NATIONAL INSTITUTE OF MATERIALS PHYSICS

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"De la excelenta la competitivitate: tehnologiile generice esentiale", 2014

"INCDFM: De la excelenta la competitivitate in domeniul materialelor avansate si nanomaterialelor"

General presentation

Scope

Basic and applied research in the field of:

condensed matter physics
advanced functional materials
nanomaterials and nanostructures

Educational activities:

diplomas
master dissertations
PhD thesis

Services:

advanced characterization
prototypes
consultancy

Present organization

5 research laboratories with 9 research teams:

- L10-**Multifunctional Materials and Structures**
  - Functional nanostructures
  - Complex Heterostructures and Perovskite Oxides
- L20-**Magnetism and Superconductivity**
  - Electronic Correlations and Magnetism
  - Superconductivity
- L30-**Physics of Condensed Matter at Nanoscale**
  - Si- and Ge –based nanomaterials and nanostructures
  - Surfaces, interfaces, thin films and single crystals. X-ray / electron spectroscopies and diffraction
  - Theory
- L40-**Optical Processes in Nanostructured Materials**
- L50-**Laboratory of Atomic Structures and Defects in Advanced Materials**

2 certified laboratories:

- Laboratory for chemical analysis of advanced materials (MAAS)
- Laboratory for testing infrared detectors (INDETIR)

Funding

Running projects (at the beginning of 2012)

- national:
  30 projects (about 4,5 million euro for 2012)
- international:
  20 projects (about 0,5 million euro for 2012)
- private sector:
  3 contracts (about 20,000 euro)

Previous record for projects (2008-present):

- national:
  200 projects as coordinator or partner
- international:
  36 projects (20 were bilateral collaborations in the frame of inter-guvernment agreements)
- private sector:
  27 contracts
- EU structural funds
  1 project (about **10 million** euro between 2009 and 2011)

Average funding per year (2008-2011):

some **11 millions** euro

Human resources

Total number of employees :

243

Total number of peoples involved in research activities:

193 (~43 % women), among which:

97 senior researchers (49 rank 1, equivalent prof.)

56 junior and assistant researchers

40 engineers and technicians

15 PhD supervisors

Total number of peoples with PhD title:

108

Total number of PhD students:

25

Total number of peoples involved in auxiliary services:

50

Mean age:

44.3 years (in research, **42.6** years)

Infrastructure

Some **15 millions** euro invested in new equipments:

10 millions from structural funds

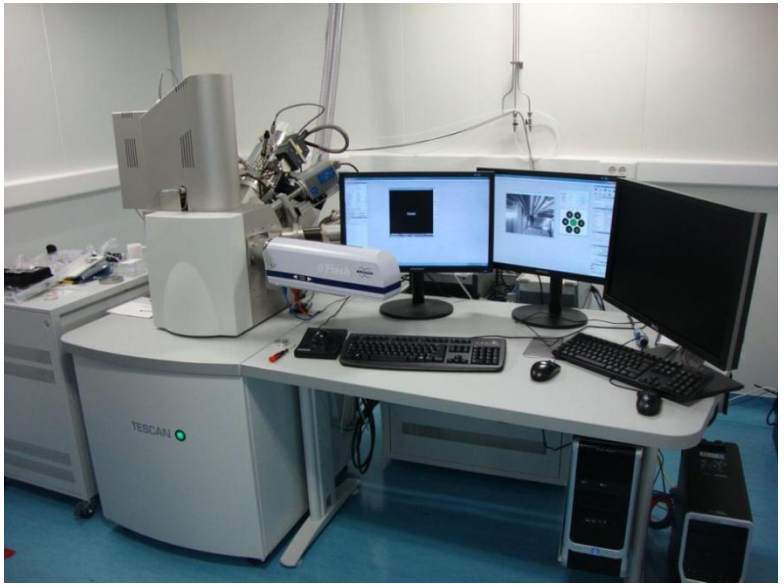
3 millions from Capacity type projects (national funds)

2 millions from other projects

X-Ray Diffractometer D8-ADVANCE type-BRUKER (AXS)

Clean room

Superconducting Quantum Interference Magnetometer (SQUID)



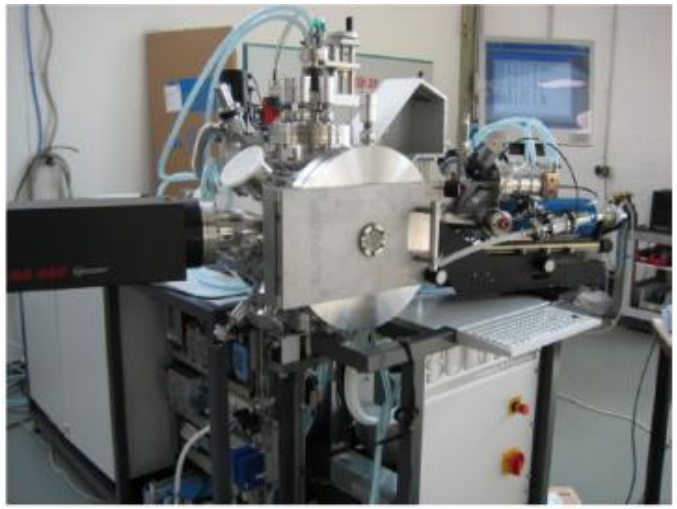
SEM-FIB

Scanning electron microscope S3400-N with nanolithography-system

RF-sputtering with in-situ characterization techniques: Auger, ellipsometry

Growth methods:

- Wet chemical (sol-gel, solution bath deposition, Langmuir-Blodgett); mechanochemical (high energy ball milling); standard ceramic technology; spark plasma sintering; hot pressing; pulling machines for single crystals growth; hydrothermal and solvothermal growth; electrodeposition; melt spinning; MBE; RF-sputtering, PLD; clean room for nanostructures fabrications (photolithography, electron beam lithography, FIB).



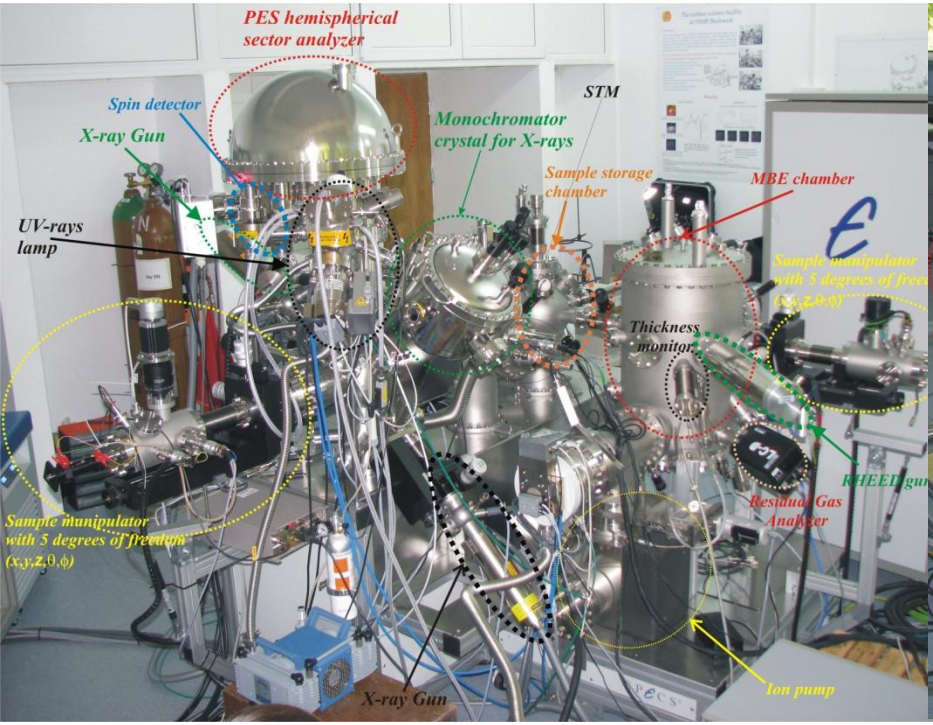
PLD with excimer laser

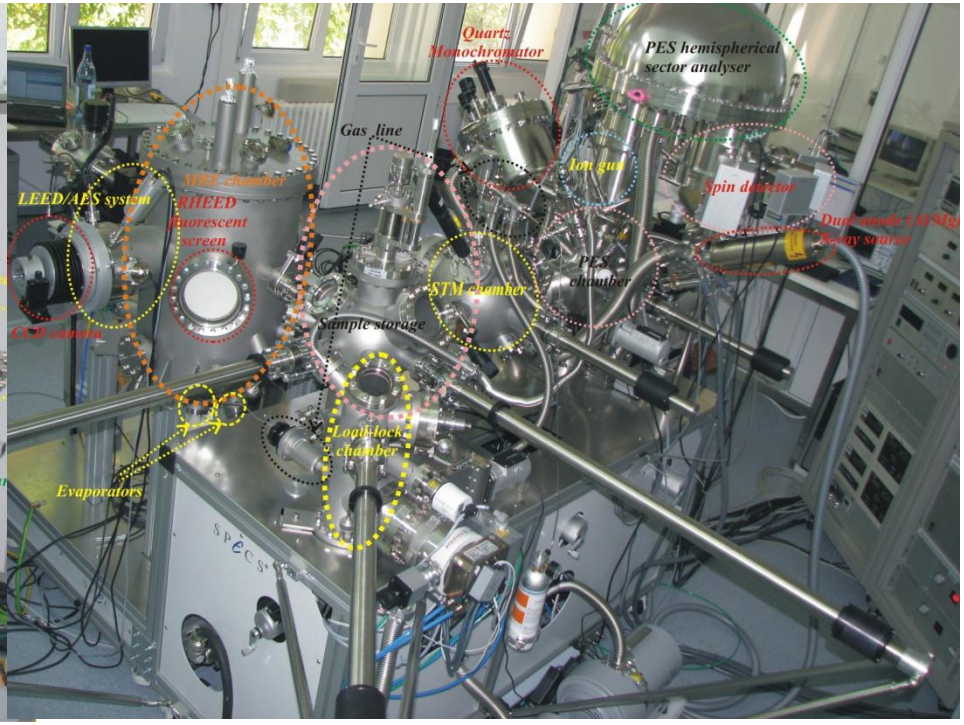
Surface and interface science facility:

Molecular beam epitaxy: 5 evaporators, plasma source, LEED, RHEED, AES, RGA

Scanning tunneling microscopy: STM, STS

Angle- and spin-resolved photoelectron spectroscopy: XPS, ARUPS, SR-PES, depth profiling, X-ray photoelectron diffraction.





Base pressure: 1-2 x 10^{-10} mbar

Scientific production: 30-40 papers / year since 2010

Angew. Chem. Int. Ed., J. Amer. Chem. Soc., ChemSusChem, ChemCatChem, J. Catal., Green Chemistry (x 2), ACS Adv. Mater. Interf. (x 2), Phys. Chem. Chem. Phys. (x 3)

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Characterization:
-structural: XRD; SEM; Raman; RES; Moessbauer; HRTEM, TEM, SAED; AFM, SPM.
-physical properties: magnetism (VSM, MOKE, PPMS, SQUID); optical (luminescence, fluorescence, transmission-absorption-reflectivity, ellipsometry, near field optical microscopy); dielectric; superconducting; semiconductor (Hall); electric-photoelectric; ferroelectric and piezoelectric; trap investigations (DLTS); THz spectroscopy; broad band dielectric spectroscopy; a cluster for surface physics (XPS, SARPES, ARUPS, STM); a XAS spectrometer for EXAFS and XANES studies; etc.

