Superconductivity, Spintronics and Surface Science Center

Prof.dr. Traian Petrisor

Proiec t ID 106

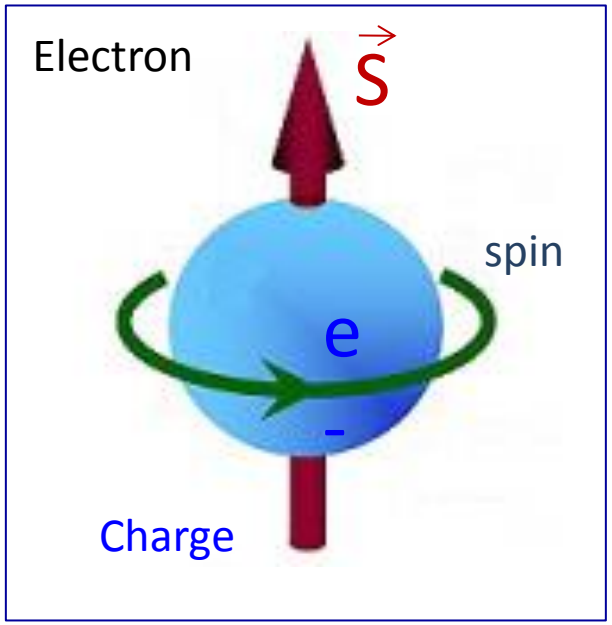
Efectele dopajului si ale dimensionalitatii asupra proprietatilor magnetice, structurale si morfologice si dinamicii de spin in micro si nanostructuri oxidice feromagnetice.

Director proiect: Prof. dr. TRAIAN PETRIŞOR
Instituţie coordonatoare proiect: Universitatea Tehnica din Cluj-Napoca

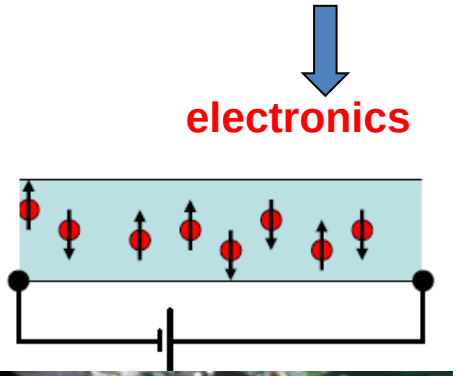
OBIECTIVUL PROIECTULUI

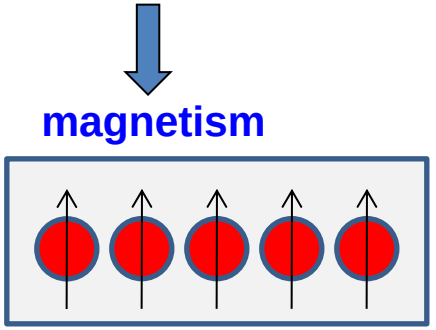
Obiectivul general al proiectului consta in studiul efectelor dopajului cu ioni 3d asupra proprietatilor magnetice, electrice, structurale, morfologice, precum si asupra dinamicii de spin in micro si nanostructuri de semiconductori oxidici feromagnetici oxidici in vedere folosirii acestora in dispozitive spintronice semiconductoare ca si sursa de electroni polarizati pentru cresterea eficientei injectiei de spin.

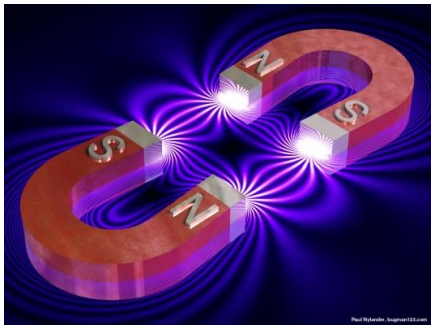
SPINTRONICA



Electron = charge + spin







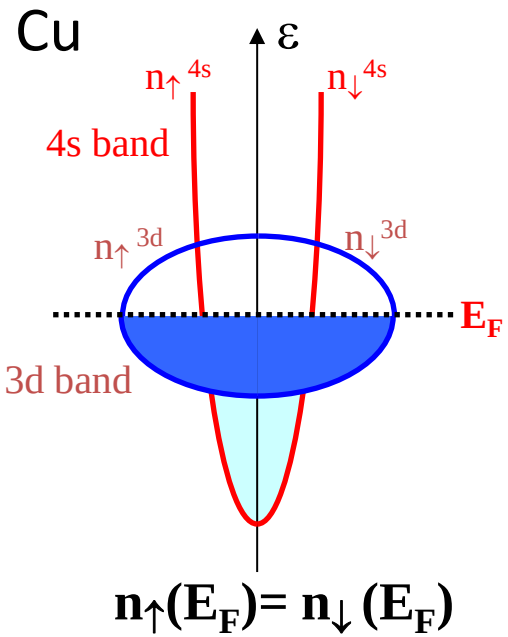
Purpose of spin-electronics: ``*Teaching electrons new tricks´´*
by manipulating the electron spin in solid state electronic devices

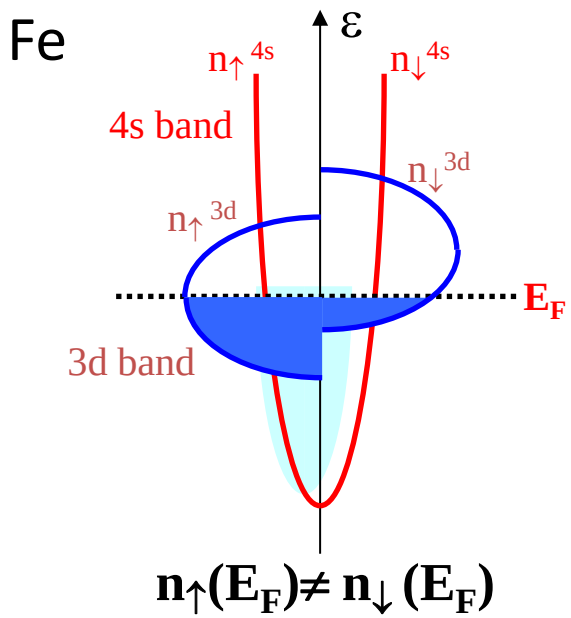
combine electronics and magnetism in order to make new devices
in which both the charge and the spin of the electron play an active role

FUNDAMENTELE SPINTRONICII

m*(d) >> m*(s) ⇒ J mostly carried by s electrons in transition metals

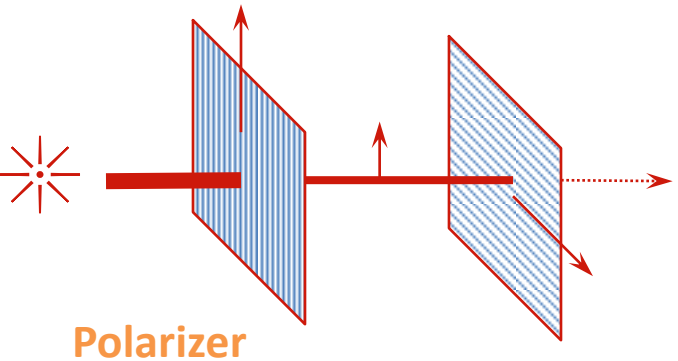
Fermi Golden rule : $P_{i\to f} \propto \left|\langle i|W|f\rangle\right|^2 n(E_F)$ ⇒ Spin-dependent scattering rates





