BEAMS

LIFE SCIENCES AND MICRO-CHARACTERIZATION

Cryo-Dual Beam

SEM-FEG Quanta

SEM FEG INSPEC

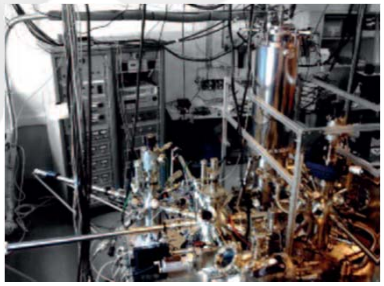


XPS Kratos

Scanning Probe Microscopy

SPM IN UHV and Low T

MONCAYO: 1K-100K, 3T
ARAN:VT-STM/AFM
ORDESA: 5K STM
AINSA:5K STM/AFM



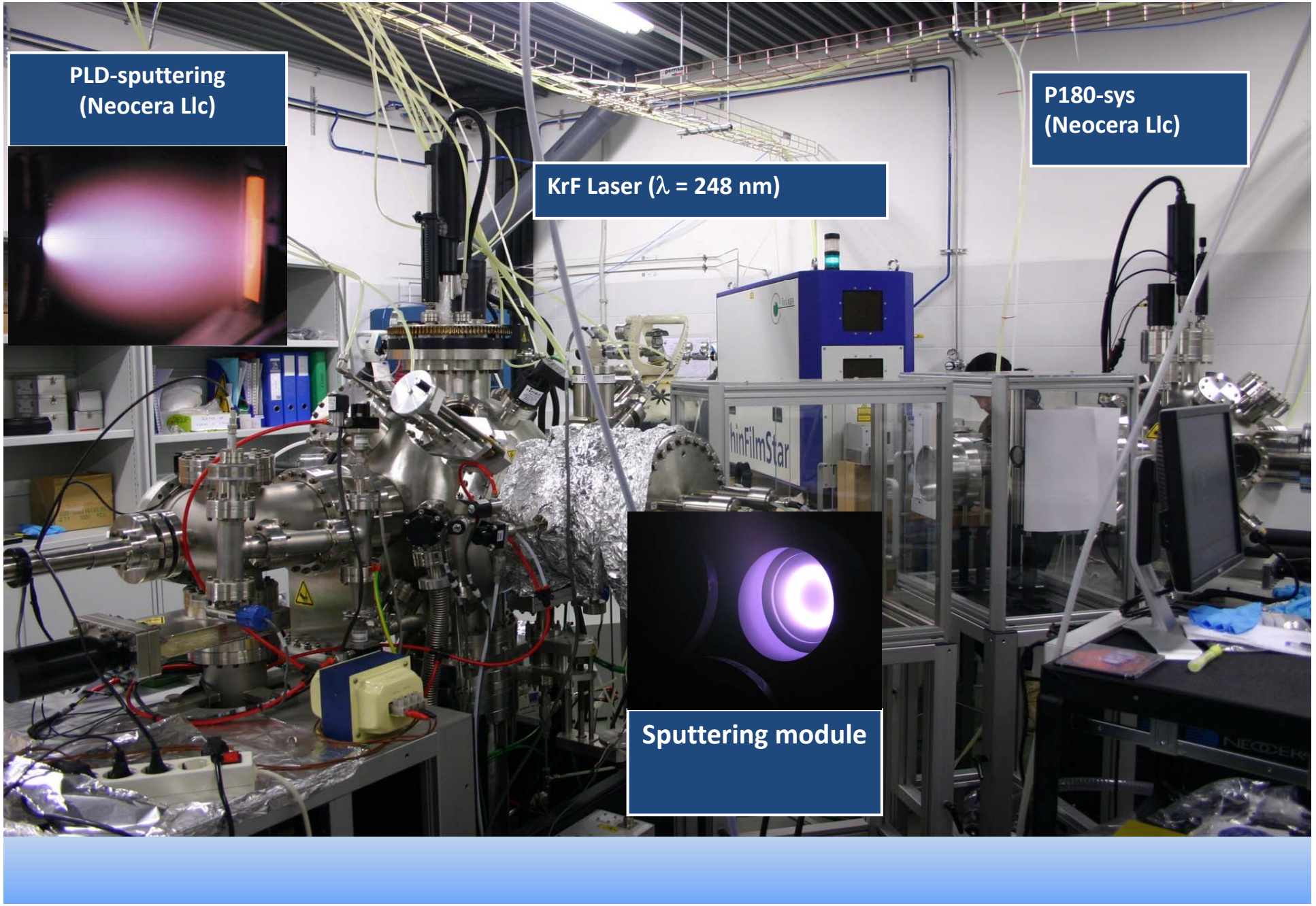
SPM in high Magnetic Field

EBRO: 2K-300K, 8T/2T

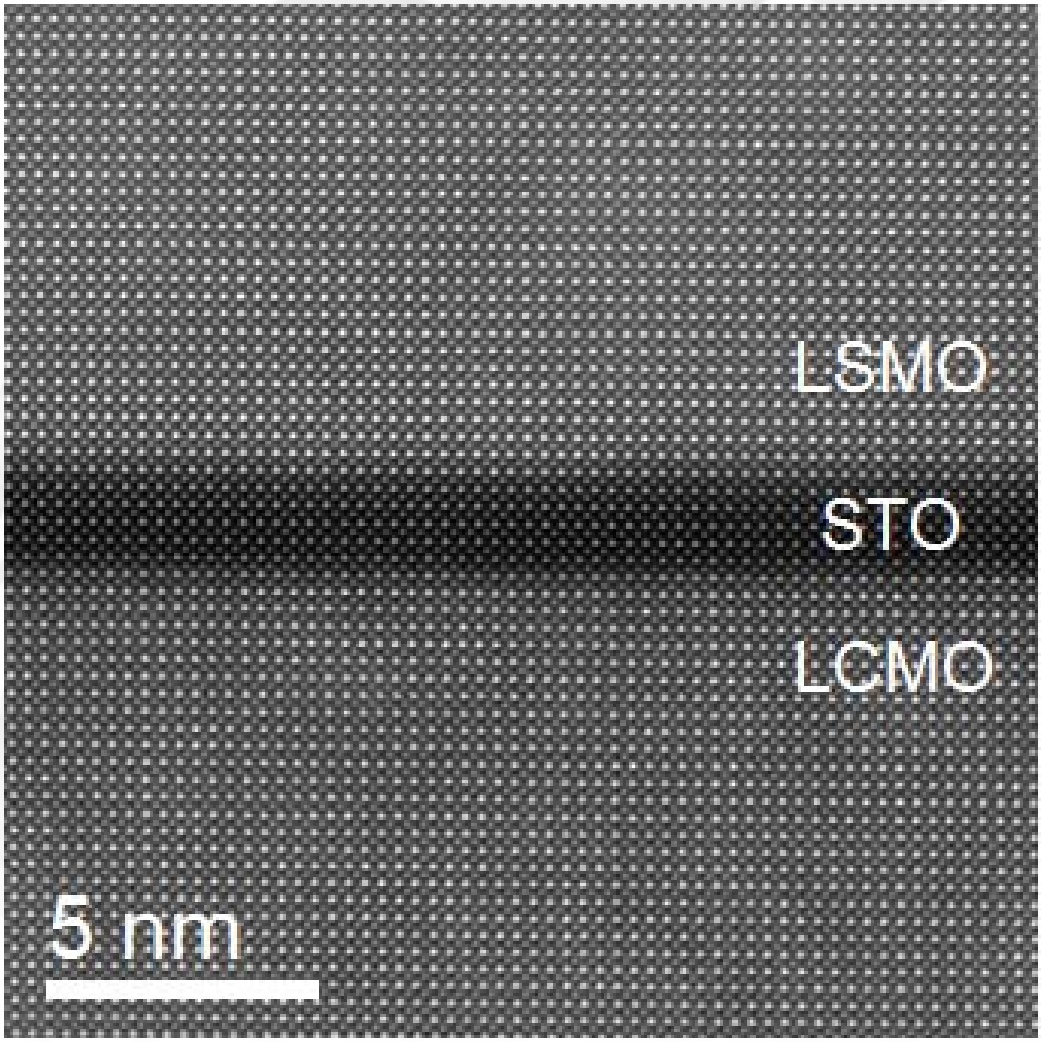
SPM under environmental conditions

AFM/MFM Nanotec
SPM multimode SPM Veeco
EC-STM Home-made

COMBINED PLD & SPUTTERING



Characterization with atomic resolution



SEVENTH FRAMEWORK PROGRAMME

esteem2
european network for electron microscopy

Free transnational access

to the most advanced TEM equipment and skilled operators for HR(S)TEM, EELS, EDX, Tomography, Holography and various in-situ state-of-the-art experiments

http://ina.unizar.es/lma

OUTLINE

-FIBID&FEBID new direct nanopatterning method of functional materials

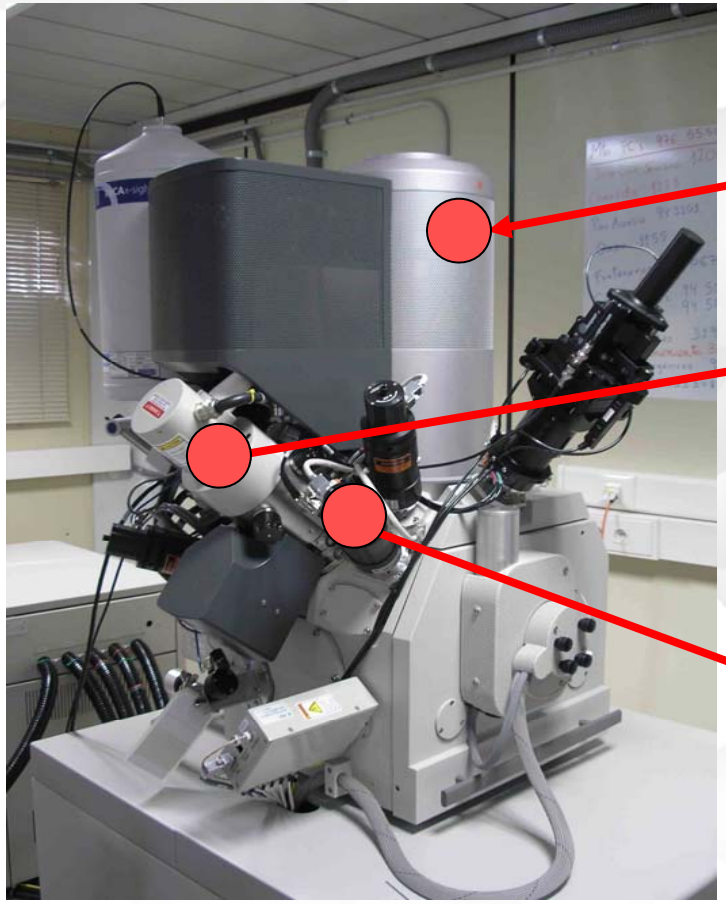
-Co based nanostructures (nano-Hall sensor)

-Vortex confinement in superconductor nanostructures

-Ferromagnetic-superconducting planar nano-junction

-Conclusions

MICROSCOPE OF FOCUSED PARTICLES BEAMS



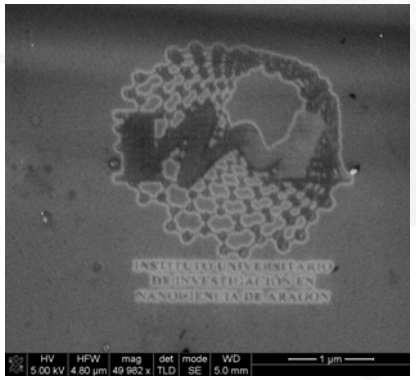
FEG SCANNING ELECTRON SOURCE

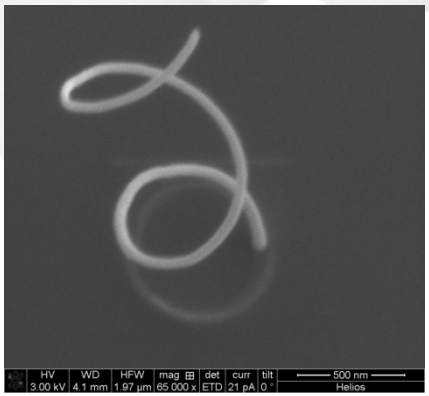
Ga^+ FOCUSED ION BEAM

GAS INJECTORS (GIS)