SEM with Cathodoluminiscence

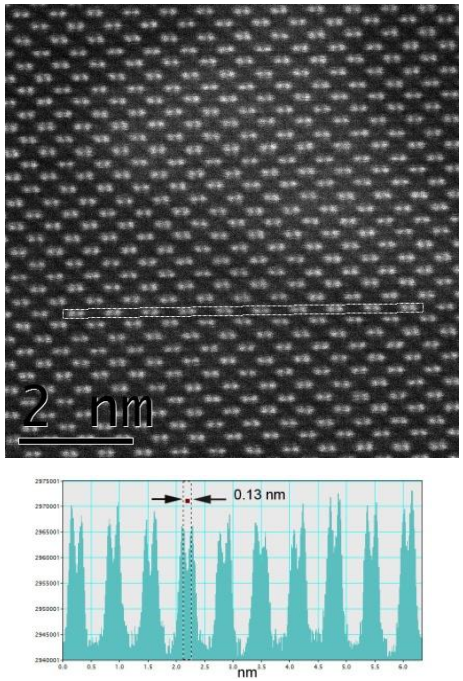
Vibrating Sample Magnetometer VSM (Cryogenics)

FT Raman Spectrophotometer RFS/100S (Bruker)

High Resolution Analytical Transmission Electron Microscopy

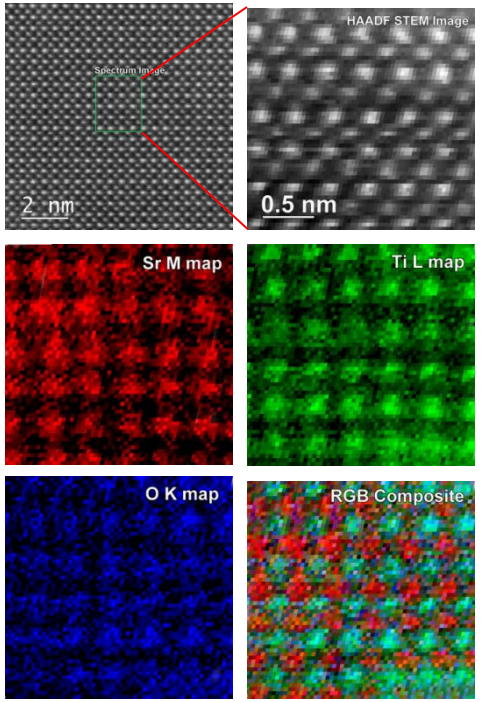
JEM ARM 200F microscope

- Field Emission Gun (FEG)
- Cs-corrector for STEM mode
- STEM-HAADF resolution: 0.08 nm
- EDS Unit: JEOL JED-2300T
- Gatan Quantum SE Image Filter



Atomic resolution HAADF-STEM image of Si along [110]

Intensity line profile revealing 1.3 A separation of the Si(110) dumbbell



Atomic resolution elemental map of $SrTiO_3$ by EELS spectrum imaging

Atomic resolution HAADF-STEM image of $SrTiO_3$
HAADF-STEM image of selected area for EELS-SI
Atomic resolution elemental map of Sr
Atomic resolution elemental map of Ti
Atomic resolution elemental map of O
RGB composite image

“De la excelenta la competitivitate: tehnologiile generice esentiale”, 2014

Publications NANO

1990-2014, Bucharest, Romania

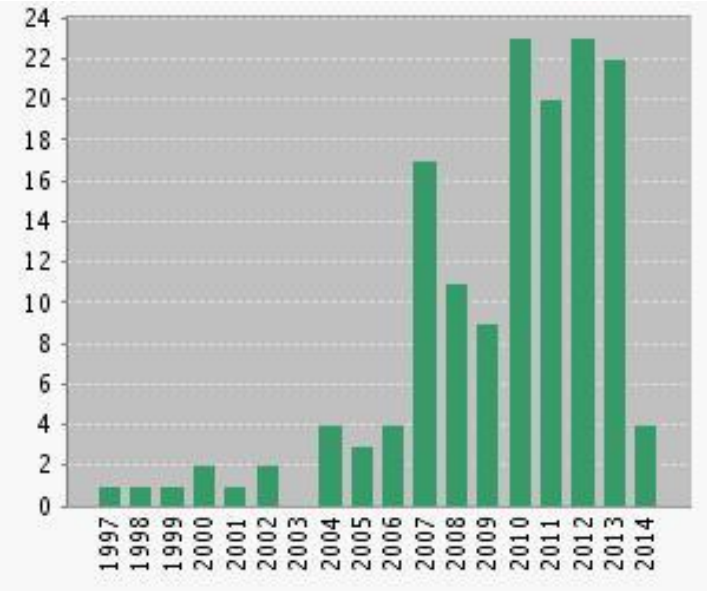
Field: Institutions	Record Count	% of 42895	Bar Chart	Data rows displayed in table All data rows
POLYTECHN UNIV BUCHAREST	362	33.3 %		
UNIVERSITY BUCHAREST	220	20.3 %		
NAT INST MAT PHYS	148	13.6 %		
IMT BUCHAREST	109	10.0 %		
NAT INST LASER PLASMA RAD PHYS	102	9.4 %		
ROMANIAN ACAD SCIENCES	70	6.4 %		
H H NAT INST PHYS NUCL ENG	26	2.4 %		

WITH ONLY~150 RESEARCHERS

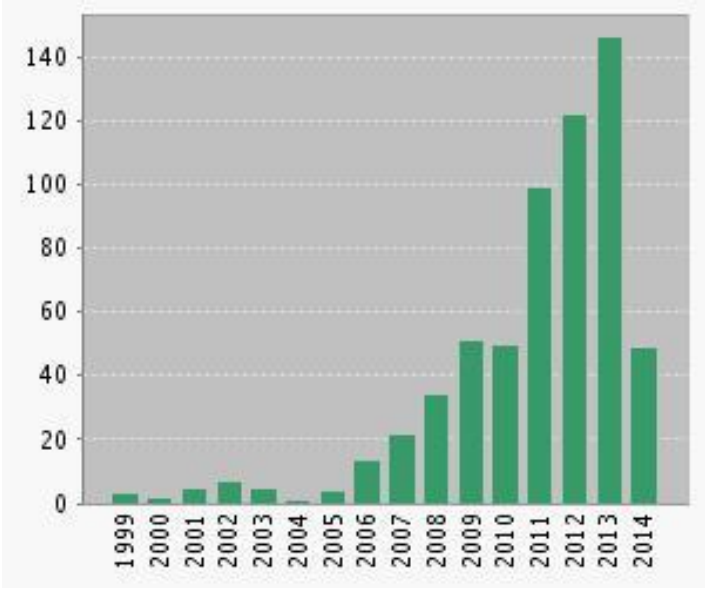
	Field: Institutions	Record Count	% of 42895	Bar Chart	Data rows displayed in table All data rows

(6015 Institutions value(s) outside display options.)
(32 records(0.075%) do not contain data in the field being analyzed.)

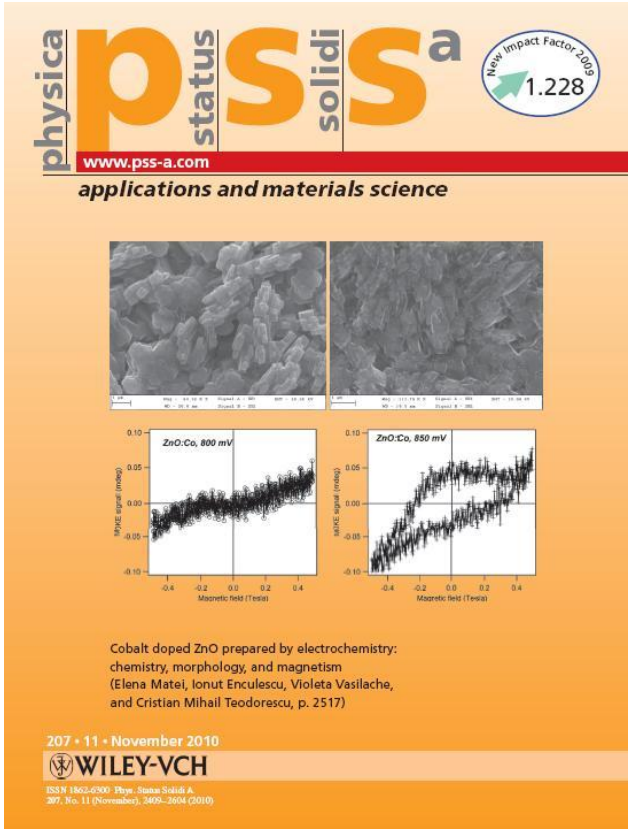
Articles NANO NIMP

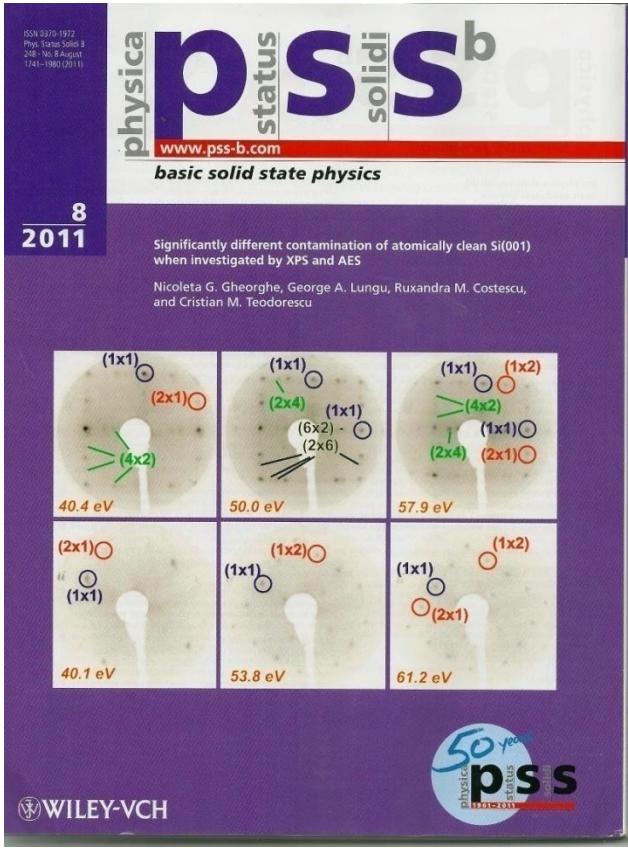


Citations NANO NIMP



Front covers in international journals





The average number of articles published per year:
160 in the last five years

Total impact factor: **240** (2010); **350** (2011);**370** (2012); **390** (2013)

International collaborations

-**International projects** (FP, Euratom, COST, SCOPES, EUROCORE, NATO, etc.)