FUNDAMENTELE SPINTRONICII

Optics analogy

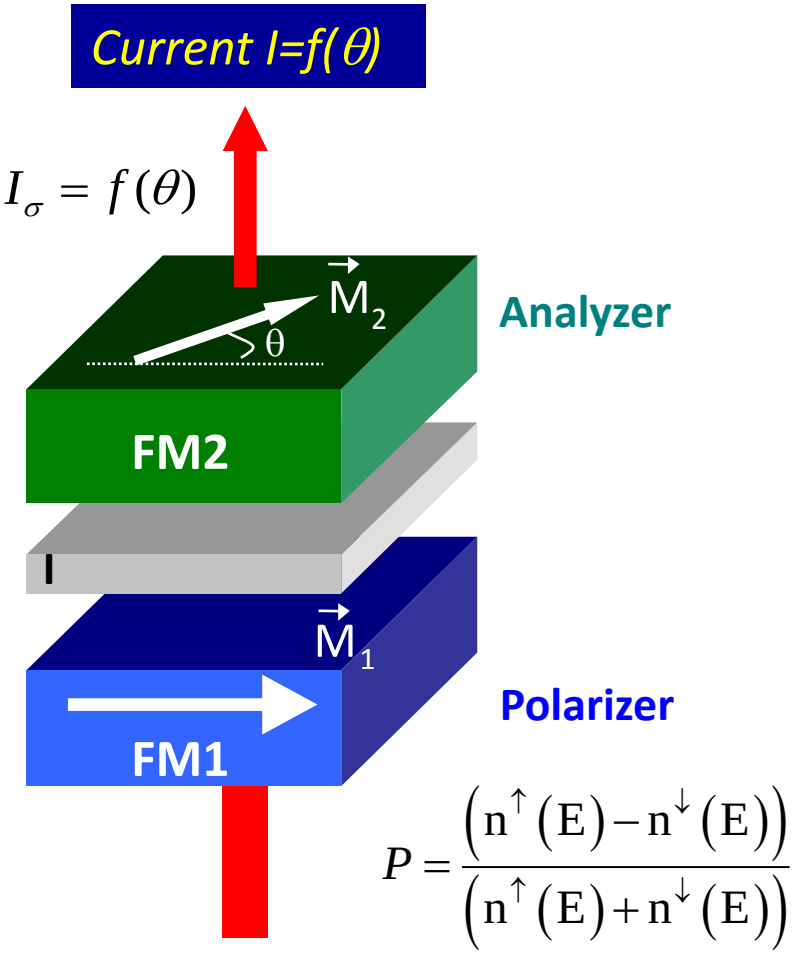


Polarizer

Analyzer

Spin dependent tunnel current

$I_\sigma = f(\theta)$



I: Spin dependent tunneling

FM: Spin filtering

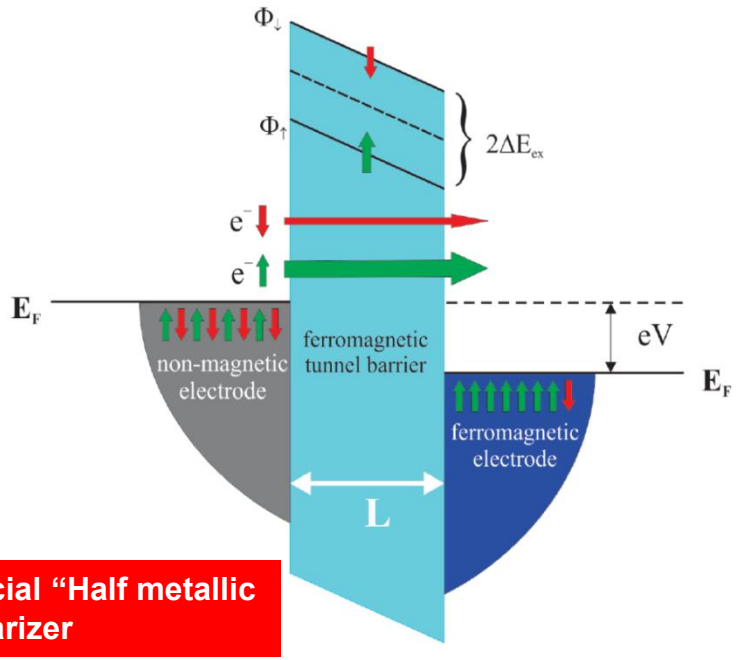
$n^{\uparrow}(E) - n^{\downarrow}(E)$

$$P = \frac{\left(n^{\uparrow}(E) - n^{\downarrow}(E)\right)}{\left(n^{\uparrow}(E) + n^{\downarrow}(E)\right)}$$

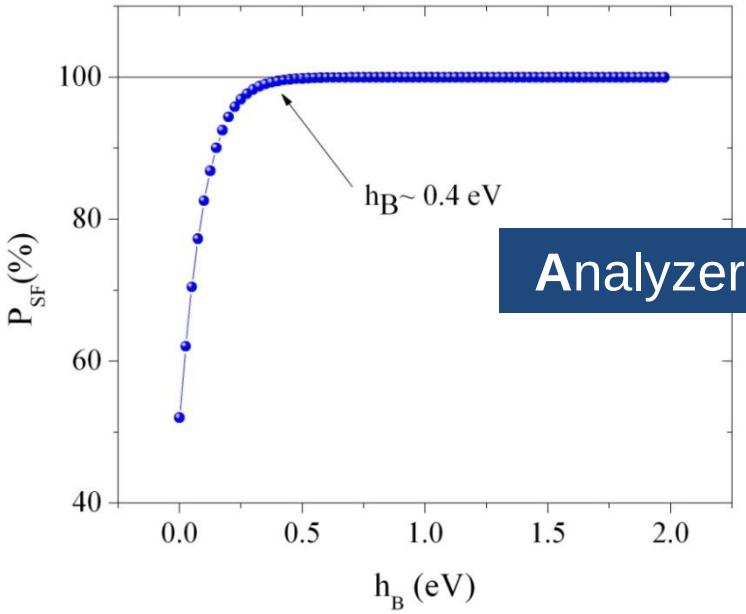
DE CE OXIZI FEROMAGNETICI SEMICONDUCTORI ?