NANOLABORATORY

NANOLAB





Imaging

Ectching

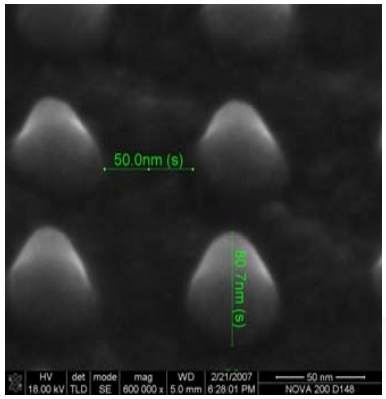
Deposition

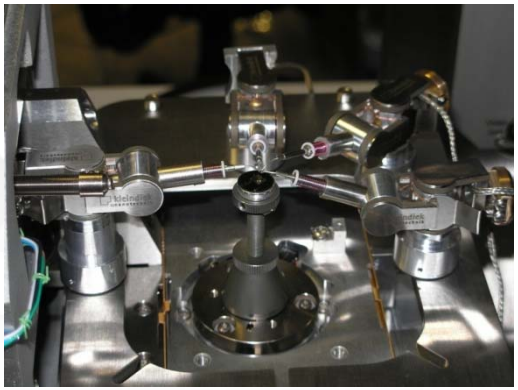
Chemical analysis

Nanopatterning

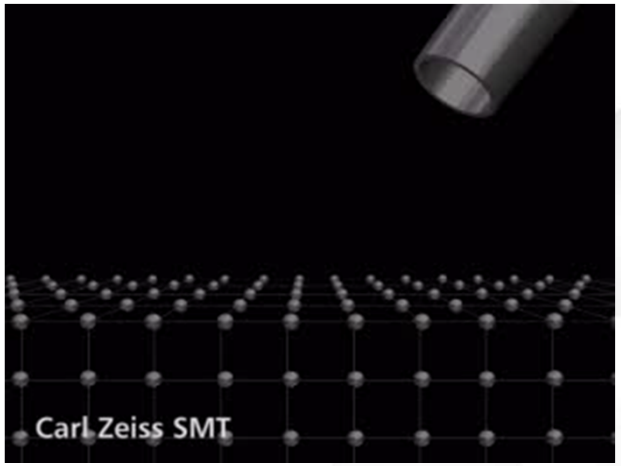
e-beam lithography

Electrical characterizarion



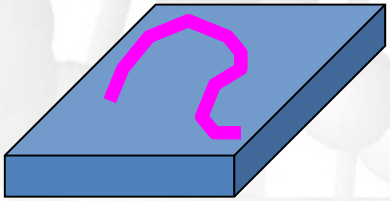


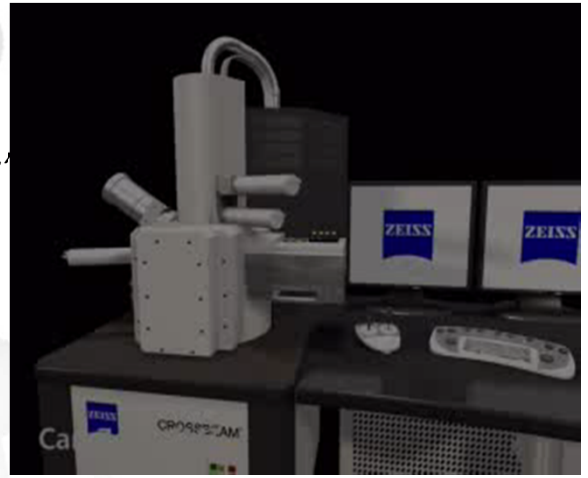
DUAL BEAM LABORATORY



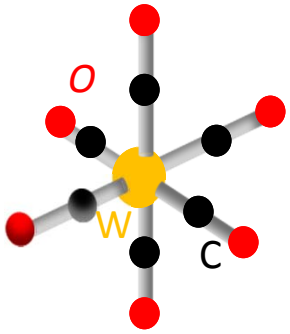
FEBID/FIBID: one-step nanolithography process:

"just as a pencil writing on a paper"

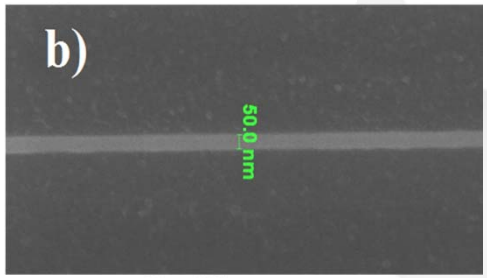


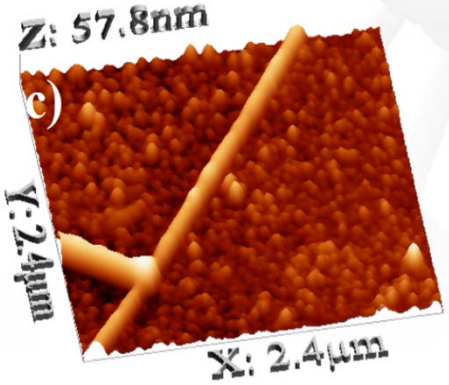


Superconductor nanostructures FIBID

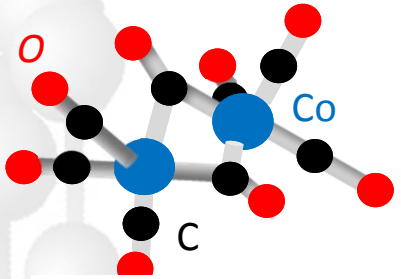


$W(CO)_6$

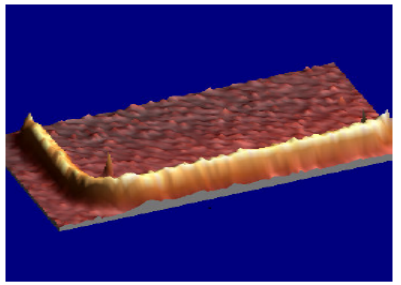


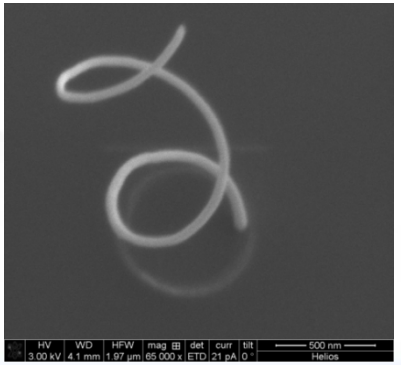


Ferromagnetic nanostructures FEBID



$Co_2(CO)_8$





OUTLINE

-FIBID&FEBID new direct nanopatterning method of functional materials

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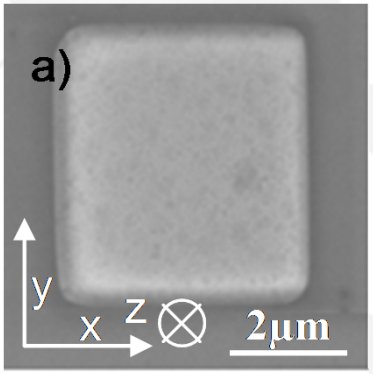
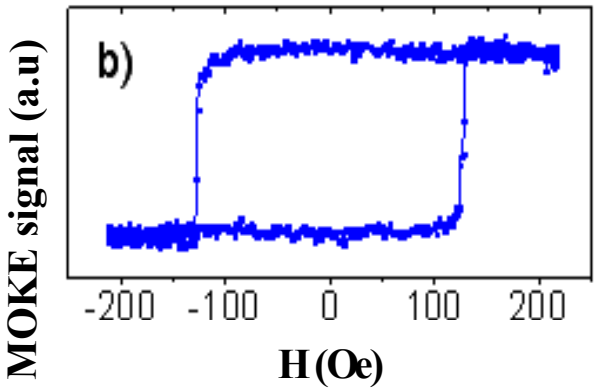
-Conclusions

Ferromagnetism of FEBID deposits

Nano-MOKE

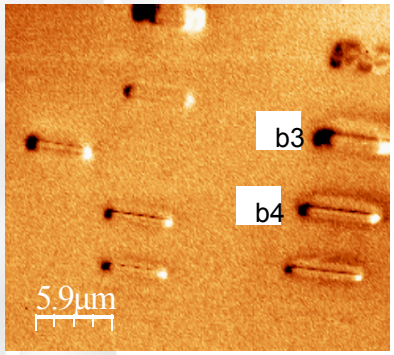


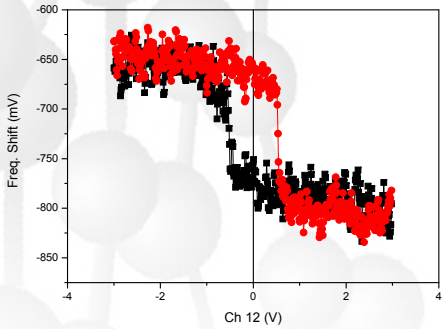


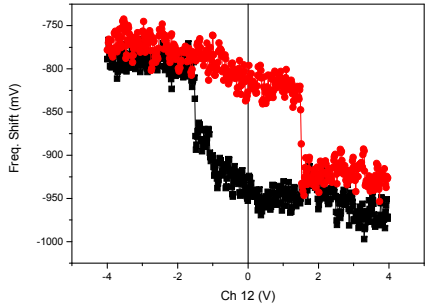
Nanotechnology 20, 475704 (2009)

Col. Prof. Cowburn (Cambridge University)