-**Large research infrastructures**: partners in two RD projects launched by CERN:

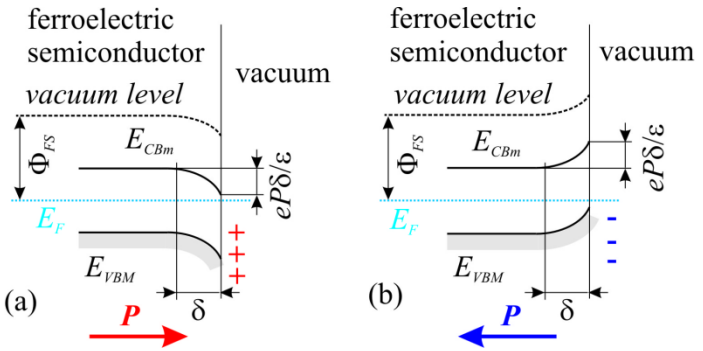
- **RD48-Research and development on silicon for future experiments**
- **RD50-Radiation hard semiconductor devices for very high luminosity colliders**

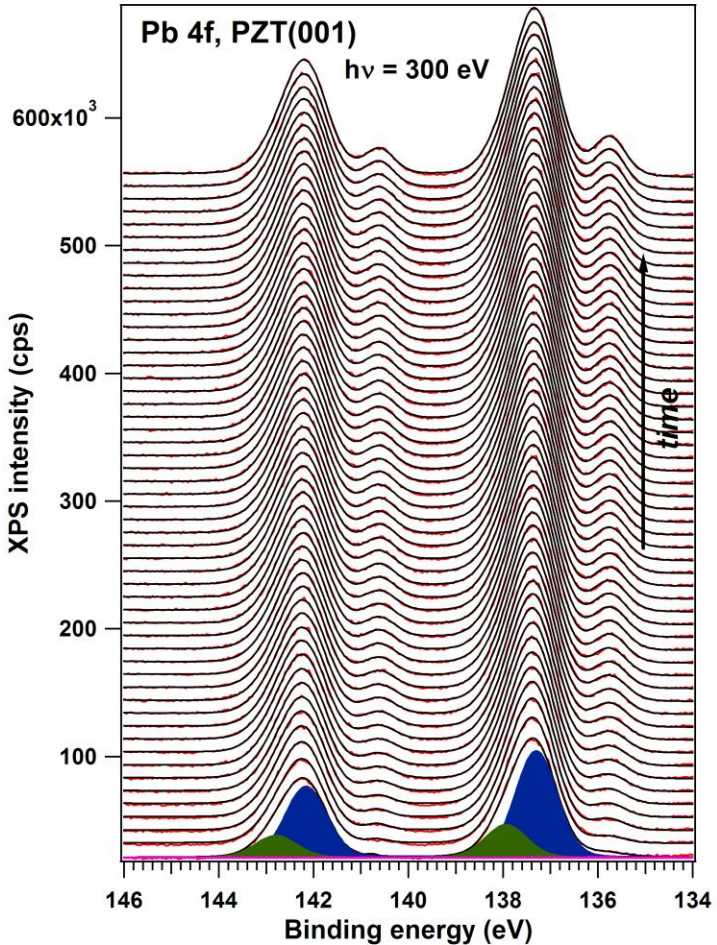
Bilateral cooperation with over 60 research institutions and universities from all over the world:

Germany, France, UK, the Netherlands, Italy, Norway, Spain, Hungary, Belgium, Poland, Portugal, Greece, Moldavia, Ukraine, Russia, China, Japan, Australia, USA, Brazil, Canada, etc.

About **50 %** of the published articles are results of international collaborations.

Implantation at Elettra on the SuperESCA beamline (Long term project 20130333)





in situ photoinduced polarization switching: studied for PZT(001), PZT(111), $BaTiO_3$(001), BaTiO3(111).

Patents and relation with industry

An average of 8 patents and patent requests per year in the last 5 years

Service contracts with some companies:

Turbomecanica Bucuresti

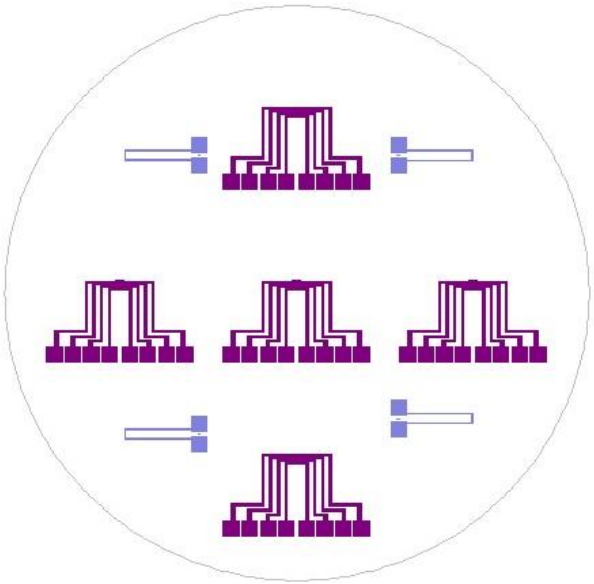
Honeywell Romania

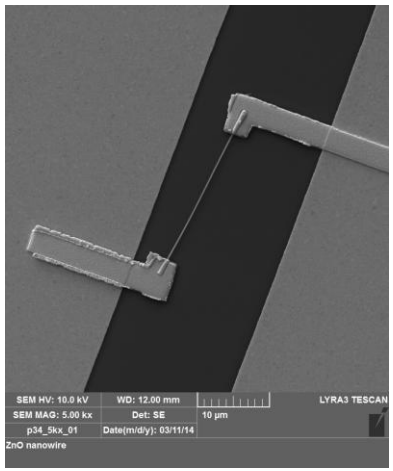
Zentiva Romania

Oerlikon Solar, Switzerland

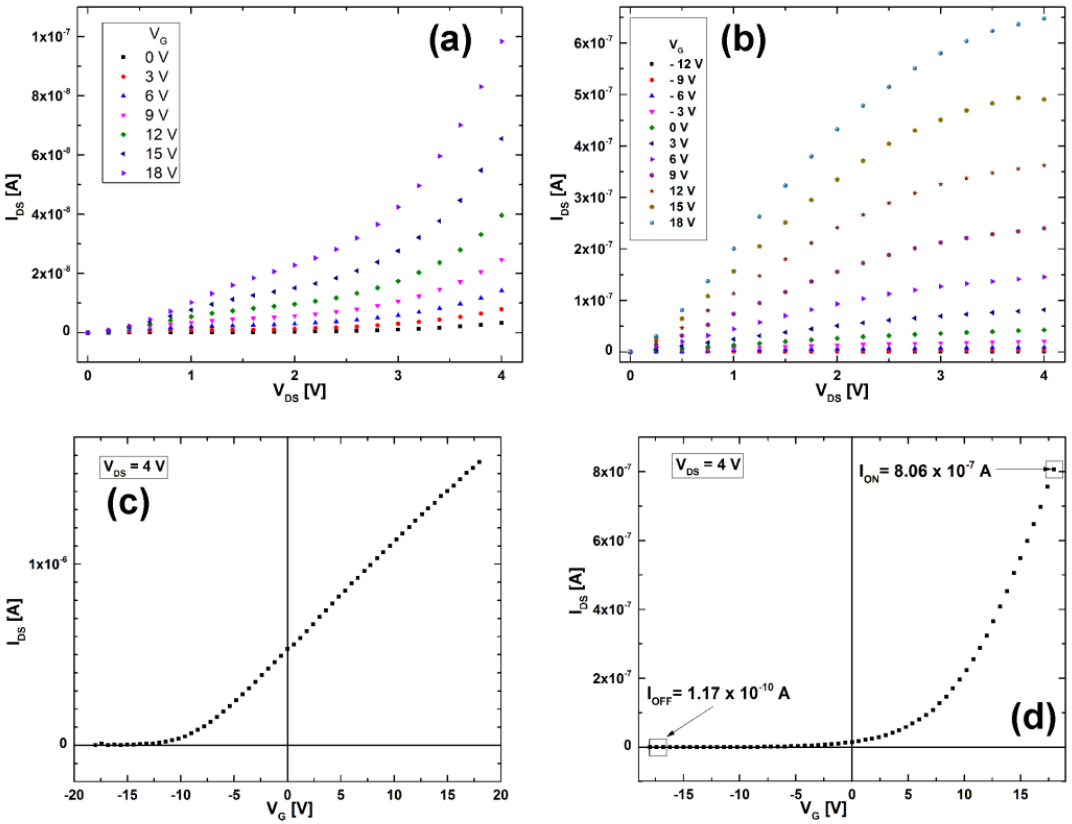
Other SME from Romania for small service contracts

Nanostructures based multifunctional devices chemical or electrochemical fabrication combined with lithography and clean room techniques





Nanowire based field effect transistors



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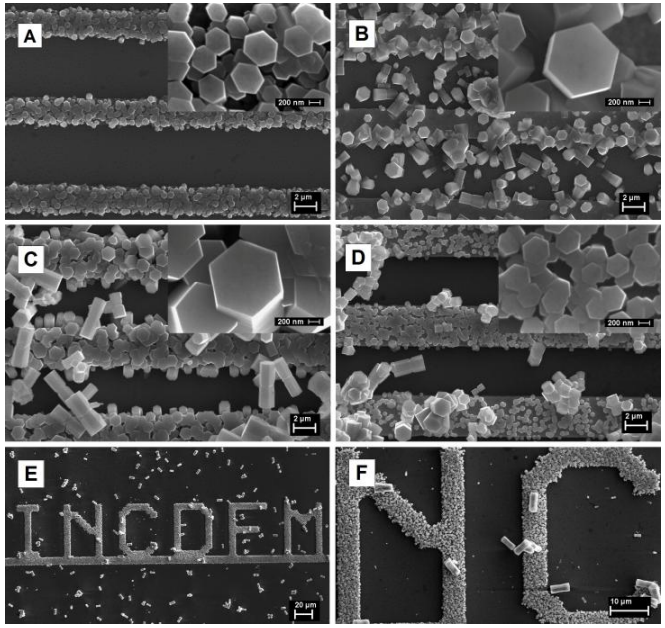