I. metalic electrode / ferromagnetic barrier (FMO/NM) artificial half metal P=100%

Numerical results
Free electron model with voltage dependent barrier shape



Artificial "Half metallic " polarizer

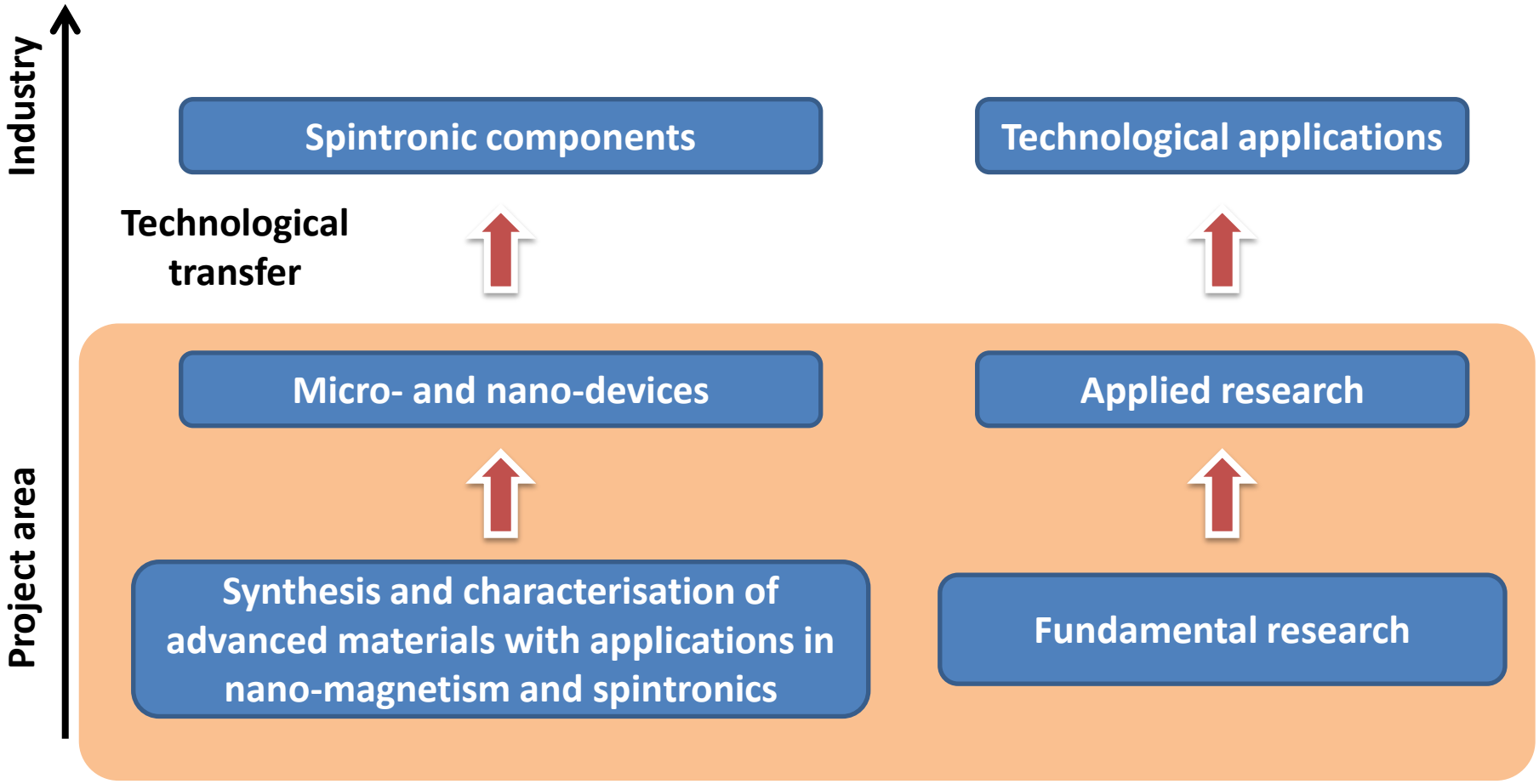


Analyzer

$$P_{SF} = \frac{J_\uparrow - J_\downarrow}{J_\uparrow + J_\downarrow} \Rightarrow 100\%$$

COMPLEXITATEA PROIECTULUI

From advanced materials towards spintronic devices and components



ECHIPA PROIECTULUI

P1. Universitatea Tehnică din Cluj-Napoca (UTCN), Centrul de cercetare C4S

P2. Institutul Naţional de Cercetare Dezvoltare pentru Tehnologii Izotopice şi Moleculare (INCDTIM)-Cluj-Napoca , Departamentul de Fizica Sistemelor Nanostructurate.

P3. Institutul Naţional de Cercetare Dezvoltare pentru Fizica Tehnica (INCDFT)-Iasi, Secţia de Materiale si Dispozitive Magnetice.

P4. Institutul Naţional de Cercetare Dezvoltare pentru Fizica Materialelor (INCDFT) - Bucuresti, Laboratorul de Microstructura Defectelor in Solide.

P5. Institutul Naţional de Cercetare Dezvoltare pentru Metale Neferoase si Rare (INCDMNR)-Bucuresti, Laboratorul de Materiale Nanostructurate

P6. Universitatea Politehnică Bucureşti; Facultatea de Chimie Aplicată şi Stiinţa materialelor / Catedra de Ştiinţa şi Ingineria Materialelor Oxidice şi Nanomateriale.

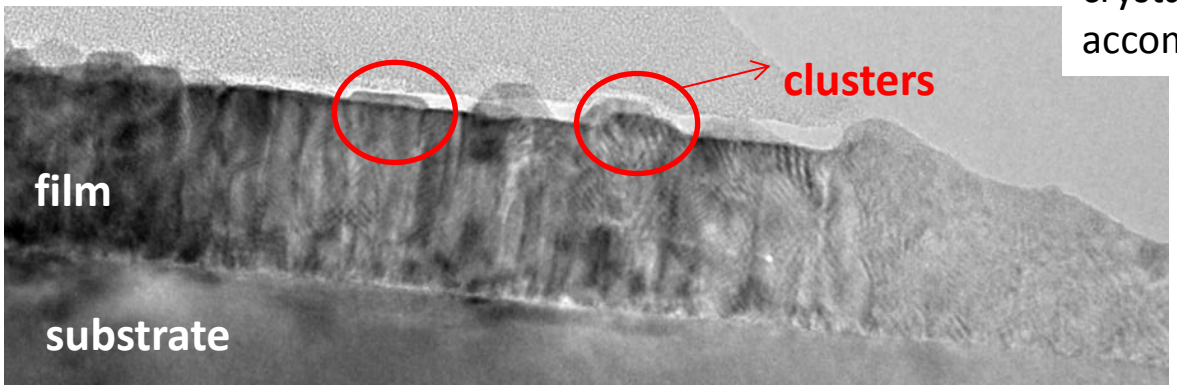
Responsabili echipe parteneri: CSI. Dr. LIVIU GIURGIU (P2), Prof. Dr. HORIA CHIRIAC (P3), CSI. Dr. GRECU MARIA (P4), CSI. Dr. RADU PITICESCU (P5), Prof. Dr. ECATERINA ANDRONESCU (P6).