MFM



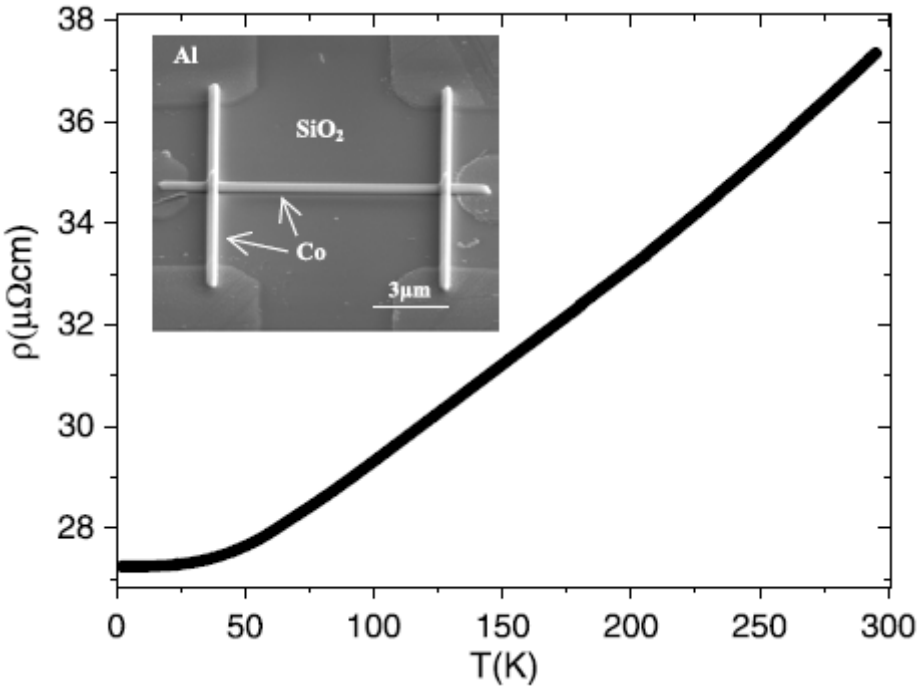


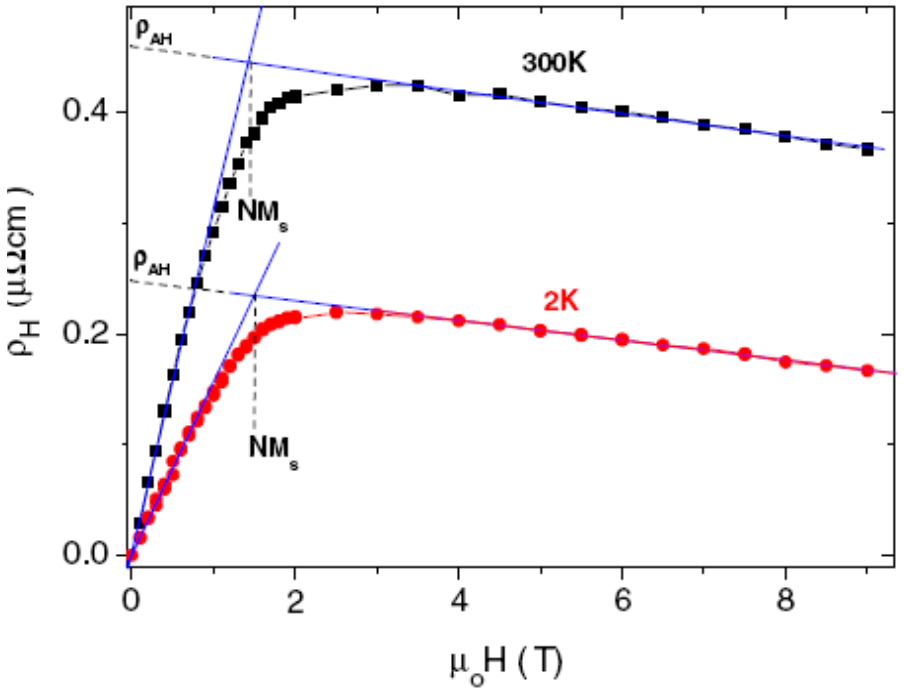


Beilstein J. Nanotechnol. 2, 552 (2011)

Col. Dr. A. Asenjo (ICMM, Madrid)

Resistivity and Hall effect of FEBID Co nanowires



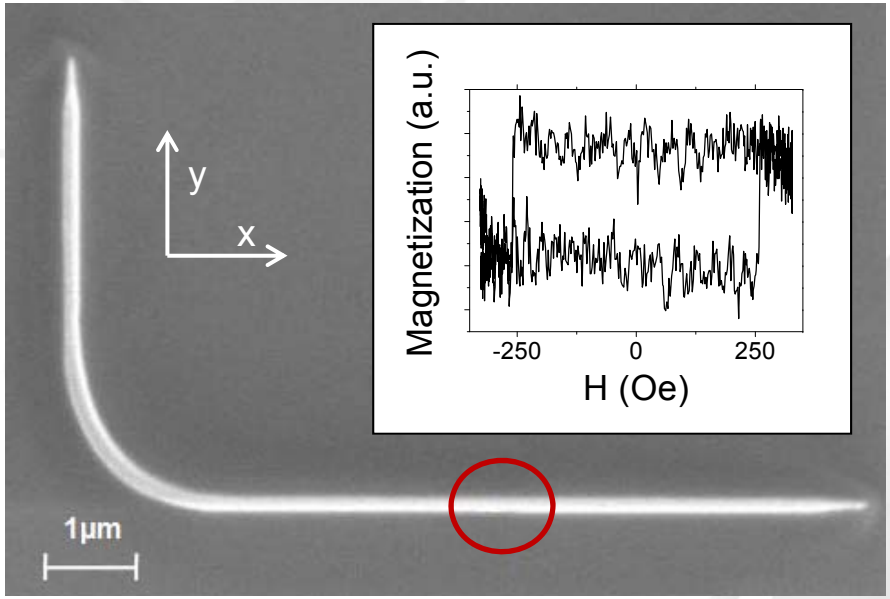


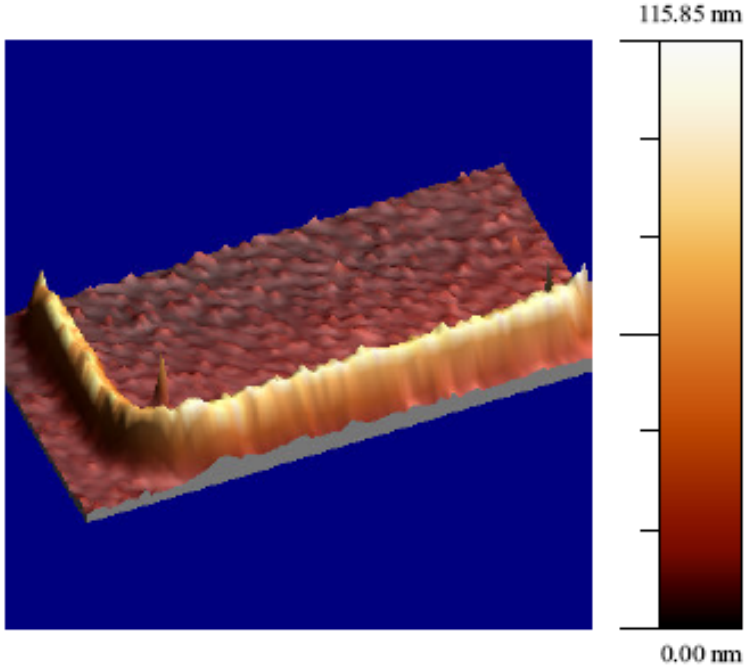
⇒ Full metallic behaviour observed in the resistivity measurements

⇒ Hall effect: ordinary & anomalous
From H_s: M_s=1329±20 emu/cm^3 (**97% of pure Co**)

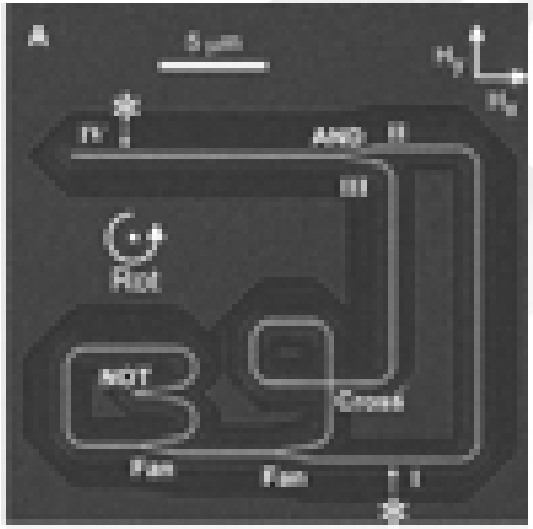
A. Fernández-Pacheco et al., J. Phys. D: Appl. Phys. 42, 055005 (2009)

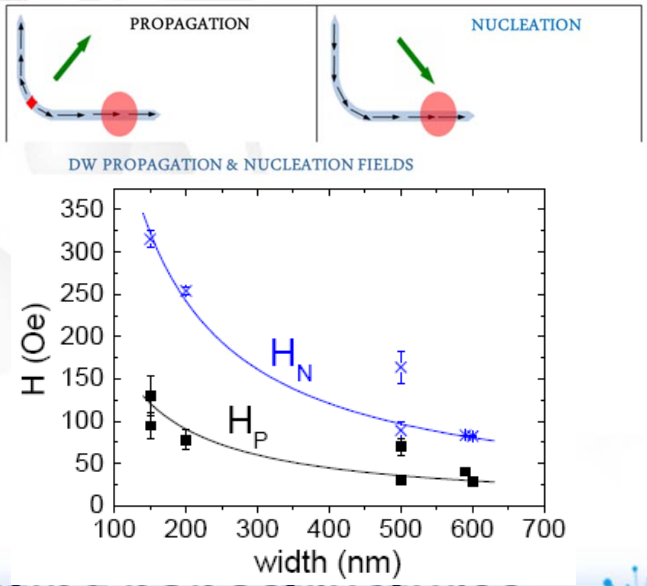
Domain wall propagation in L-shaped FEBID Co nanowires



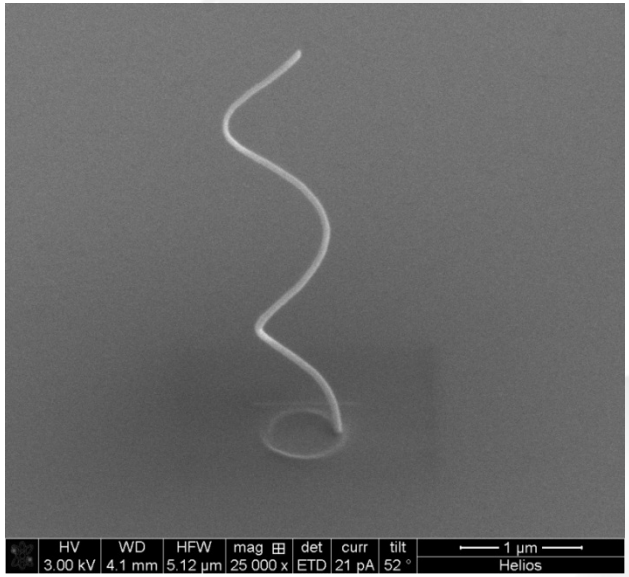


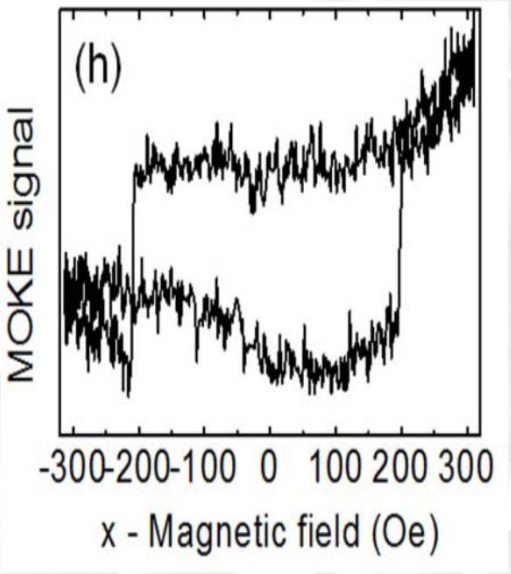
Magnetic Logic
D. Allwood et. al.
Science **309** (2005)

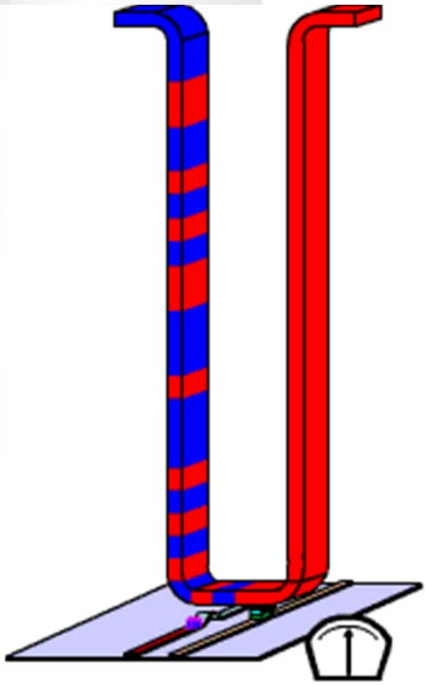




3D Magnetic nanostructures





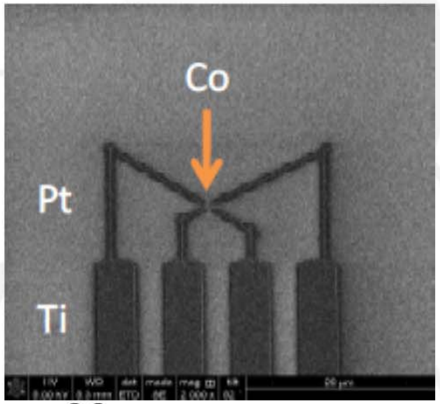


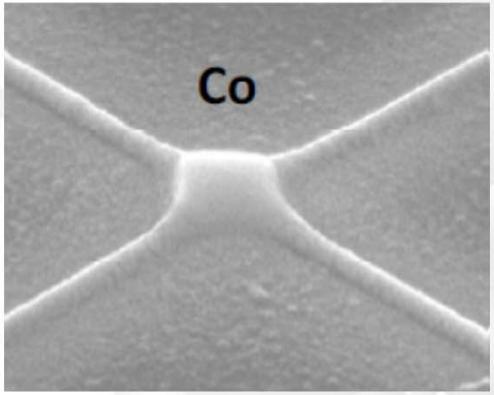
Fernández-Pacheco, A. et al. Three dimensional magnetic nanowires grown by focused electron-beam induced deposition.