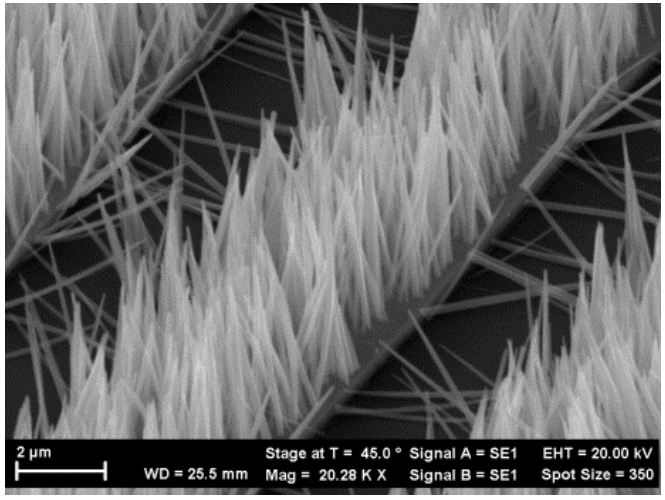

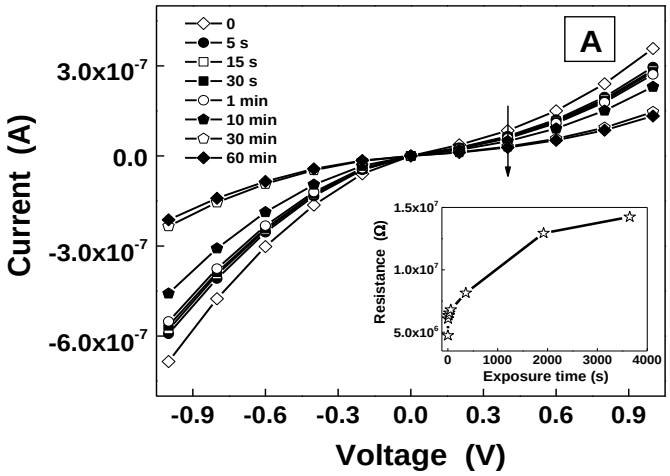

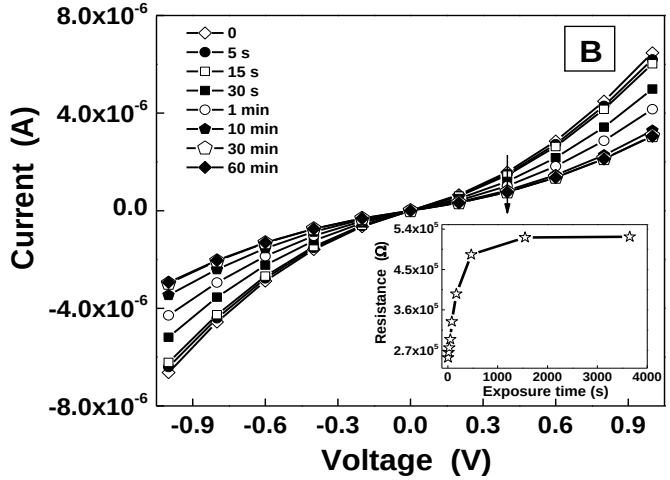

Nanowire and nanorod based biodetectors

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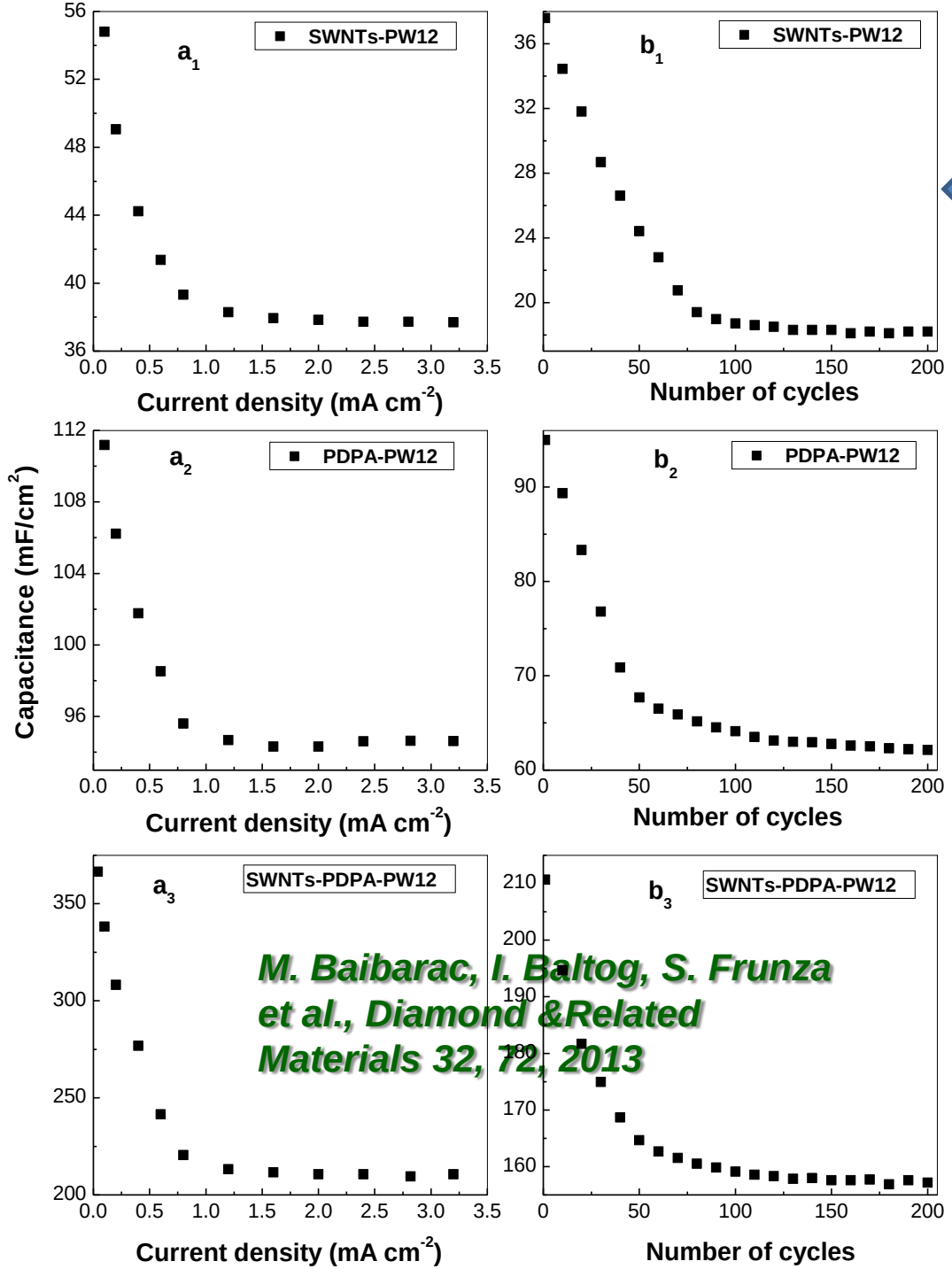

SWNTs functionalized with polydiphenylamine doped with heteropolyanion as active material in super-capacitors

During the charge-discharge tests, the following equations can be taking into account:

Discharge (eq.1)

$SWNT\text{-}PDPA^{3n+}[PW_{12}O_{40}^{3-}]_n + 3ne^- \rightarrow SWNT\text{-}PDPA + n\,[PW_{12}O_{40}^{3-}]$

Charge (eq.2)

$SWNT\text{-}PDPA + n\,[PW_{12}O_{40}^{3-}] \rightarrow SWNT\text{-}PDPA^{3n+}[PW_{12}O_{40}^{3-}]_n + 3ne^-$

Charge (eq.3)

$SWNT\text{-}PDPA + 3n[HSO_4^-] \rightarrow SWNT\text{-}PDPA^{3n+}[3(HSO_4^-)]_n + 3ne^-$

Discharge (eq.4)

$SWNT\text{-}PDPA^{3n+}[3(HSO_4^-)]_n + 3ne^- \rightarrow SWNT\text{-}PDPA + 3n[HSO_4]$

M. Baibarac, I. Baltog, S. Frunza et al., Diamond &Related Materials 32, 72, 2013

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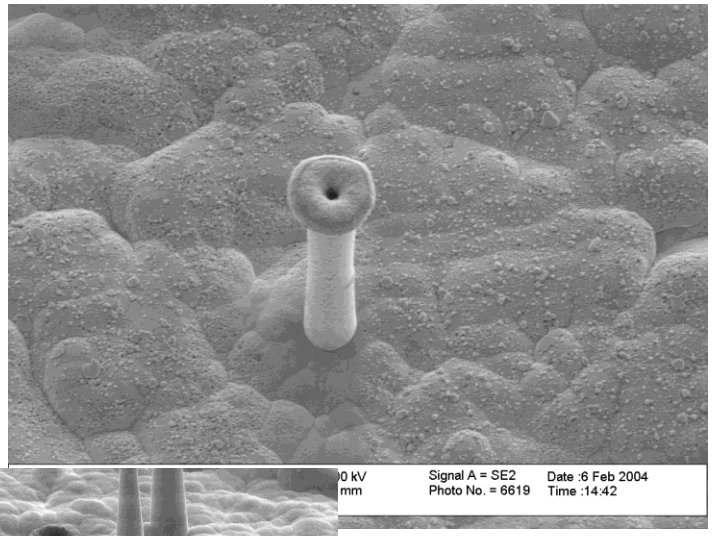
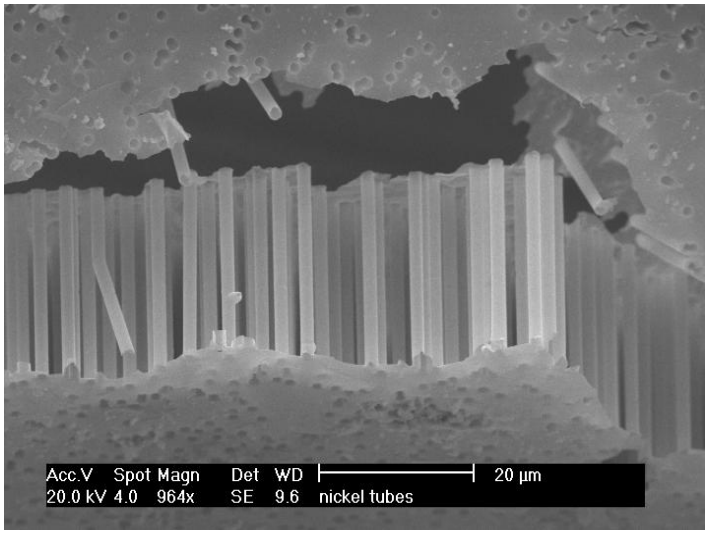
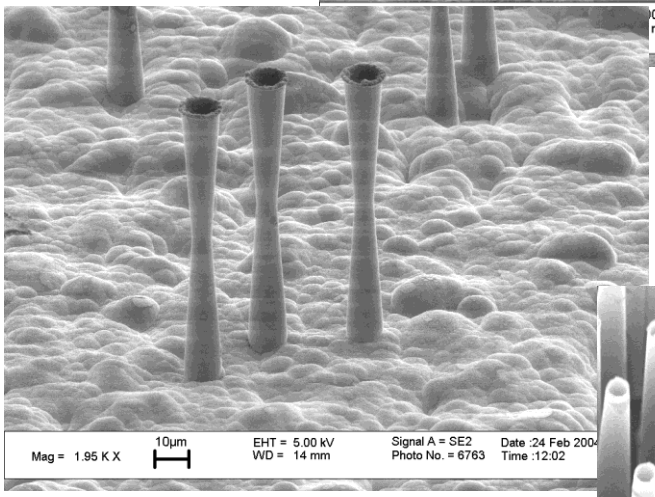
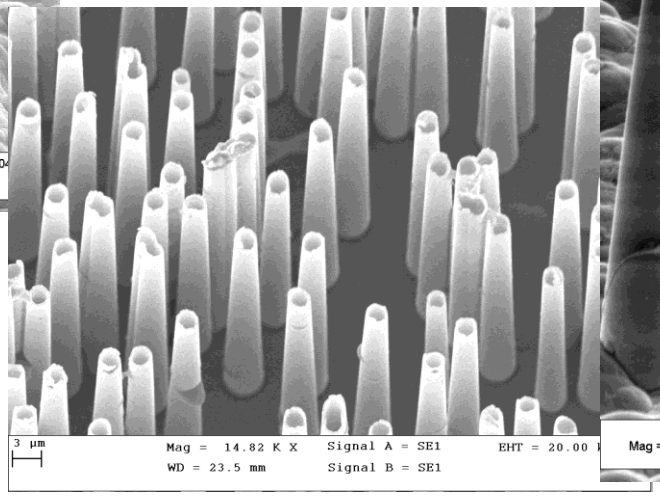
Metallic micro and nanotubes