REZULTATE RELEVANTE

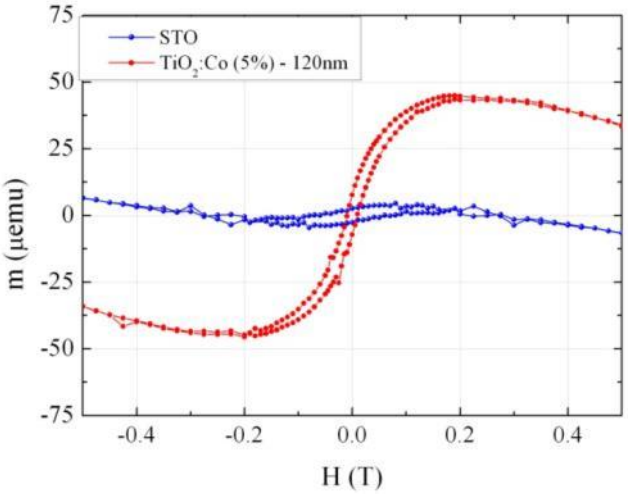
- Demonstrarea naturii extrinseci a feromagnetismului in straturile subtiri de oxizi magnetic diluati cu implicatii asupra aplicabilitatii acestora in domeniul dispozitivelor spintronice.
- Metoda de nanostructurare utilizand terasarea la nivel atomic a substratului.
- Model si soft pentru simularea numerica predictiva a răspunsului magnetorezistiv al unei joncţiuni de tip filtru de spin în funcţie de parametrii barierei tunel şi a punctului de functionare.
- Metode alternative de nanolitografie.
- Dezvoltarea unui prototip de senzor magnetorezistiv cu efect tunel folosind electrozi feromagnetici semimetalici.
- Modelarea structurii locale, a anizotropiei magnetice si a cimpurilor fine si hiperfine in nanopulberi si filme subtiri dopate controlat cu ioni paramagnetici.
- Modelarea cineticii de nucleatie in solutii hidrotermale a sistemelor oxidice $Zn_{1-x}TM_xO$ si $Ti_{1-x}TM_xO_2$ (TM = Mn, Fe,Co).

Natura extrinseca a feromagnetismului in straturile subtiri de oxizi magnetic diluati

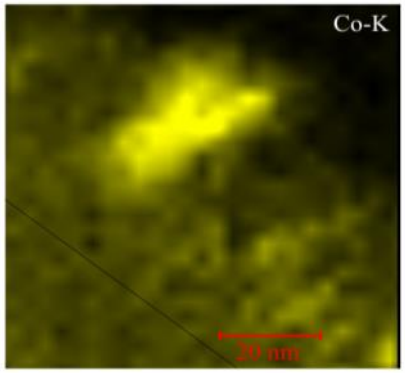
TEM analysis indicates the presence of clusters



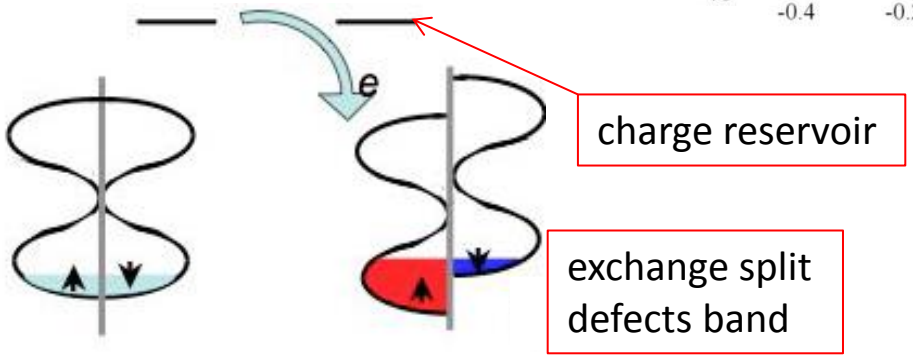
Clusters have the same crystalline structure as the film and are accompanied by large structural defects



EDAX images



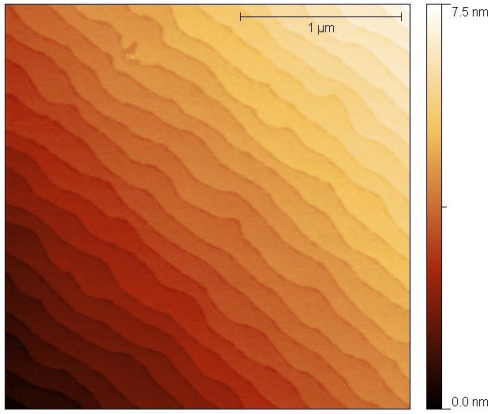
Charge-transfer ferromagnetism*



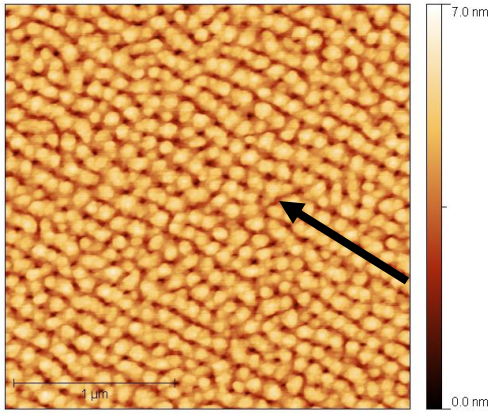
- **all the Co is found within the clusters**

M.S. Gabor et al. JR11-9583R, Journal of Applied Physics 111 (2012) 083917).

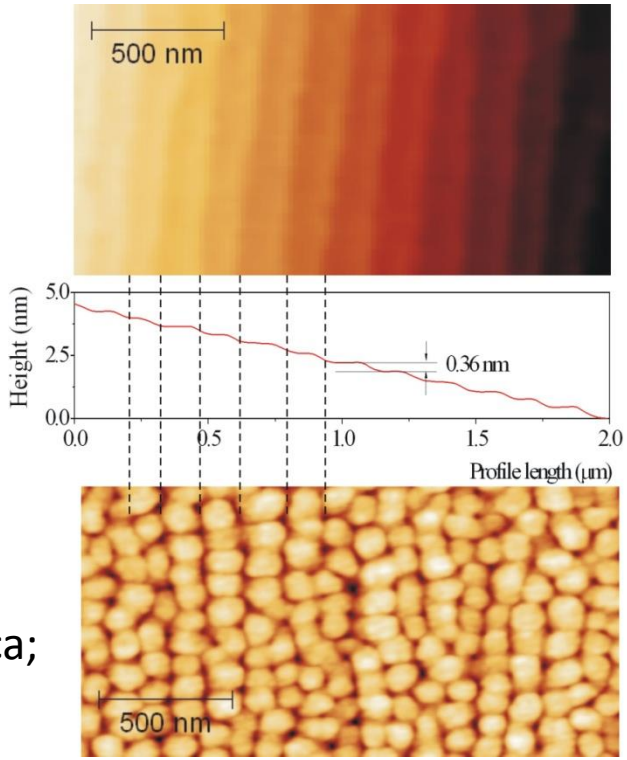
Metoda de nanostructurare utilizand terasarea la nivel atomic a substratului