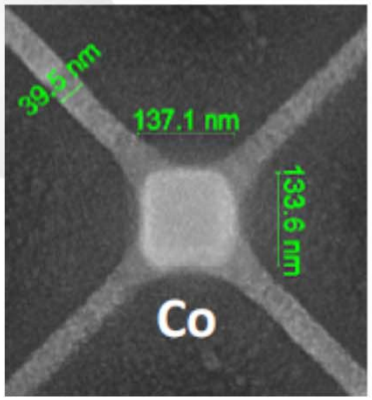
npg Sci. Rep. 3, 1492; DOI:10.1038/srep01492 (2013)

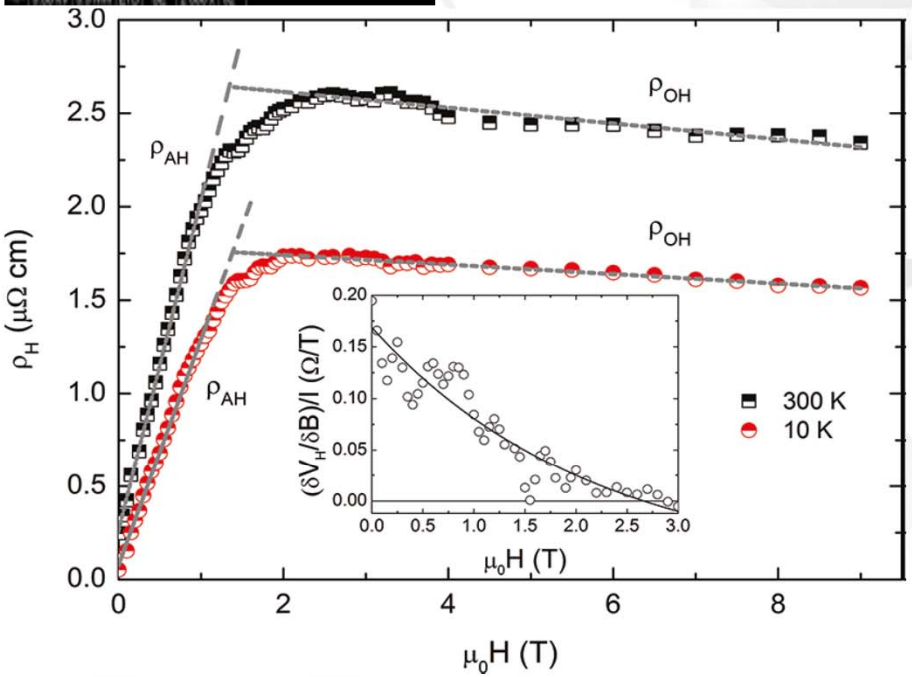
Magnetic Racetrack Memory
Stuart Parkin
Science **320** (2008)

Ultra-small Hall sensors offer the possibility to increase the sensibility of the detection







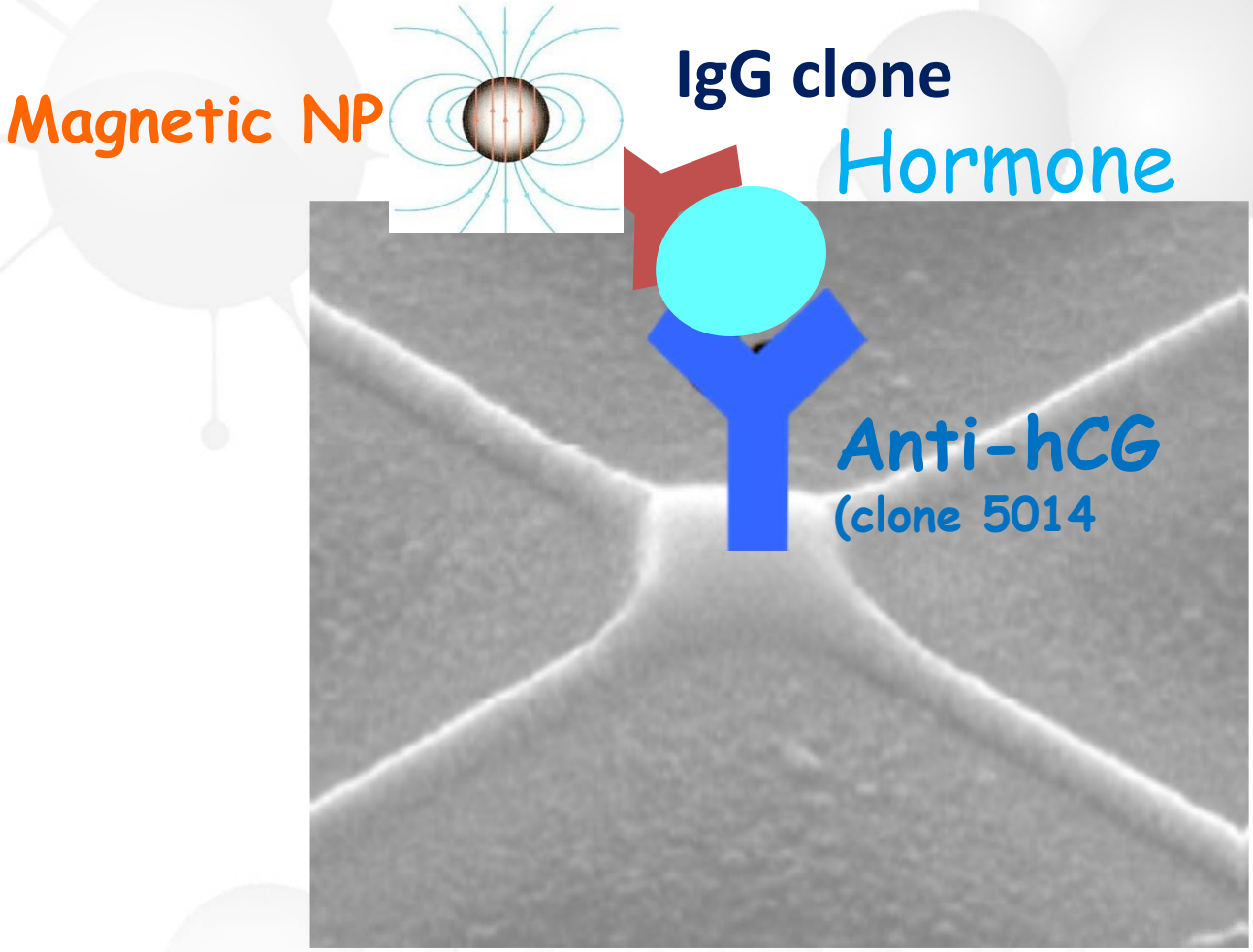


$$\rho_H = \frac{V_H t}{I} = \mu_0 (R_0 H + R_S M)$$

$$S_I = \frac{\delta V_H / \delta B}{I}$$

Luis Serrano-Ramón et al ., ACSnano **5** 7781 (2011)

Biorecognition based in nano-hall probes



OUTLINE

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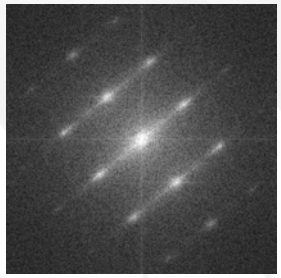
-Conclusions

Superconductivity in Tungsten

Crystalline



Tc=0.012 K

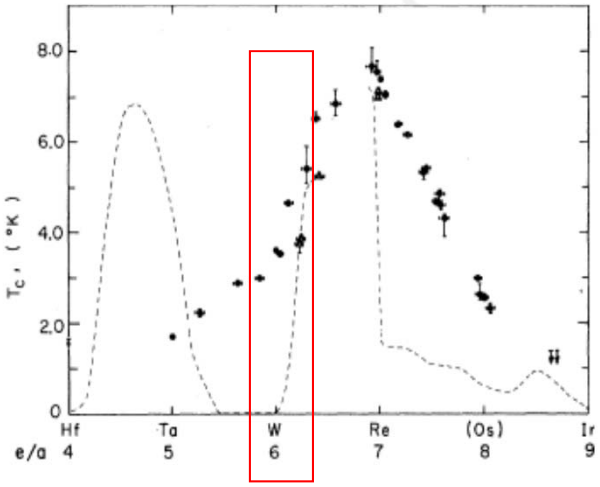
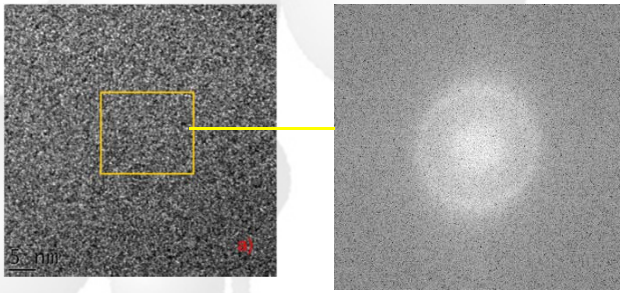


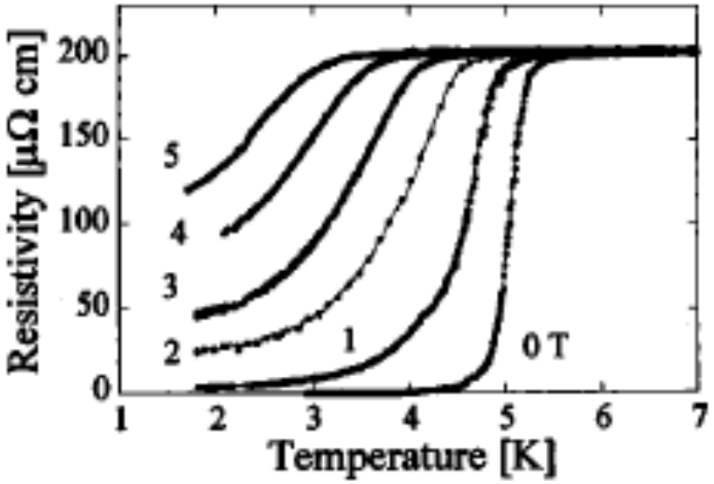
FIG. 2. Superconducting transition temperatures of vapor-quenched 5*d* transition-metal alloys are shown as a function of e/a. Corresponding crystalline T_c data are indicated by the dashed curve. Amorphous T_c data are for the 5*d* elements and Ta-W, Ta-Re (Δ), W-Re, and Re-Ir alloys.