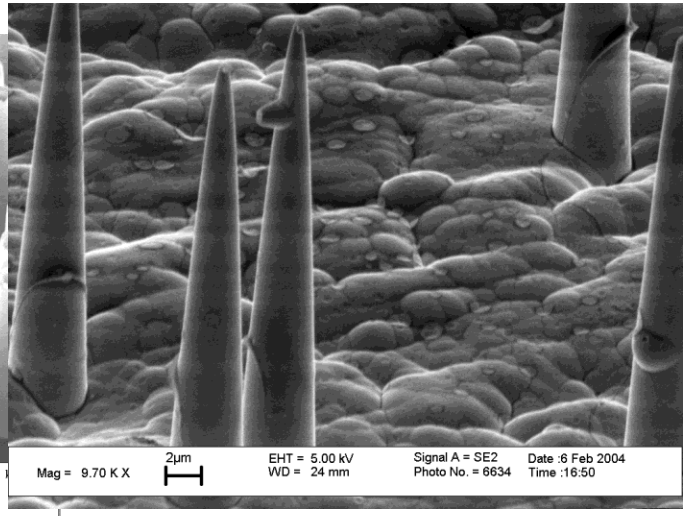






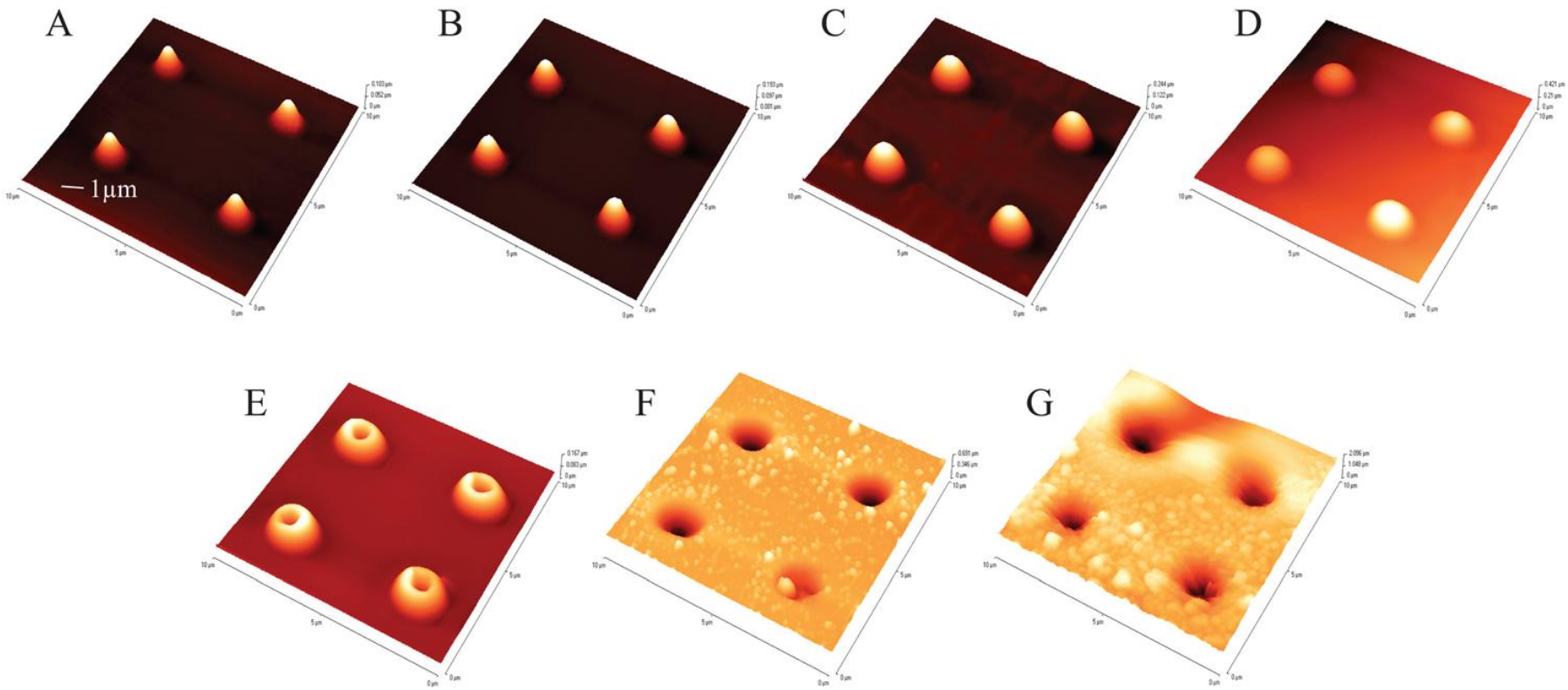
Auto-catalytic deposition using the template method





Copper tubes prepared by electroless deposition in ion track templates

Nano-lenslet formation in amorphous As2S3 thin films for applications in planar optoelectronic circuits



It has many uses but is commonly found in Shack-Hartmann wavefront sensors and beam homogenization optics for projection systems.

A. Velea, M. Popescu*, F. Sava, A. Lőrinczi, I. D. Simandan, G. Socol, I. N. Mihailescu, N. Stefan, F. Jipa, M. Zamfirescu, A. Kiss, and V. Braic

JOURNAL OF APPLIED PHYSICS 112, 033105 (2012)

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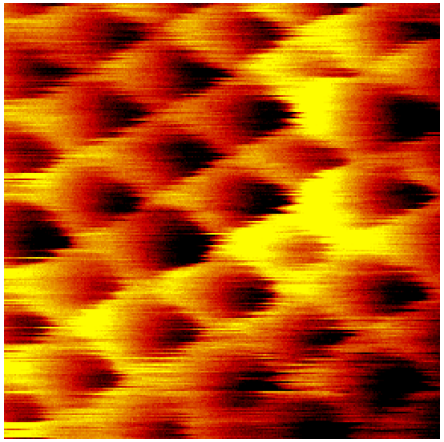
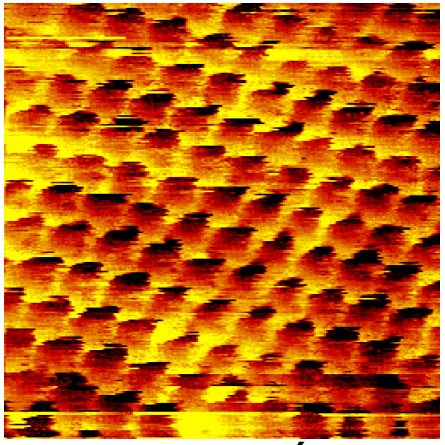
Graphene/Ir(111), STM with atomic resolution

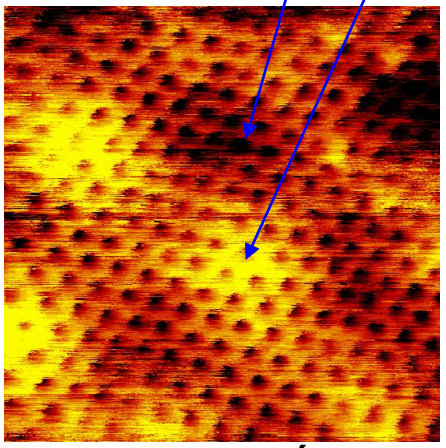
Moiré patterns



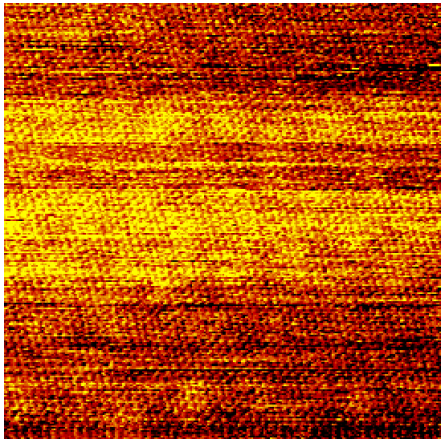
10 x 10 Å^2



20 x 20 Å^2



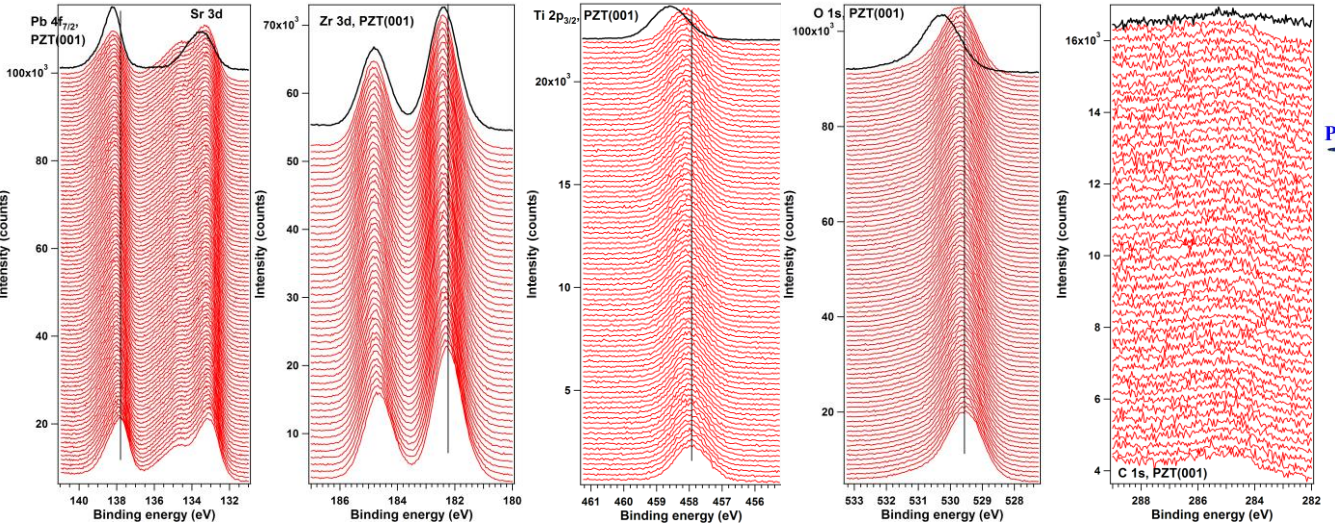
30 x 30 Å^2

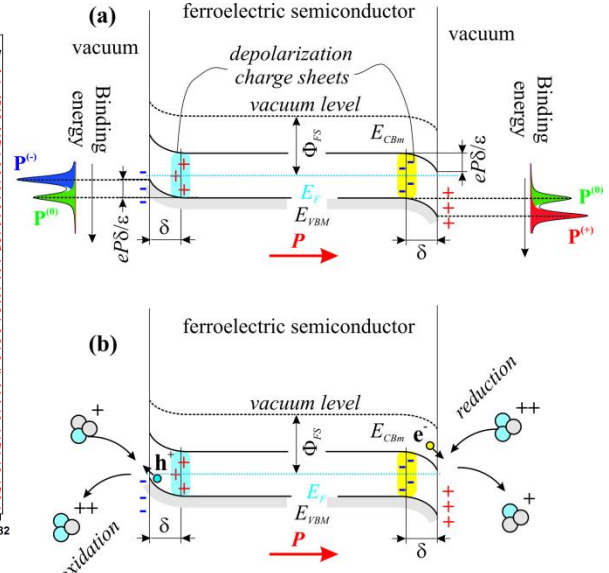


10 x 10 nm^2

CO adsorption on PZT(001) and PZT(111)
interplay between polarization and [CO]

Ferroelectric surfaces:
potential catalysts for automotive industry





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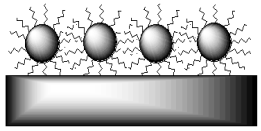
SELF - ASSEMBLED CORE_SHELL COLLOIDAL MAGNETIC NANOPARTICLES

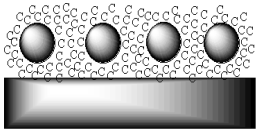
❖ **Principle of the self-assembly**

As-synthesized particles are coated by Oleic acid and oleyl amine



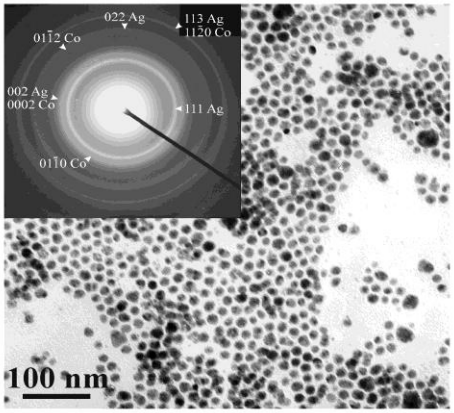
Annealing

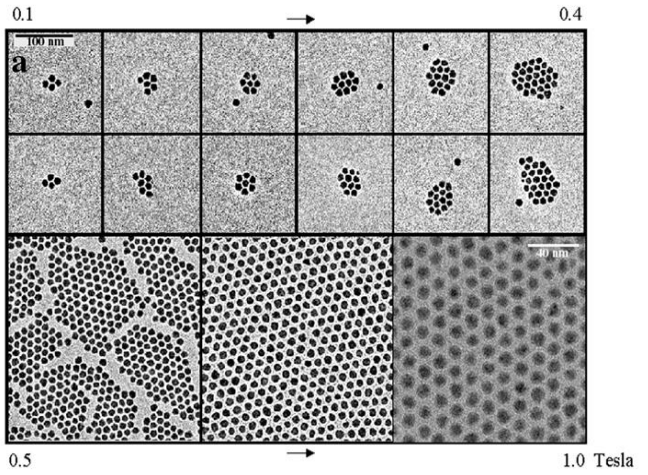
After thermal annealing, the organic groups decompose to carbonaceous coating. The exact nature of this coating has yet to be studied.