Substrat STO (001) terasat



Film de LSMO nanostructurat



✓ tratamentul de terasare:

chimic – 10 sec. NH_4:HF (pH=5,5) ⟶ uniformitate chimica;

termic – 950 ^oC, 12 min. in O_2 ⟶ terasare;

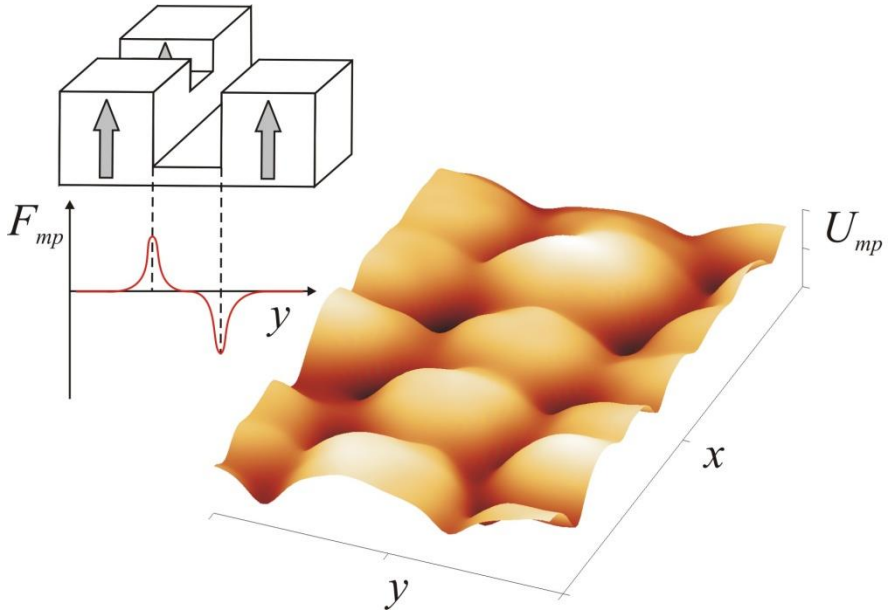
✓ inaltimea teraselor (~4 Å) corespunde la a_{STO} (a_{STO} = 3.905 Å)

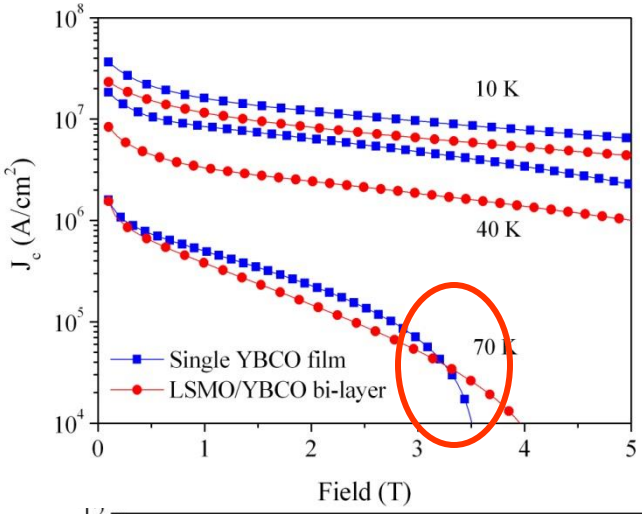
✓ profilele de inaltime ale substratului (Figura), respectiv ale filmului indica limitarea cresterii insulelor de LSMO de catre largimea teraselor de STO.

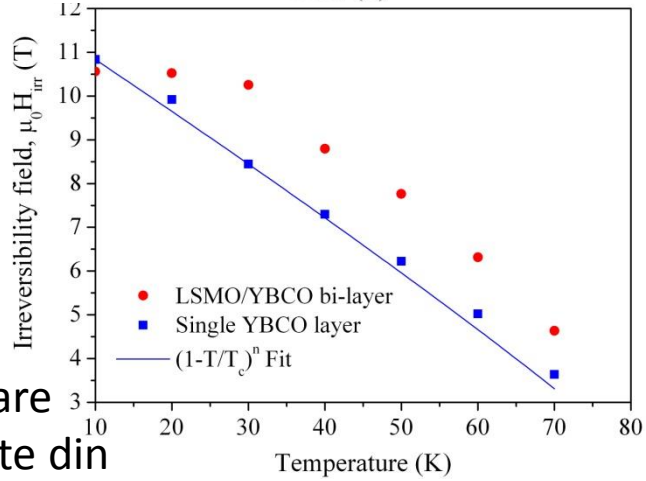
T. Petrisor jr. et al. J. Appl. Phys. 112 (2012) 053919.

Ancorarea magnetica a vortexurilor supraconductoare

Aplicatii ale filmelor nanostructurate de LSMO





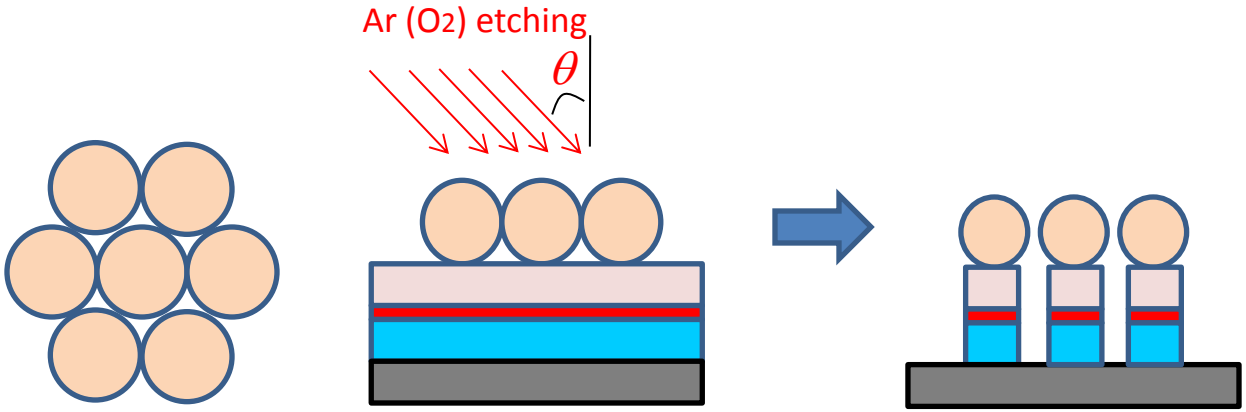


- ✓ imaginea AFM a suprafetei filnului de LSMO corspunde cu cea a potentialului de ancorare magnetica la saturatie;
- ✓ vortexurile supraconductoare vor fi ancorate la limitele dintre nanostructurilor de LSMO;
- ✓ studiile efectuate confirma existenta unui potential de ancorare magnetic, eficient la campuri si temperaturi ridicate (relevante din punct de vedere al apicatiilor practice).