Collver, PRL 30 (1973) 92

Amorphous FIBID



Tc=5 K



Sadki et al., APL 85 (2004) 6206

Chemical analysis of FIBID of W by XPS

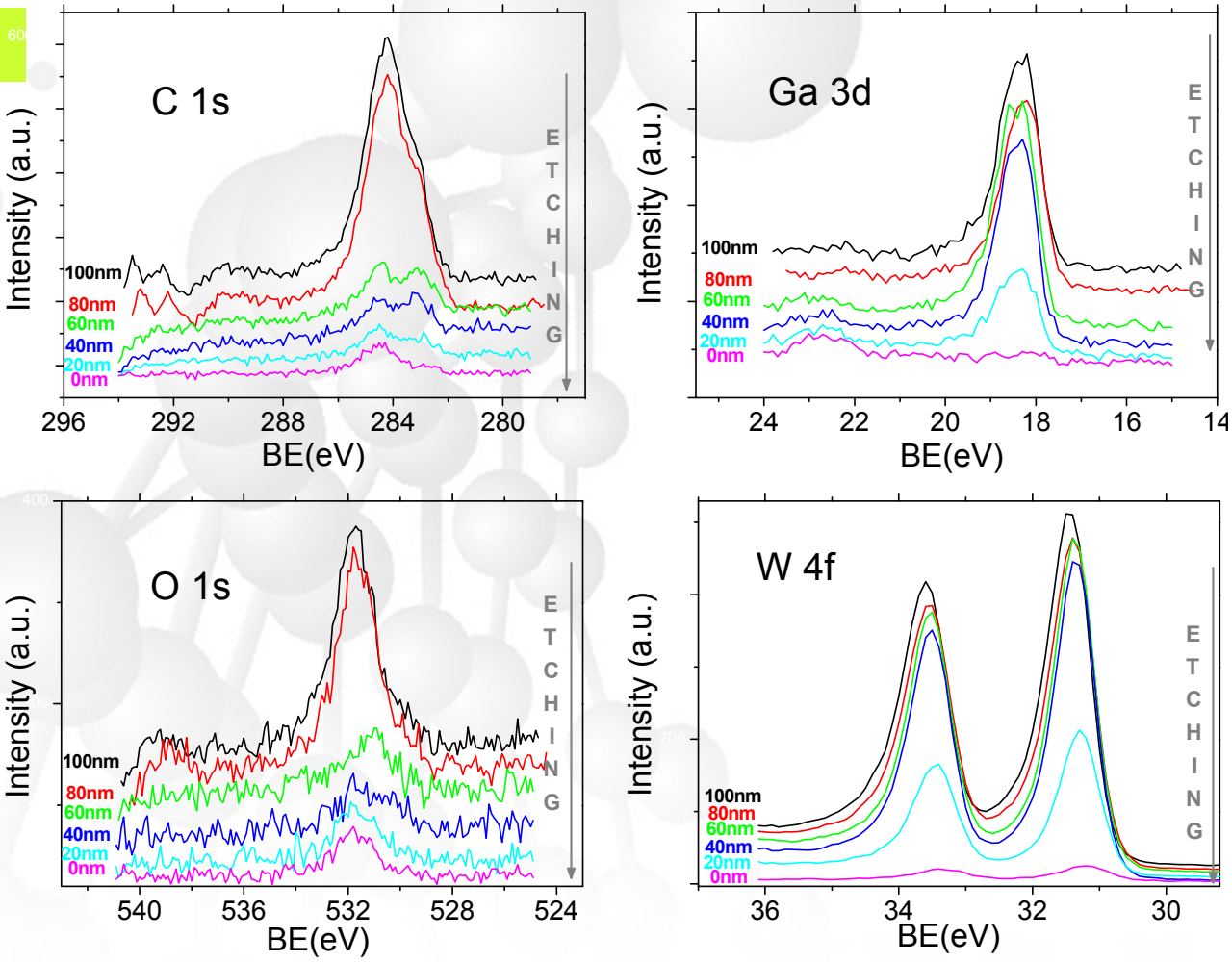
XPS measurements

-W=40±7%

-C=43±4%

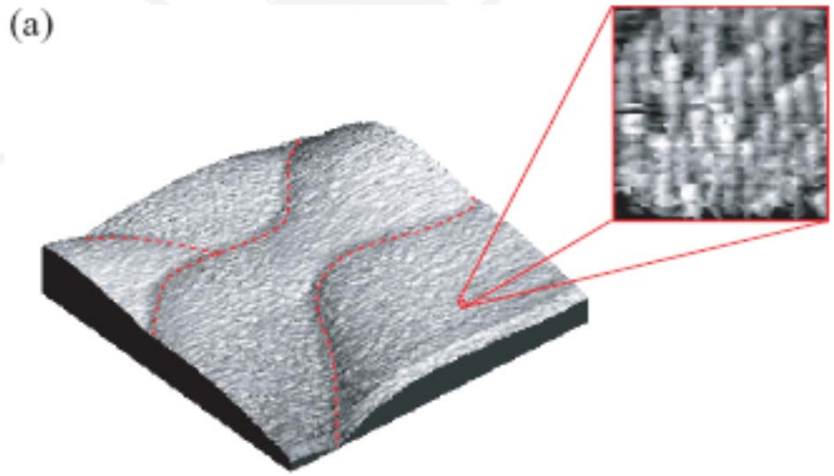
-Ga=10±3%

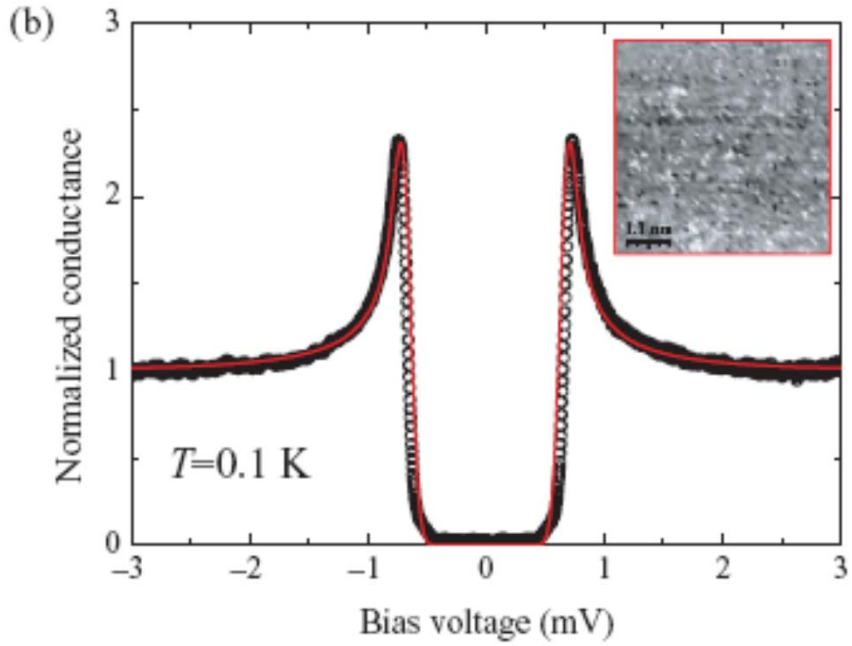
-O=7±2%



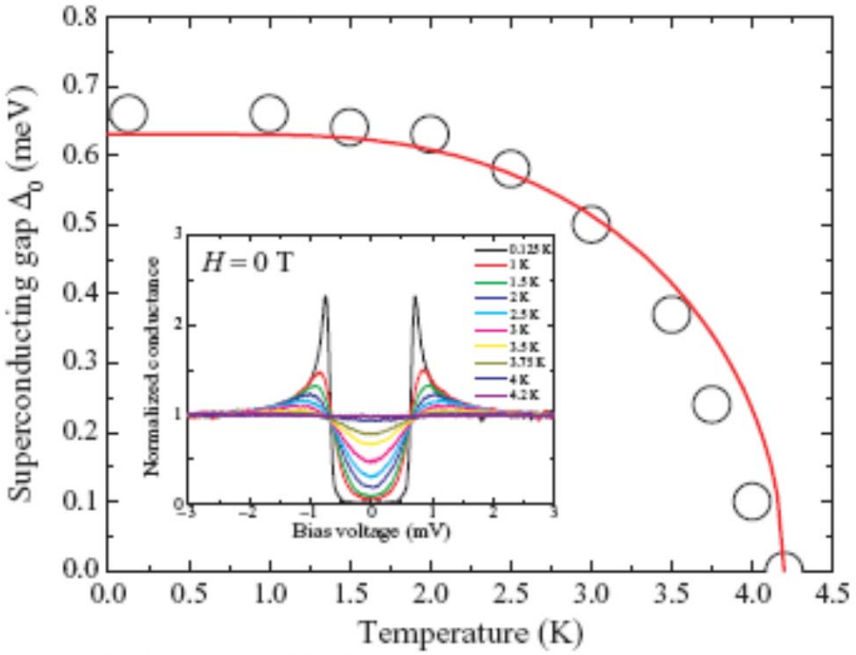
Depth profiling XPS measurements indicate that the composition is homogeneous across the whole sample thickness

STM study of FIBID of W





STM study by S. Vieira, H. Suderow, and I. Guillamón (UAM, Spain)

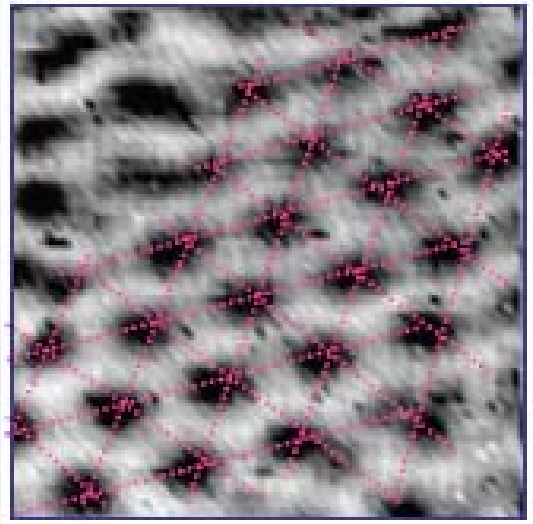


Clean surface, well-defined and homogeneous SC gap, BCS behaviour

I. Guillamón et al., New Journal of Physics 10 (2008) 093005

STS study of FIBID of W: vortex lattice

T=1.2 K and B=2 T



-Very stable surface

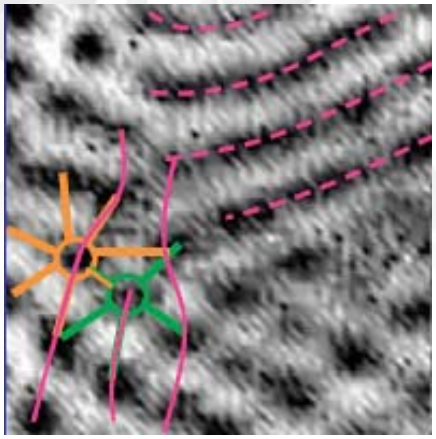
-Abrikosov vortex lattice well defined

-BCS standard, no anisotropy, no significant pinning centers.