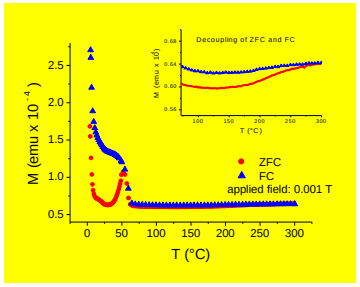
Core-shell Ag-Co nanoparticles

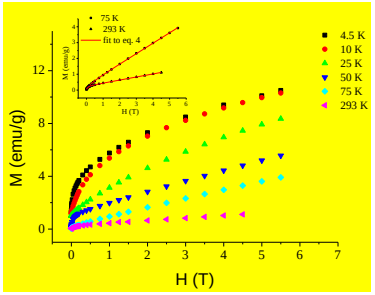
$$Co_2(CO)_8 + 2AgClO_4 \rightarrow 2Ag + Co + 8CO + Co(ClO_4)_2$$



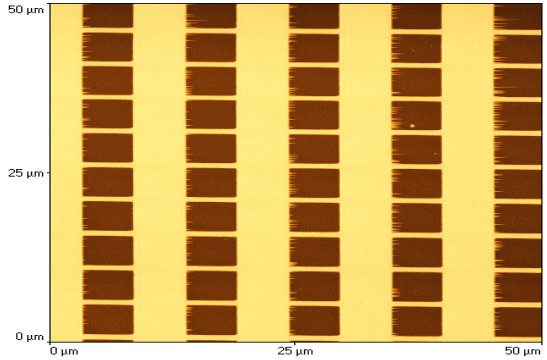


❖ **Breakthrough in data storage, biomedicine, catalysis and nanoelectronics**





$$M_{tot} = M_{sat}^{SPM} \cdot L\left(\frac{\mu_{SPM} H}{k_B T}\right) + M_{sat}^{FM} \cdot \left(\frac{\mu_{FM} H}{3 k_B T}\right)$$



APPLICATIONS

❖ **Magnetic-conducting bimetallic nanosystems that exhibit GMR effect**

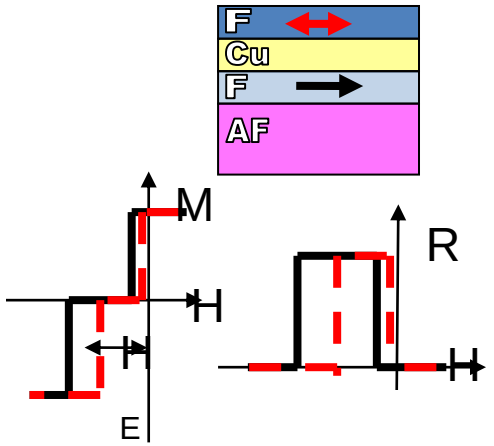
❖ **Use of patterned substrates with logic capabilities**

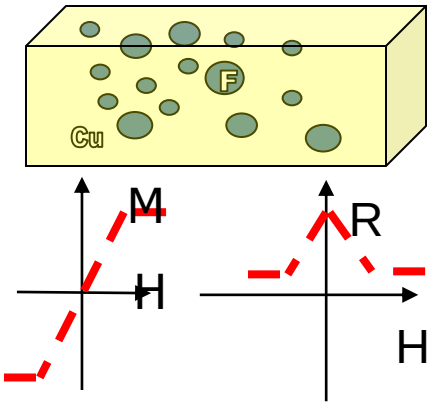
❖ **2D regular arrays of GMR nanosensors on a single chip may be achieved!**

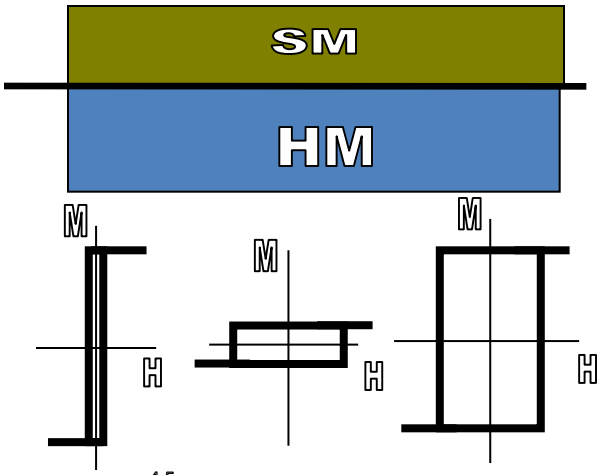
Magnetoresitive elements (spin valves). Exchange bias phenomena.

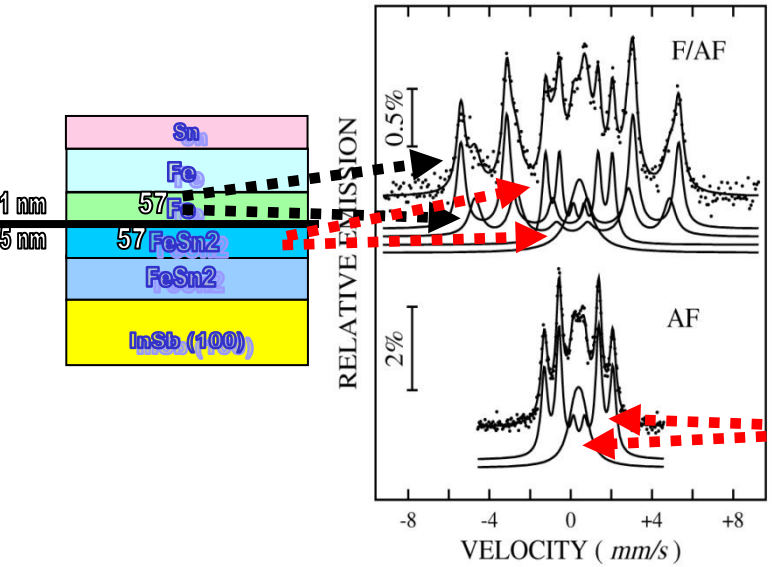
Exchange spring phenomena and interlayer magnetic coupling

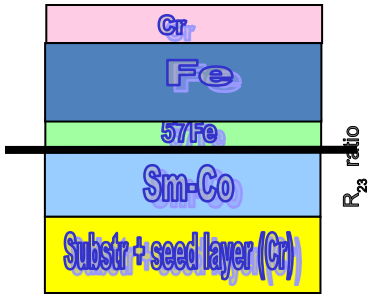
Specific problems: extending the study of interfacial phenomena by neutron reflectometry in Fe free structures.

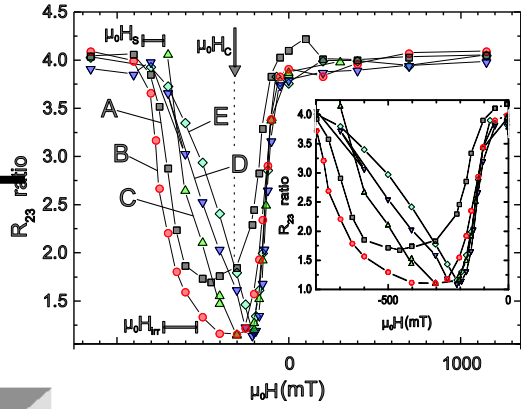


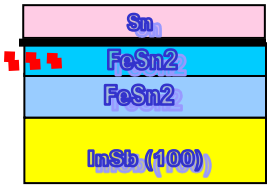


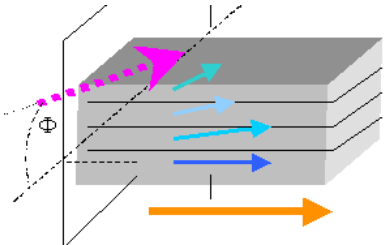












"De la excelenta la competitivitate: tehnologiile generice esentiale", 2014

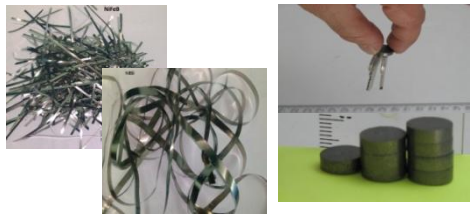
Materiale magnetice avansate si nanostructuri:

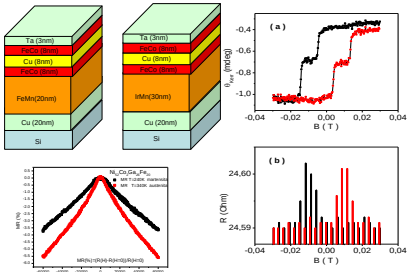
•Nanostructuri si materiale soft si hard-magnetice, materiale cu memoria formei si nanostructuri cu anizotropie de forma

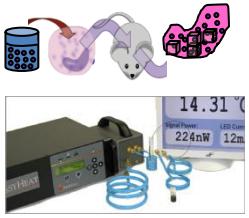
•Nanostructuri magneto-functionale (structuri magneto-conductive tip valve de spin multistrat si filme nanoglobulare, structuri magneto-strictive, magneto-electrice, magneto-optice si magneto-calorice

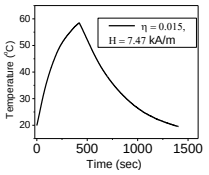
•Nanoparticule dispersate in diverse medii (metalice, semiconductoare, polimerice, nanoparticule functionalizate pentru aplicatii bio-medicale

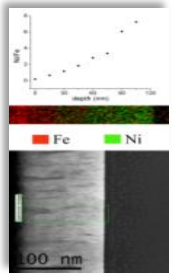
•Materiale cu gradienti compozitionali (bulk si filme-subtiri) pentru aplicatii speciale (e.g. program Euroatom)





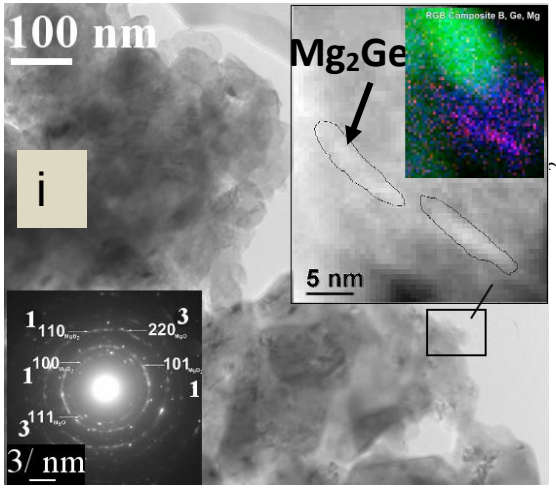


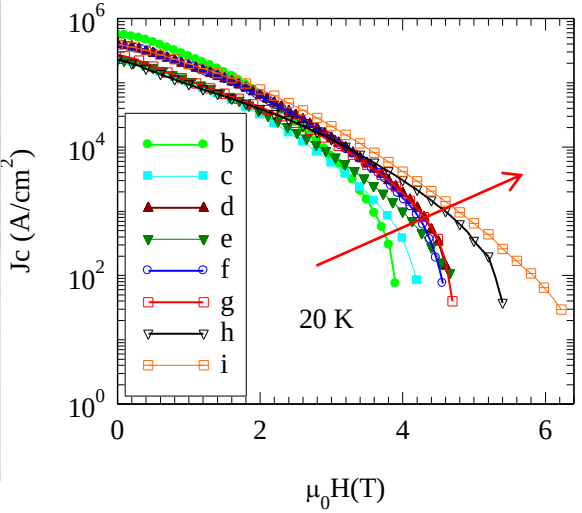


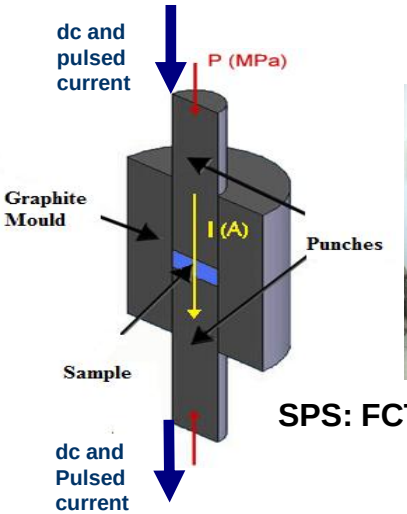


Materiale supraconductoare nanostructurate:

Materiale supraconductoare cu densitati de curent critic (*Jc*) ridicat: MgB_2 nanostructurat cu aditivi, obtinut prin Spark Plasma Sintering (SPS) si filme subtiri tip $YBa_2Cu_3O_7$ (Y123) cu nanoroduri de $BaZrO_3$ (BZO) obtinute prin PLD

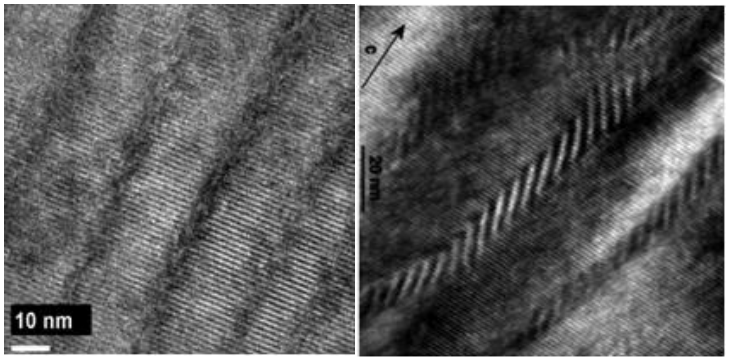






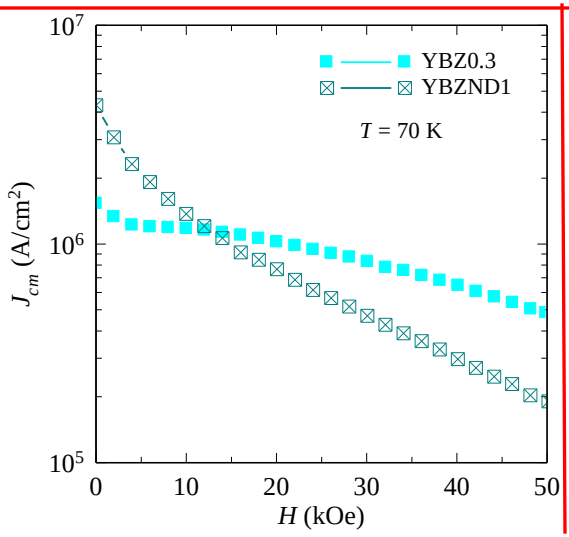
SPS: FCT-5, Germany

b-MgB_2 pur sau aditivat cu c-Sb2O3, d-Bi2O3, e-TeO2, f-Te, g-SiC, h-(SiC+Te), i-Ge2C6H10O7



Y123-BZO, small nanorod splay (YBZ0.3)

YBZND1 cu decorare de nanodots de Ag pe SrTiO3



J. Mater. Sci. 47 (2012) 3828
J Supercond. Nov. Mag. 26 (2013) 1553
Jpn. J. Appl. Phys. 51 (2012) 11PG13
J. Appl. Phys. 110 (2011) 123921
Physica C 477 (2012) 477
Supercond Sci Technol. 23 (2010) 095002
Scripta Mater. 66 (2012) 570
Scripta Mater. 68 (2013) 428
Jpn . J. Appl. Phys. 53 (2014) 05FB22
Mater. Phys. Chem. 146 (2014) 313
Scripta Mater. 82 (2014) 61
Phys Rev. B 85 (2012) 104519
Supercond. Sci .Technol. 26, (2013) 045008

Projects: 7/2012, 138/2012

Noi dezvoltari tehnologice: detectori miniaturizati pentru masuratori CEMS specifice:

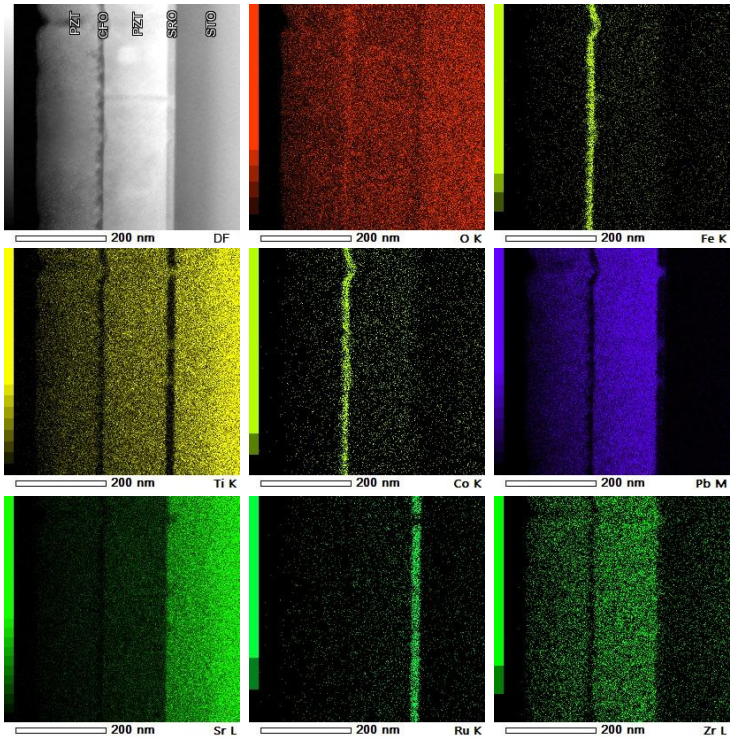
CEMS (Conversion Electron Mossbauer Spectroscopy) este o metoda puternica de obtinere a informatiei in paturi succesive de suprafata, pana la o adancime de 200 nm, care in cazul folosirii tehnicii de imbogatire a paturii de interes in izotopul de ^{57}Fe poate atinge o rezolutie de sub 1 nm. Au fost efectuate dezvoltari tehnologice n scopul obtinerii configuratiei de spin la suprafata /interfata in prezenta diversilor factori perturbatori, permitand:

•Obtinerea configuratiei de spin in camp magnetic aplicat

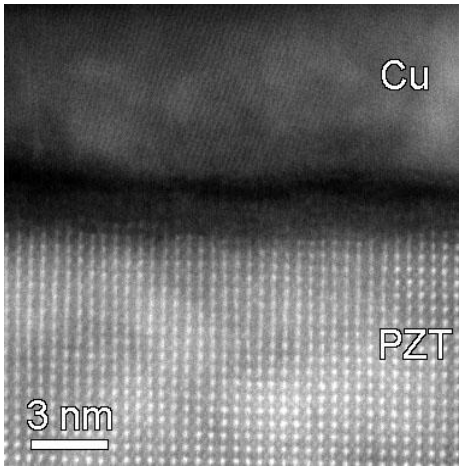
•Obtinerea configuratiei de spin in camp electric aplicat

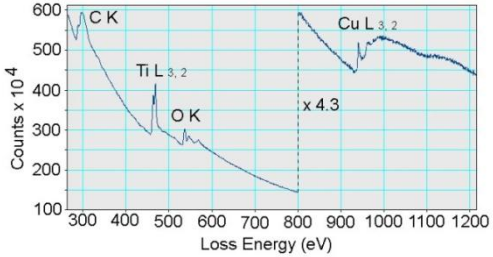
High Resolution Analytical Transmission Electron Microscopy

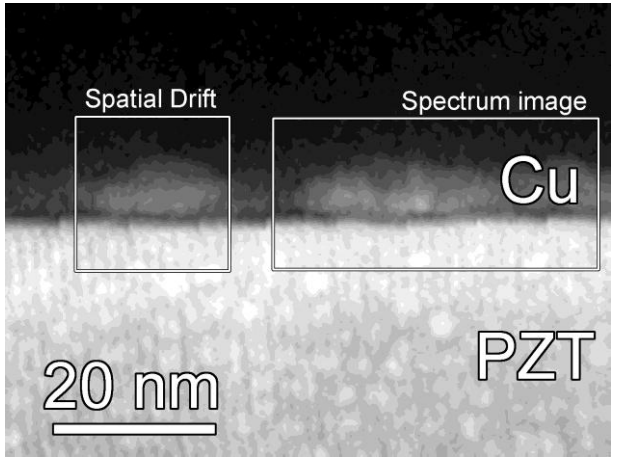
Characterization of interfaces in advanced materials

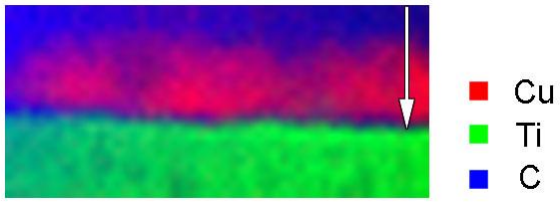


STEM-EDS elemental mapping
of PZT/$CoFe_2O_4$/PZT/$SrRuO_3$ multilayered coating on $SrTiO_3$ substrate:
Low-magnification ADF-STEM image;
Elemental maps of O, Fe, Ti, Co, Pb, Sr, Ru and Zr.

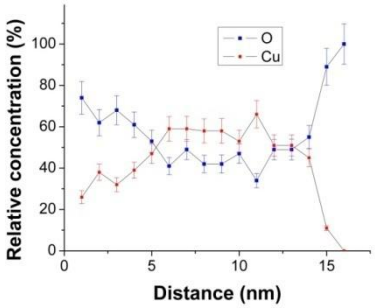








Characterization of the interface between PZT and Cu outer electrode
HAADF-STEM image of the Cu-PZT interface
EELS spectrum imaging of the Cu-PZT interface
Cu and Ti elemental maps extracted from the EELS-SI
Relative concentration of Cu and O measured close to the Cu-PZT interface.
ACS Appl. Mater. Interfaces **6**, 2929-2939 (2014)



"De la excelenta la competitivitate: tehnologiile generice esentiale", 2014

HOTMAT @ NIMP:
materiale, compozite si tehnologii de prelucrare avansate bazate pe tehnici de sinterizare asistata

traditie & experienta + infrastructura noua + corelare internationala

Domeniu de aplicare :

- ➔ materiale pentru conditii extreme (radiatie, temperatura, coroziune)
- ➔ materiale pentru aplicatii legate de energie (e.g. termoelectrice)
- ➔ materiale pentru dispozitive electronice si senzori

Modalitate:

echipamente de sinterizare asistata: camp electric, presiune uniaxiala, camp de microunde + aliere mecanica + racire ultrarapida + analize "state of the art"

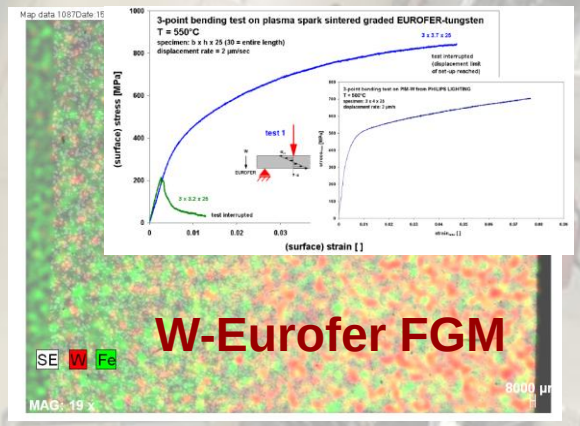
Utilizare :