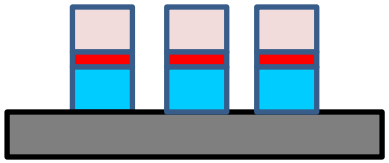
Metode noi de nanolitografie

Ion beam etching mask (SiO_2)

SiO_2 nanosphere deposition on top of multilayered structure ➡ Nano-device fabrication

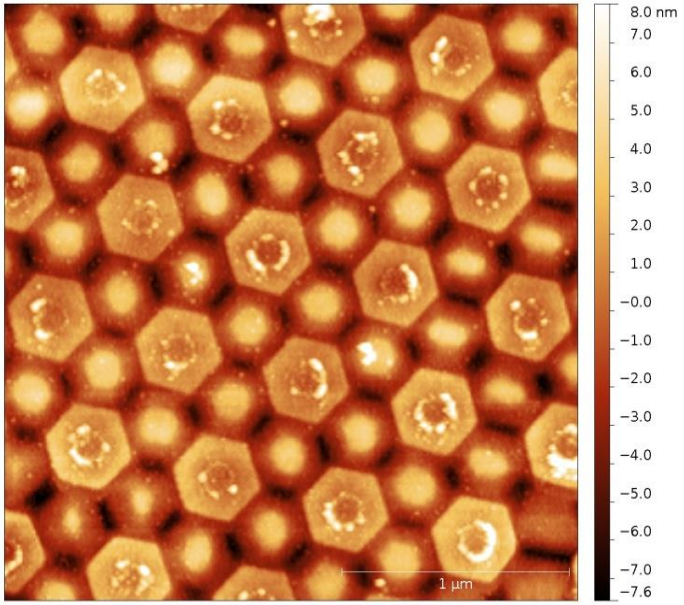


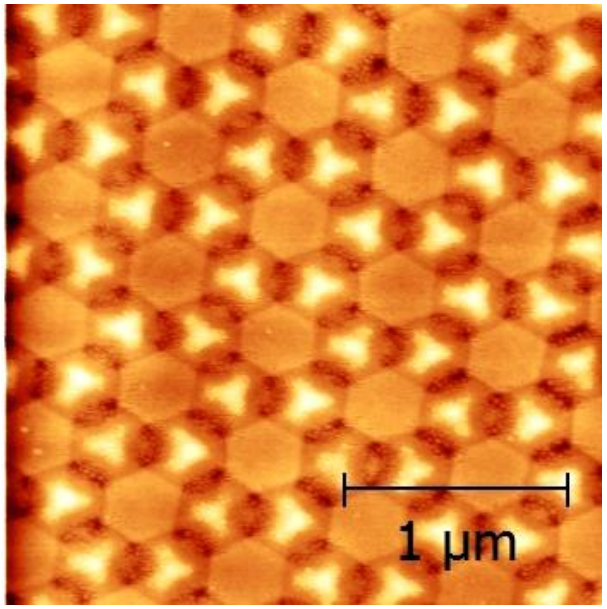
Variable shape =f(θ)
multi-layer nanostructures

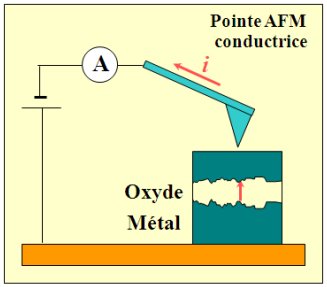


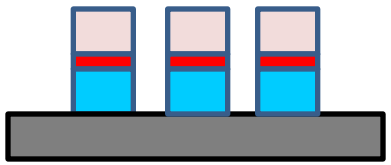
Metode noi de nanolitografie

Ion beam etching mask (SiO_2)



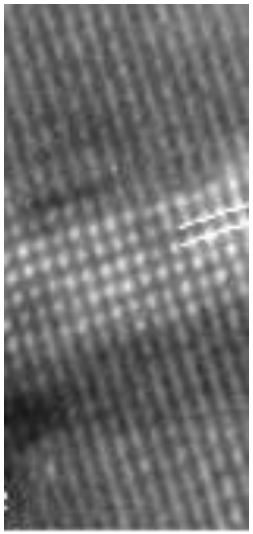




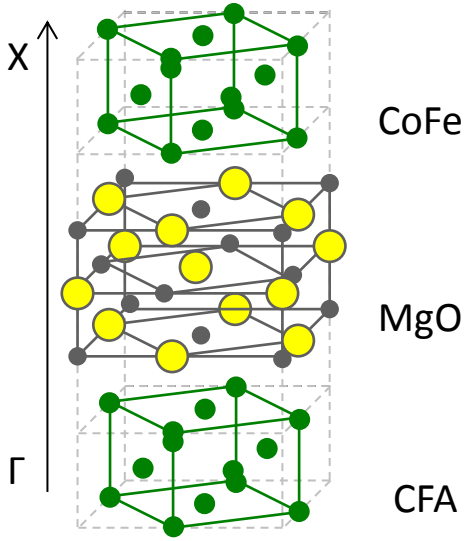


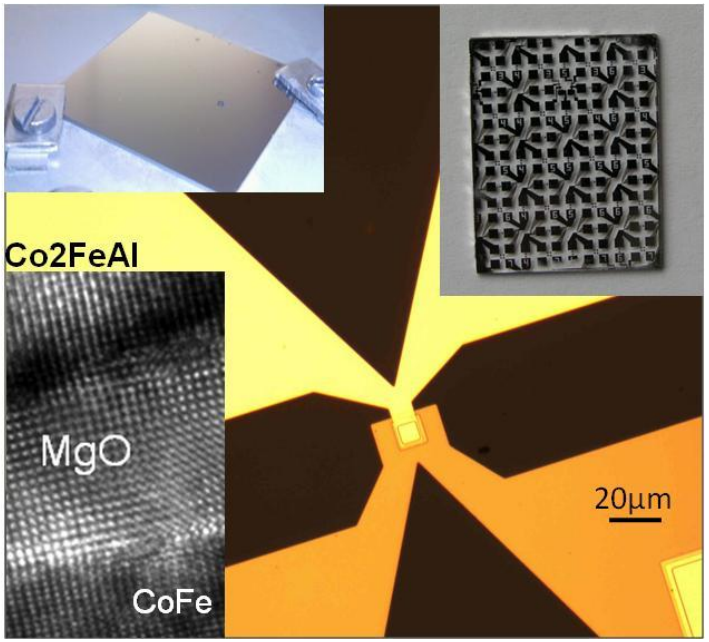
Magnetic Tunnel Junctions,
CPP-Giant Mangeto Resistance,
Nano-oscillators, etc.