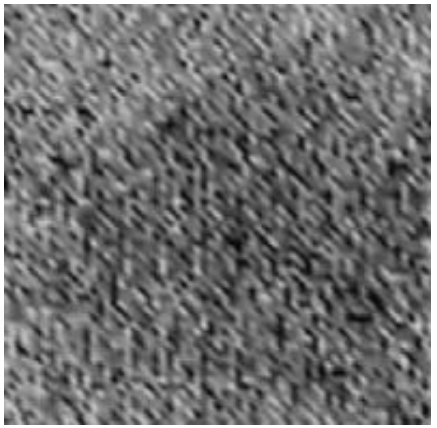
I. Guillamón et al., New Journal of Physics 10 (2008) 093005; I. Guillamón et al., J.Phys.: Conf. Series 150 (2009) 052064

Direct observation of melting in a two-dimensional superconducting vortex lattice (appearance of hexatic,smetic phases) Berezinskii, Kosterlitz and Thouless prediction

I. Guillamón et al., Nature Physics 5 (2009) 651



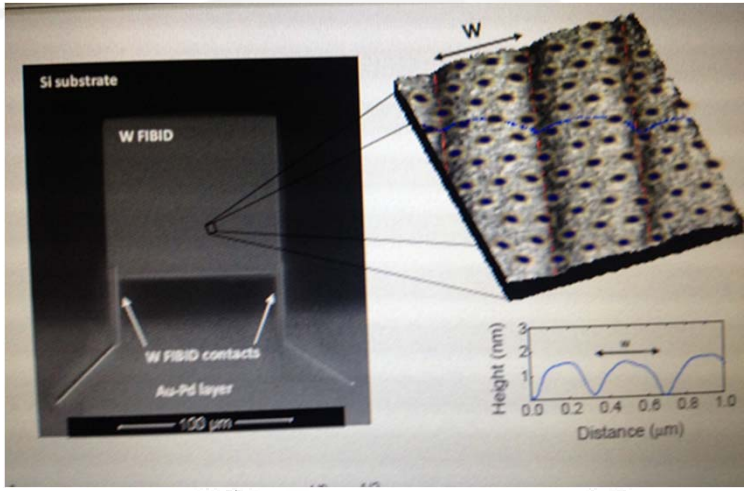
T=2 K

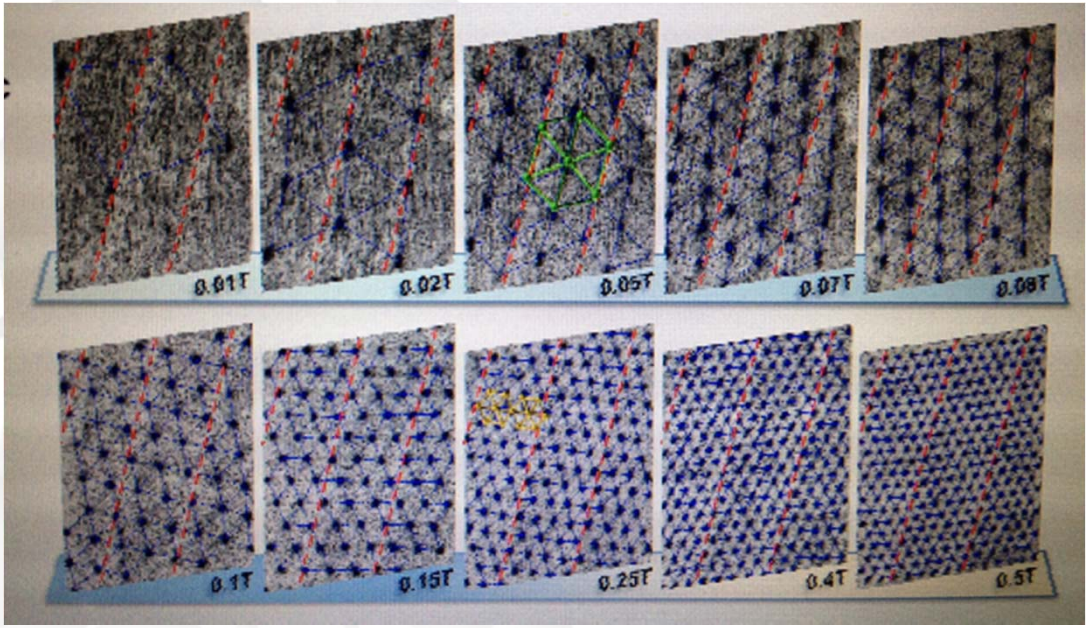


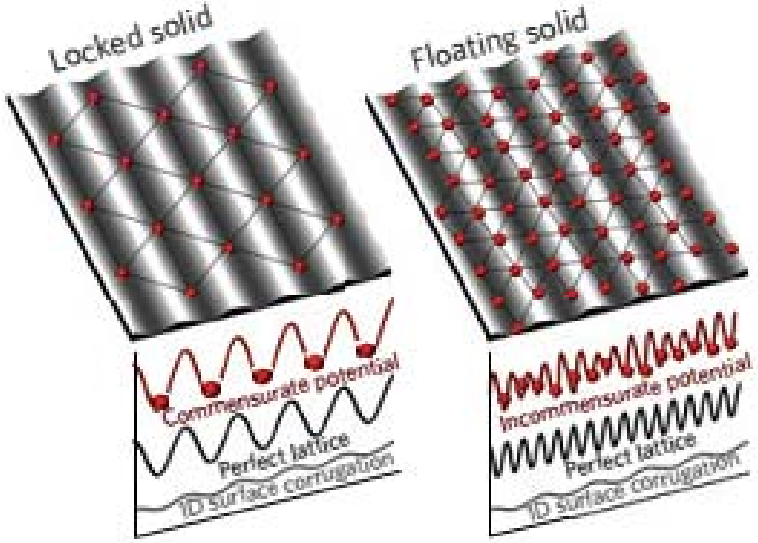
T=3 K

Enhancement of long-range correlations in a 2D vortex lattice

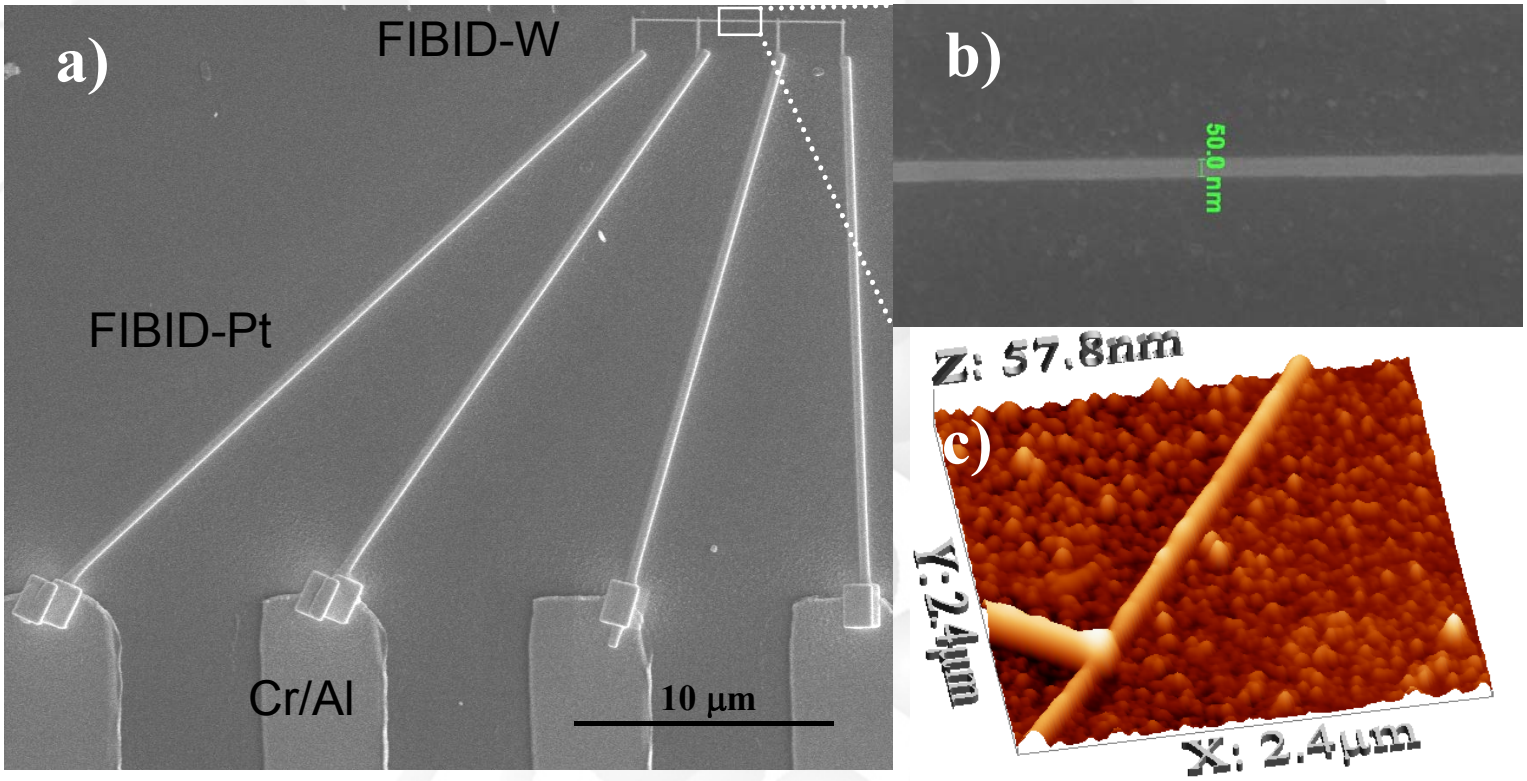
I. Guillamón et al., Nature Physics, October 2014,







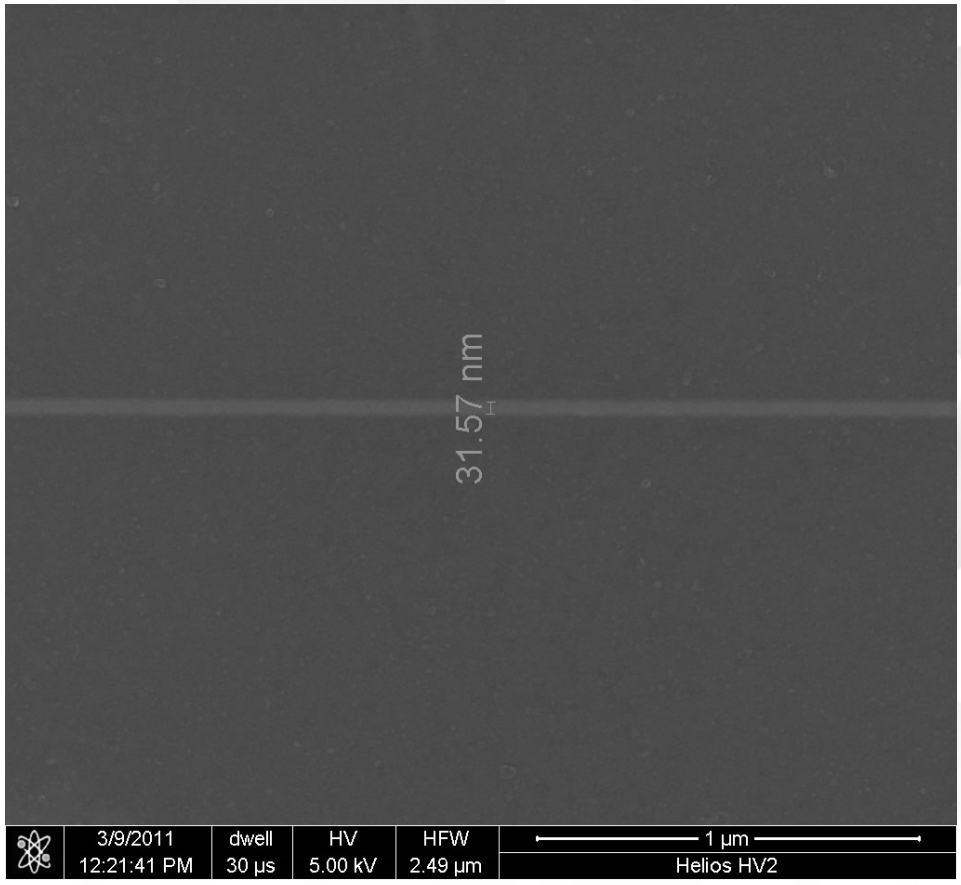
Magnetotransport of ultranarrow nanowires of W by FIBID

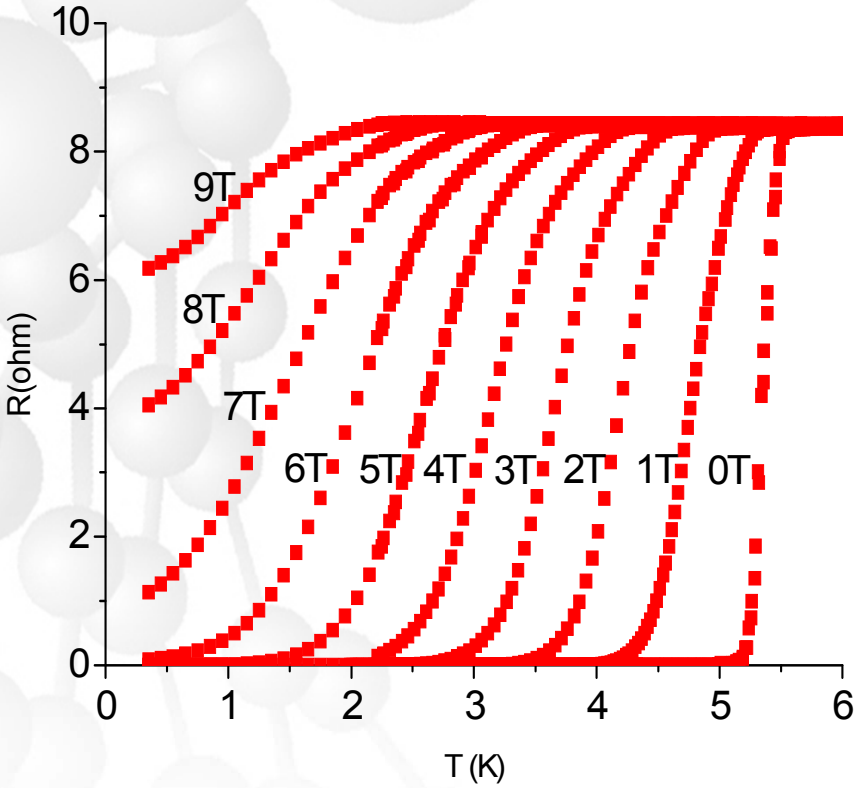


Nanowires of W by FIBID with width down to 50 nm are feasible. It might be even possible to further decrease such value… Are such nanowires still functional?

Focused ion beam induced deposition of W

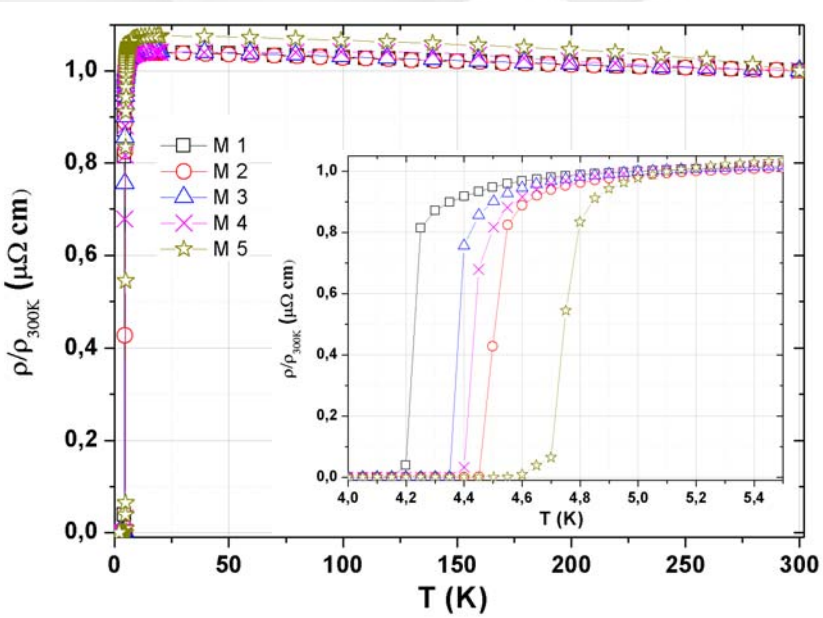
W nanodeposits are superconducting below 5 K





Magnetotransport of ultranarrow nanowires of W by FIBID

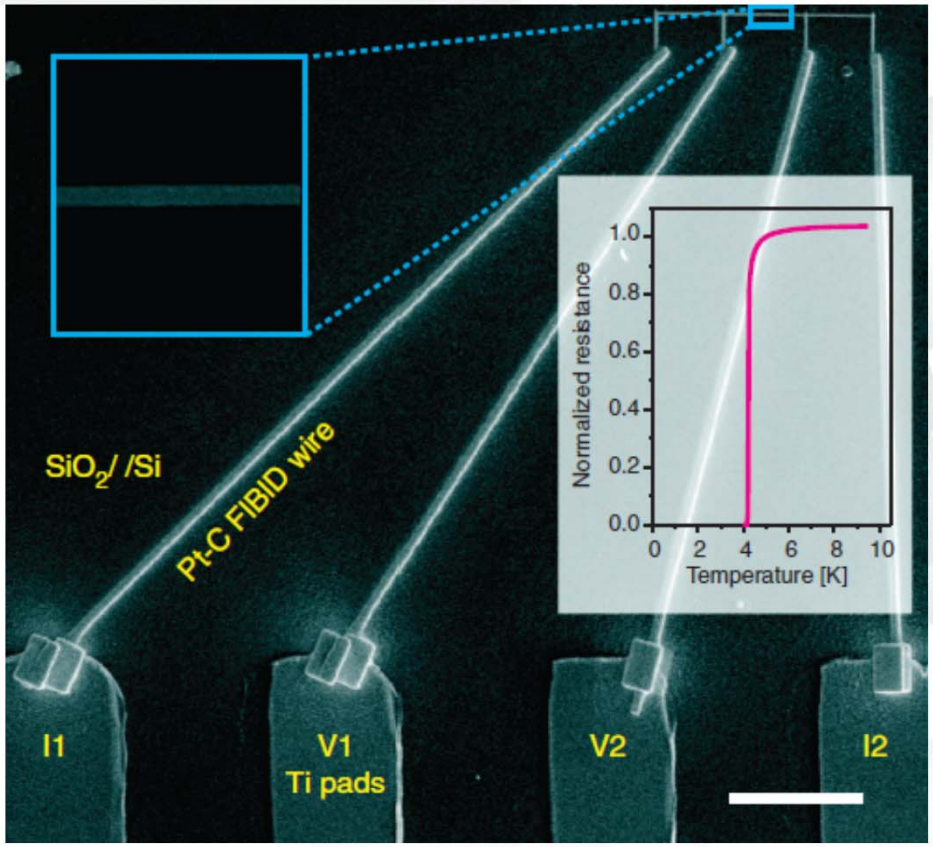
Samples	Width (nm)	Thickness (nm)	ρ_{300K} ($\mu\Omega$·cm)	T_c (K)	$J_{c\ 2K}$ (MA/cm^2)
M 1	50	30	172	4,23	0,406
M 2	60	49	254	4,50	0,221
M 3	70	44	276	4,37	0,148
M 4	65	44	223	4,42	0,161
M 5	60	37	215	4,75	0,185

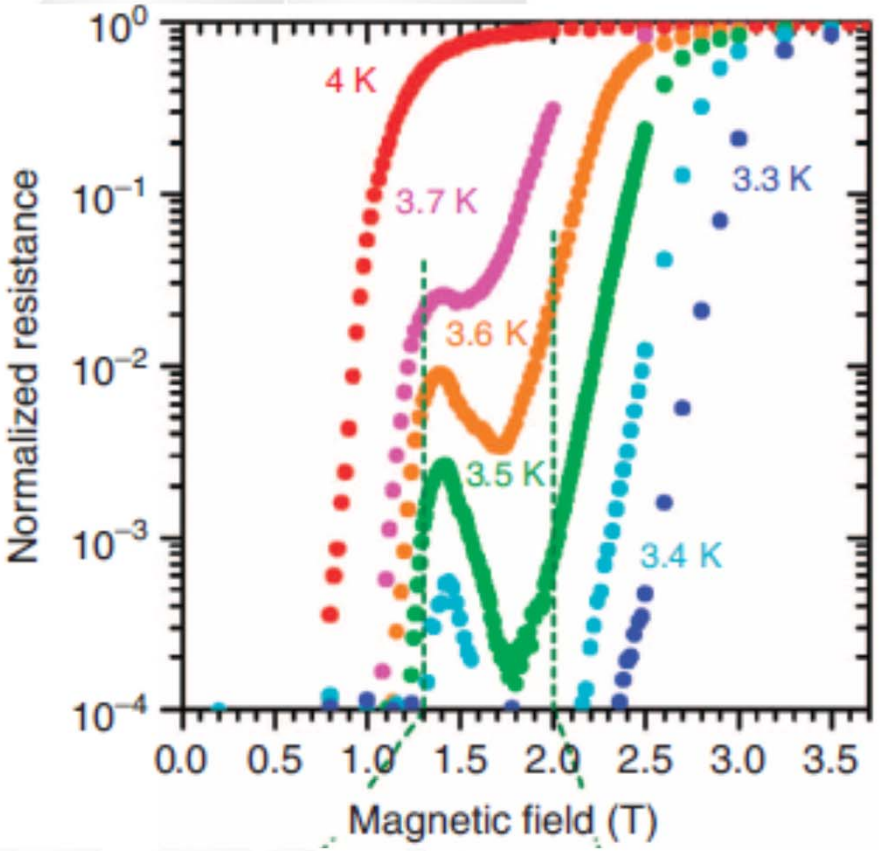


Nanowires of W by FIBID with width down to 50 nm are still functional, with T_C higher than 4.2 K and critical fields and currents similar to those found in wider wires.

Magnetotransport measurements in ultranarrow W nanowires provided the study of finite-size effects as well as non-local transport properties.

Vortex confinenment: Field induced dissipation free state





R. Córdoba, et al. Nature Communications, vol. 4, 1437. 2013

OUTLINE

-FIBID&FEBID new direct nanopatterning method of functional materials

-Co based nano-Hall sensor

-Vortex confinement in superconductor nanostructures

-Ferromagnetic-superconducting planar nano-junction

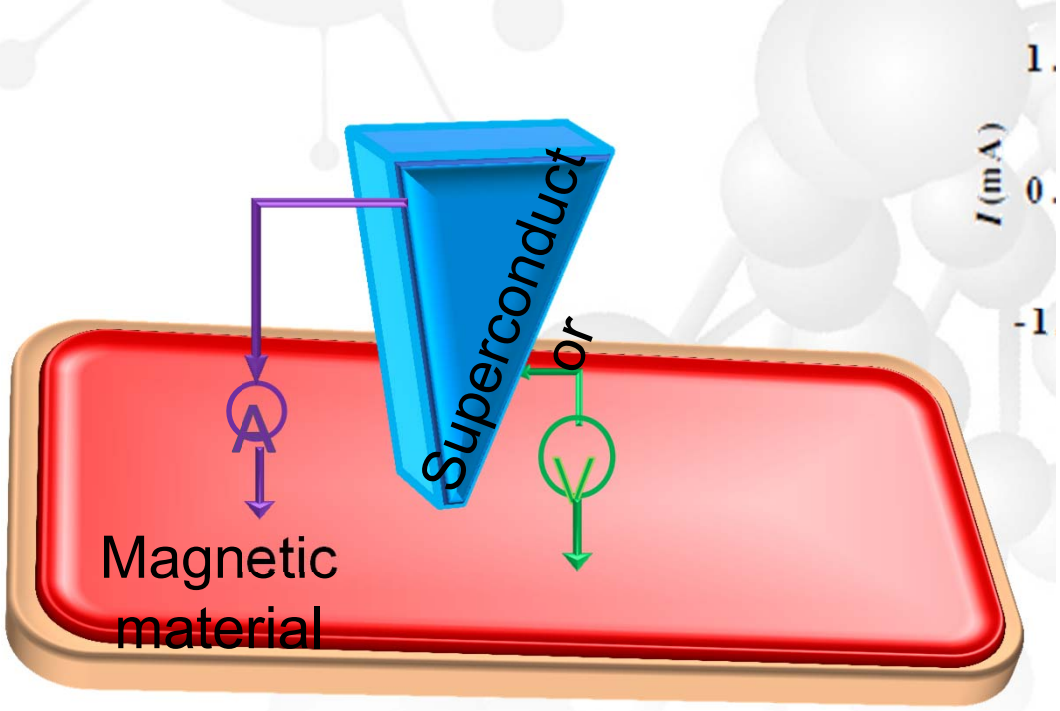
-Conclusions

Determinaton of the spin polarization using AR

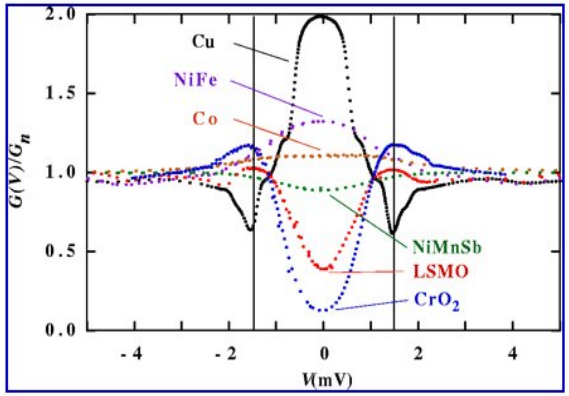
- Tunnel effect: Tedrow-Meservey
- Point contact STS
- Nanocontacts