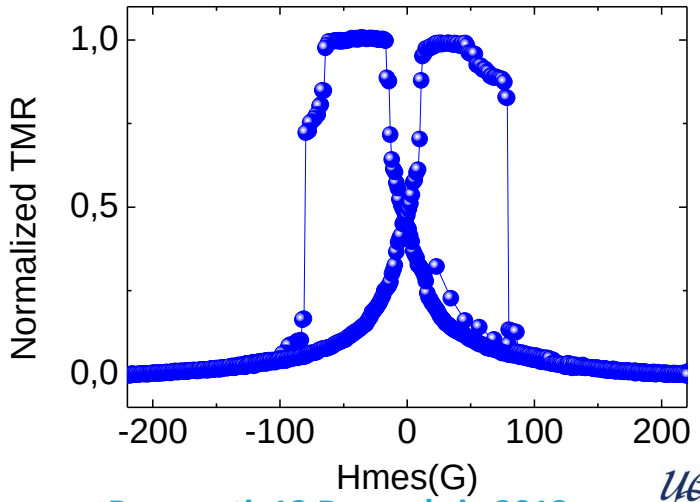
Jonctiune magnetica tunel epitaxiala pe baza de Co2FeAl



Expected
large TMR effect







REZULTATE IN DOMENIUL EDUCATIONAL -FORMATIV

- Finalizarea a 5 teze de doctorat in domeniul spintronicii si a materialelor pentru spintronica.
- Organizarea de cursuri de masterat in domeniul spintronicii, materialelor pentru spintronica si a nanomaterialelor in cadrul UTCN si UPB.
- Publicarea unei carti si a unui indrumator de laborator pe tematica proiectului .
- Efectuarea de stagii de cercetare pentru tinerii cercetatori ce insumeaza aproximativ 24 de luni.
- Angajarea pe perioada proiectului a 8 tineri cercetatori.

DEZVOLTAREA INFRASTRUCTURII DE CERCETARE

Superconductivity, Spintronics and Surface Science Center

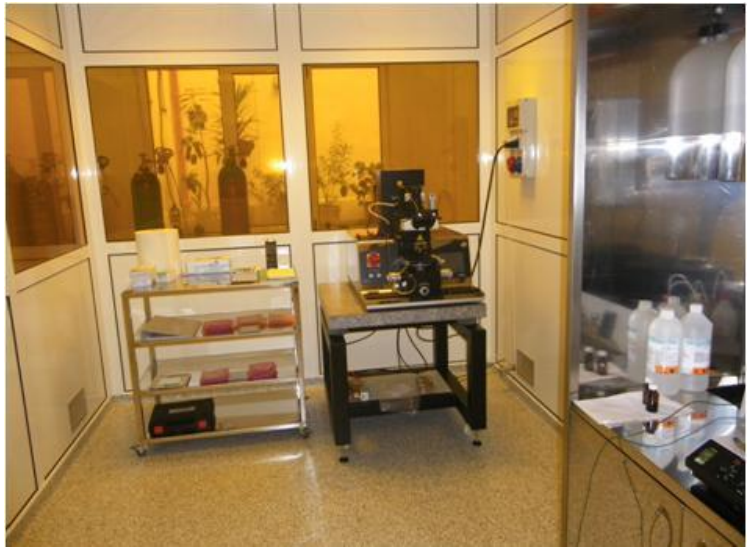
History

The Center of Superconductivity, Spintronics and Surface Science (C4S) includes the former Material Science Laboratory, created in 1995 within the **Technical University of Cluj-Napoca (TUCN) ;** *http://www.c4s.utcluj.ro*

C4S staff

- 4 Prof/Senior Researchers
- 6 permanent young researchers
- 8 PHD students
- 2 Postdocs
- 2 technicians

IMAGINI DIN CENTRUL C4S



REALIZARE INDICATORI

Indicator	Contractat	Realizat
Articole ISI	32	**36**
Factor cumulativ de impact	35	**65,1**
Scor relativ de influenta	-	**54,5**
Brevete	3	**2+3**
Articole BDI	21	**20**
Brevete internationale	-	-

- In ciuda faptului ca a trecut un timp scurt de la publicare aceste articole au peste **100** de citari

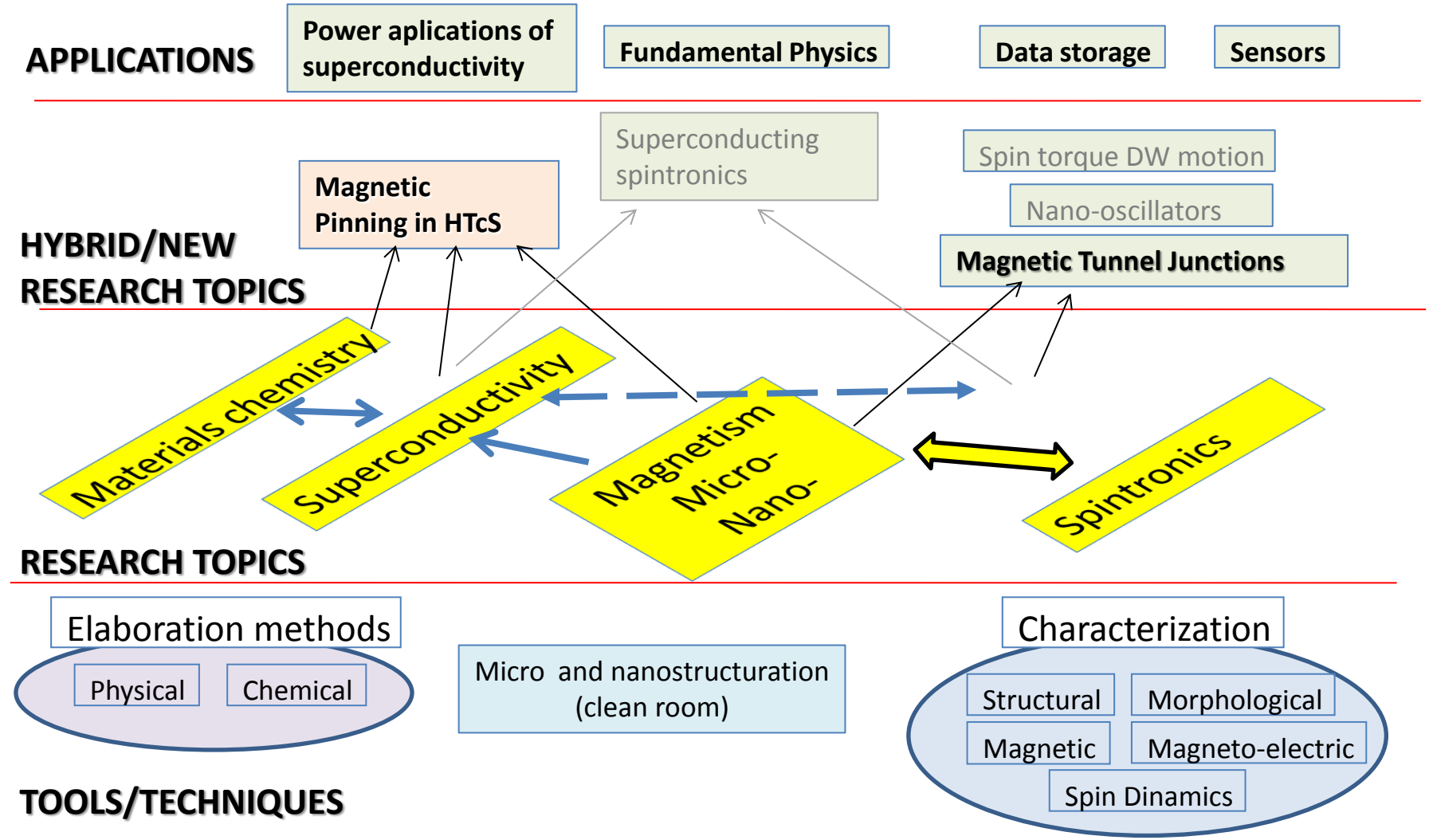
SUSTENABILITATEA PROIECTULUI

- Formarea unei comunitati de tineri cercetatori cu competente de varf in domeniul proiectului si cu o cultura a colaborarii interdisciplinare.
- Dezvoltarea, in cadrul consortiului, a unei infrastructuri de cercetare complementare.
- Deschiderea, pe baza competentelor obtinute in cadrul proiectului, a unor axe de cercetare noi, ca de exemplu: oxotronica, ancorarea magnetica a vortexurilor supraconductoare si semiconductori de banda larga multifunctionali.