Point Contact Andreev Reflection (STS)

Current-perpendicular-to-plane Andreev reflection measurements:



5. Data



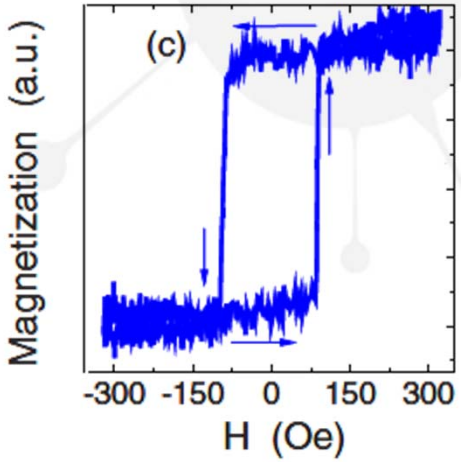
Cu : 0 CrO2 : 100% NiFe : 35% Co : 42% Ni : 45%

R. J. Soulen et al., *Science* 282, 85 (1998).
S. K. Upadhyay et al., *Phys. Rev. Lett.* 81, 2147 (1998).

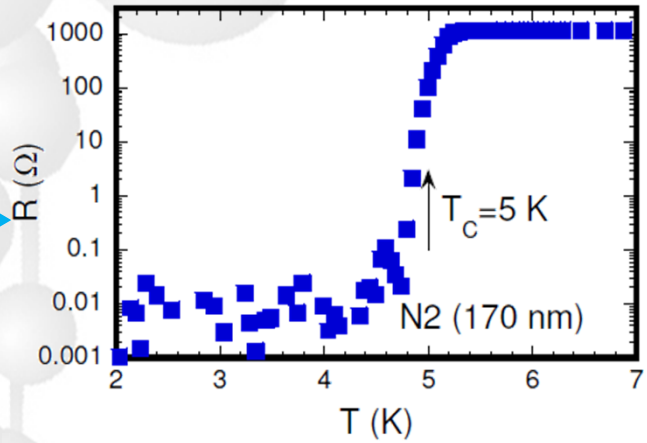
Introduction: Point Contact Andreev Reflection

Current-in-plane Andreev reflection measurements:

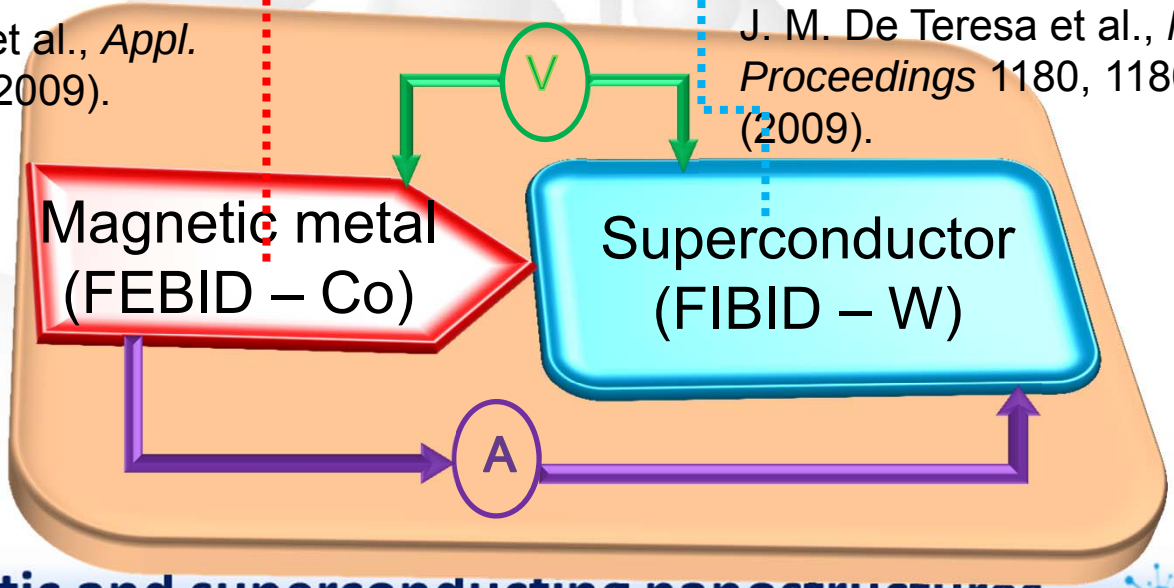
S. Sangiao et al., *Solid State Communications* 151, 37 (2011).



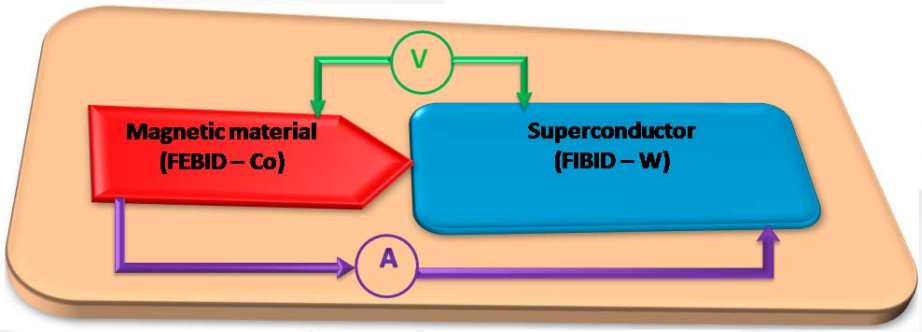
A. Fernández-Pacheco et al., *Appl. Phys. Lett.* 94, 192509 (2009).

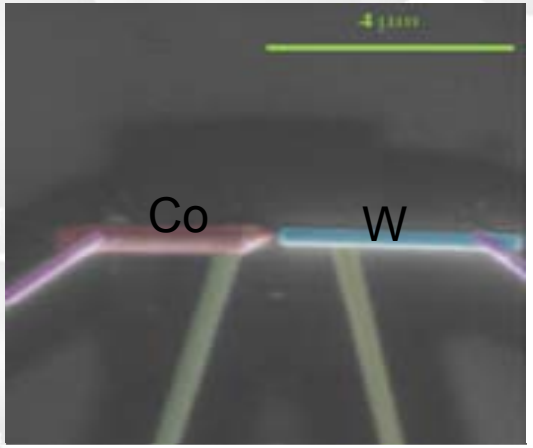


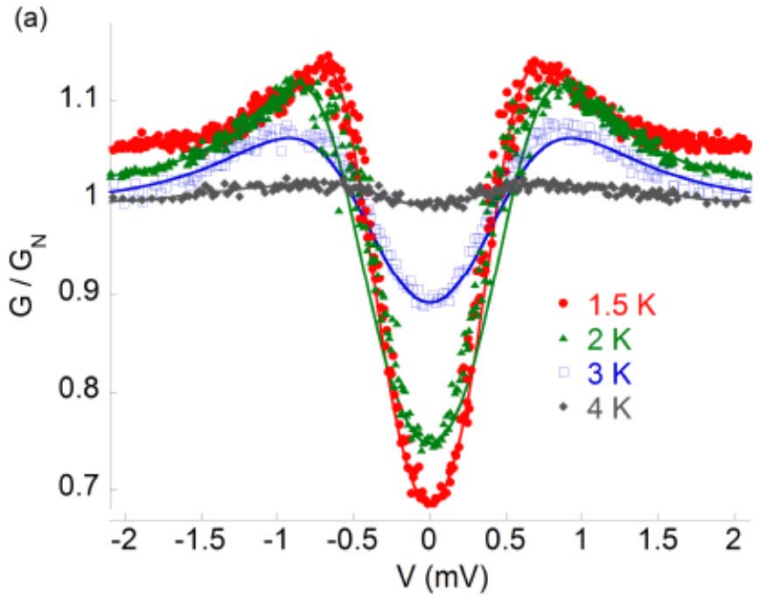
J. M. De Teresa et al., *MRS Proceedings* 1180, 1180-CC04-09 (2009).

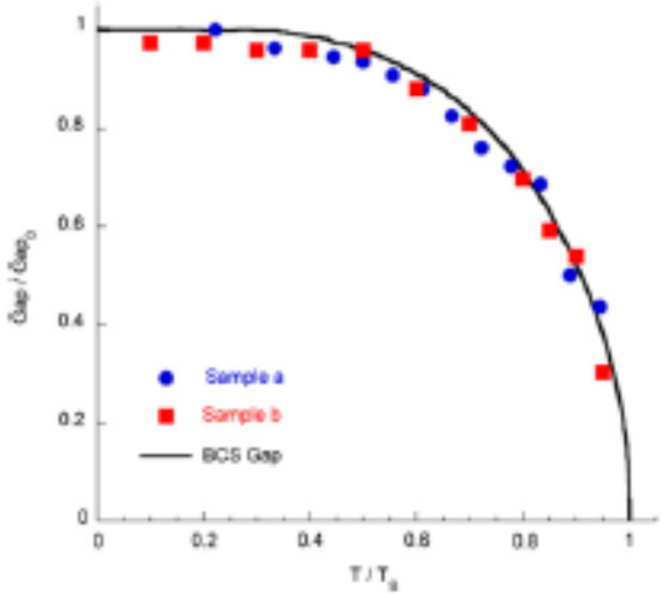


Andreev reflection observed in Co-W nanocontacts









Blonder, Tinkham and Klapwijk (BTK) fits including spin polarization gives spin polarization of 38 % for Co and reproduces the BCS gap

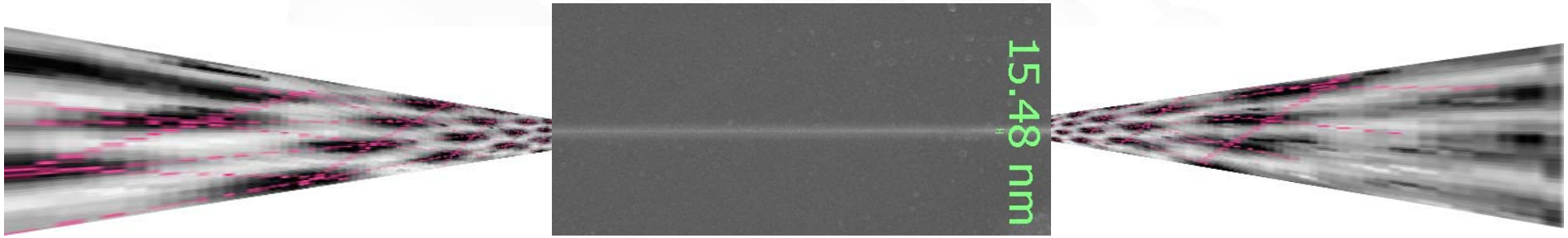
Summary and conclusions

* High-content Co nanostructures can be grown by focused electron beam induced deposition (FEBID) shows ferromagnetic and magnetotransport properties similar to pure Co. This allows design of nanosensor for magnetic immuno-recognition of biological moieties

* W by FIBID shows T_C around 5 K and well-behaved BCS properties. The geometry of W by FIBID can be controlled quite accurately. Ultranarrow nanowires of W by FIBID with width of 30 nm and good SC properties have been grown.

* Field induced reentrance of the superconductivity in narrow wires allocating only a single vortex line due to size effect.

* Co-W planar nanocontacts have been grown, showing Andreev reflection. From fits of the differential conductance, the superconducting gap of W and the spin polarization of Co have been determined.



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Magnetic and superconducting nanostructures
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