Proiecte in derulare:

- "*European developement of superconducting tapes: integrating novel materials and architectures into cost effective processes for power application and magnets*" (FP7-NMP-2011-LARGE-5; Grant agreement: No 280432; Large scale integrating project (NMP3-LA-2012-280432), http://eurotapes.eu).
- *''Dispozitive spintronice cu proprietati magnetice si de transport controlabile''* (SPITAIL PN-II-ID-PCE-2012-4-0315) .
- *„Cercetarea si dezvoltarea de dispozitive spintronice la scara mezoscopica”* (Proiect ID-574, cod SMIS-CSNR 12467).

SUSTENABILITATE-NOI DIRECTII DE CERCETARE



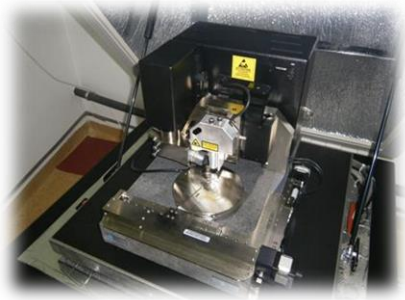
IN LOC DE CONCLUZII

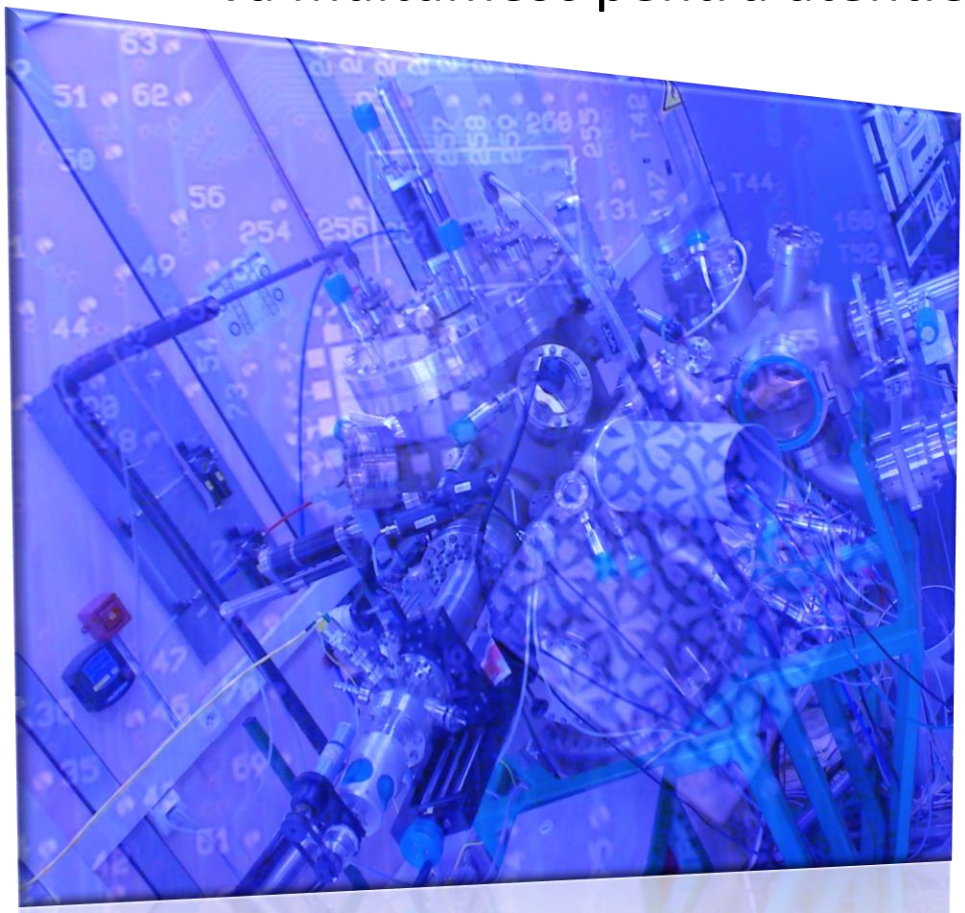
"*Principala calitate a unui cercetator consta in capacitatea de a depasi insuccesele*."

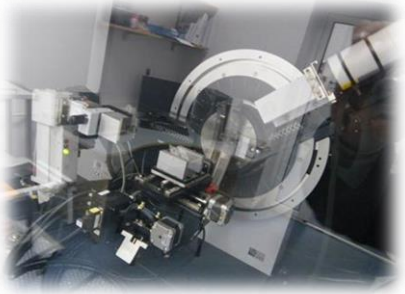
Piotr Kapita

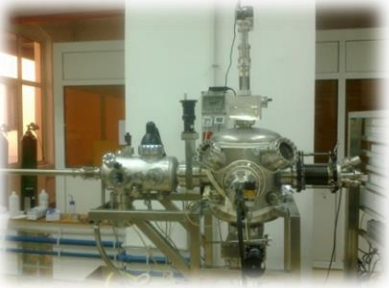
Echipa de realizare a proiectului a avut capacitatea de a gestiona riscurile si "insuccesele" proiectului in asa fel, incat , in ansamblul sau, proiectul sa fie unul de succes.

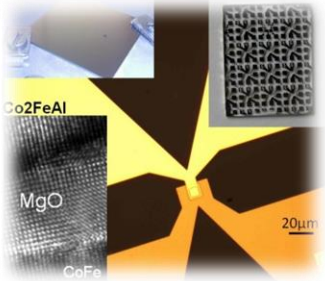
Va multumesc pentru atentie !

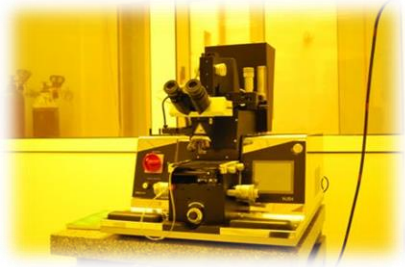


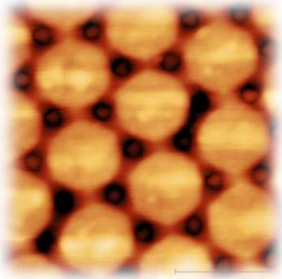












Imagini din C4S