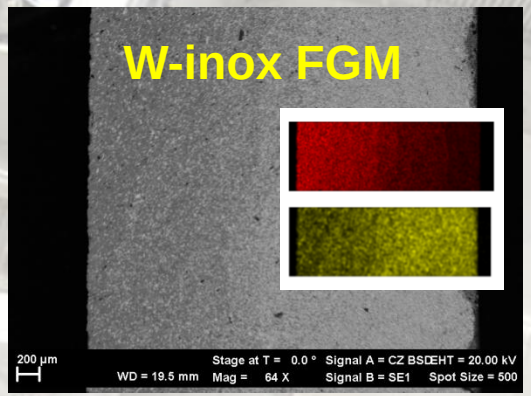
- ➢ rezolvarea unor probleme tipice de sinteza,
- ➢ realizare de materiale nanostructurate bulk,
- ➢ reducere timp procesare/nr. pasi intermediari,
- ➢ combinare si imbinare de materiale greu miscibile si dificil prelucrabile

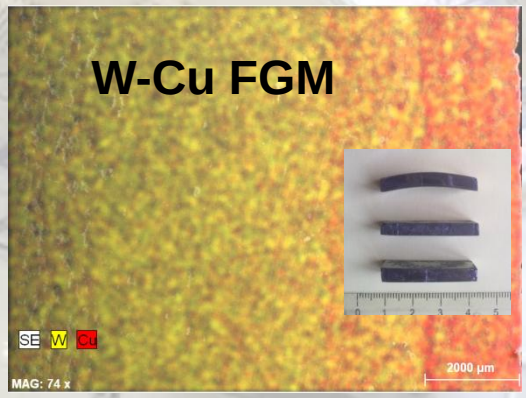
"De la excelenta la competitivitate: tehnologiile generice esentiale", 2014

Exemple :

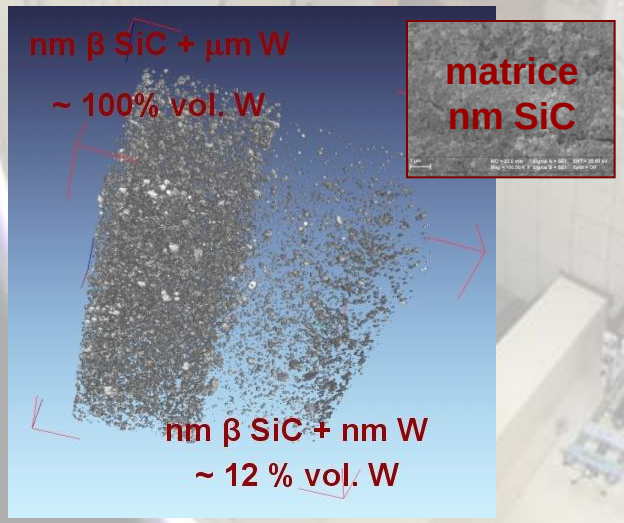
1. Realizare de materiale cu gradient functional micro si nano-structurate

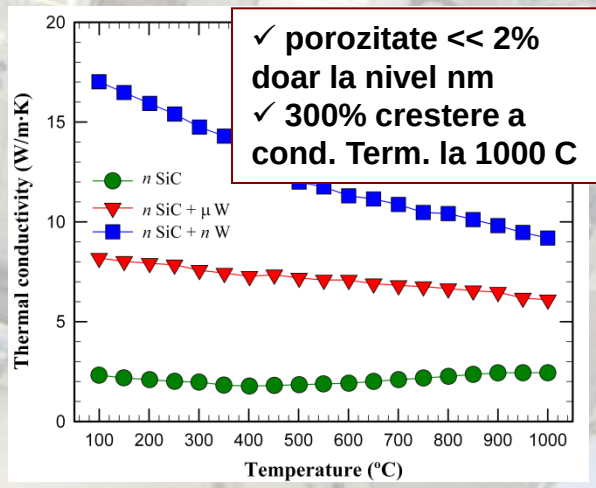




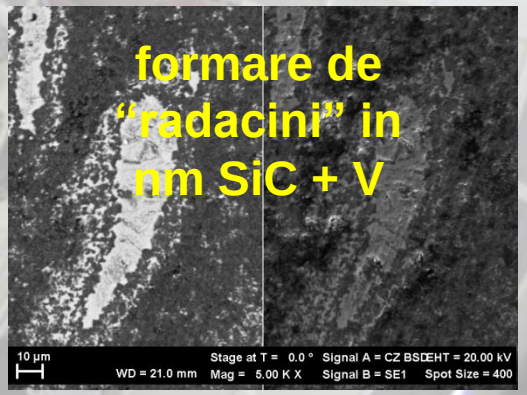


2. Compozite complexe nano-structurate SiC-metal





✓ porozitate << 2% doar la nivel nm
✓ 300% crestere a cond. Term. la 1000 C

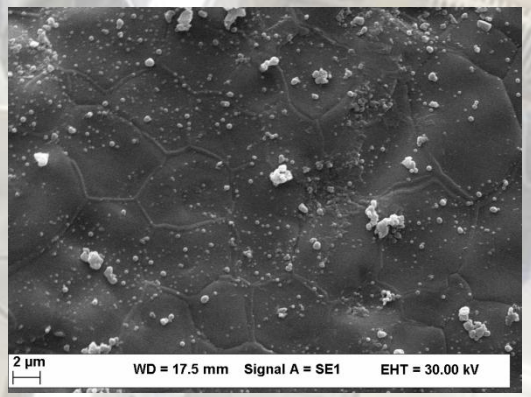


Exemple :

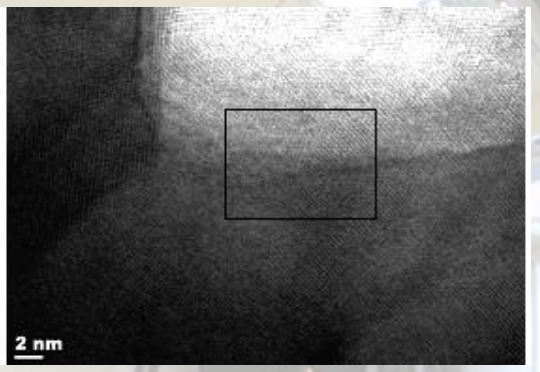
3. Ceramice ultradense

$SrZrO_3$
- electroliti in SOFC
- senzori H_2
- dielectrici (high-k gate)

timp proces: 48 h ➔ 8 h
densitate: 92% ➔ ~100%

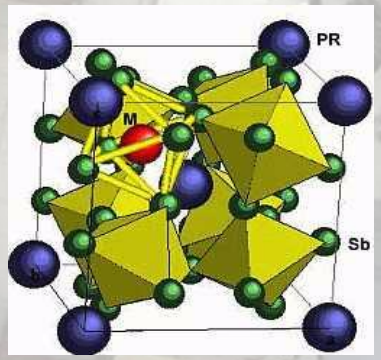


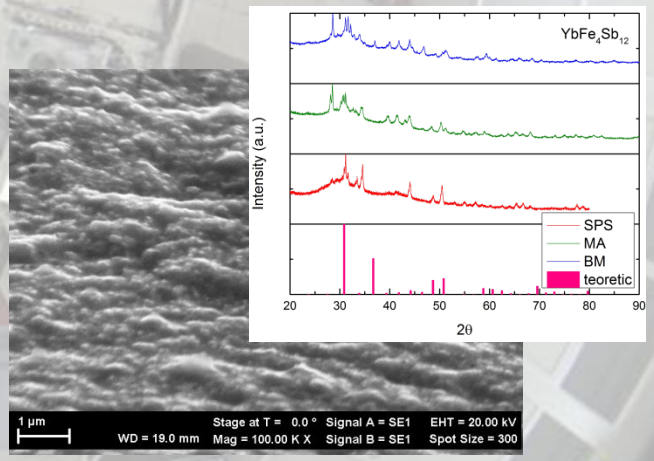
nm $Ln_{0.2}Ce_{0.8}O_{2-x}$ (Gd, Sm, Yb)
- SOFC, catalizatori



4. Intermetalici nanostructurati

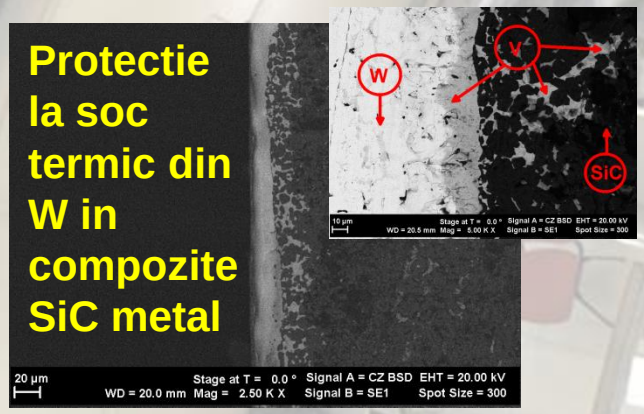
Skutteruditi dopati PR-M_4Sb_{12}
(mat. termoelectrice)
timp proces. 20+ zile ➔ 3 zile
fara trat.term. ➔ nm
reducere cond. termica
cond. electrica = cu a comp. topiti
➔ crestere Z





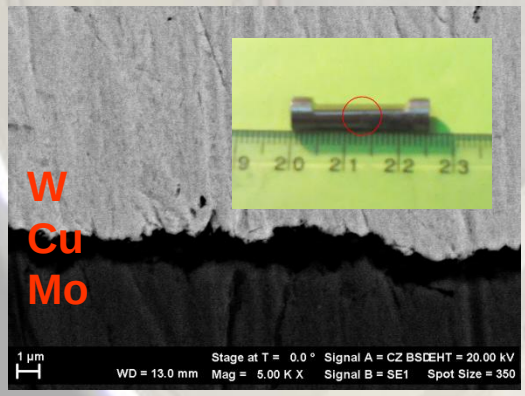
Exemple :

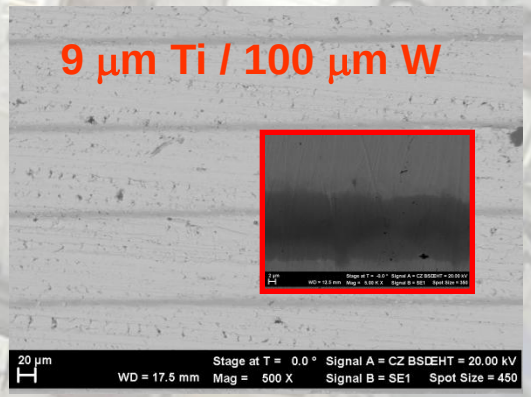
5. Compozite ceramica - metal si ceramica - ceramica

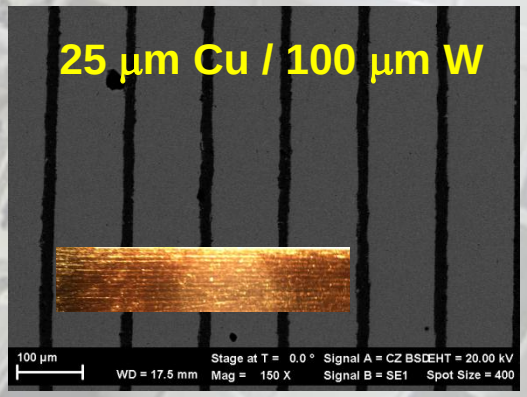


6. Imbinare metale refractare si compozite multistrat

Brazare de metale refractare

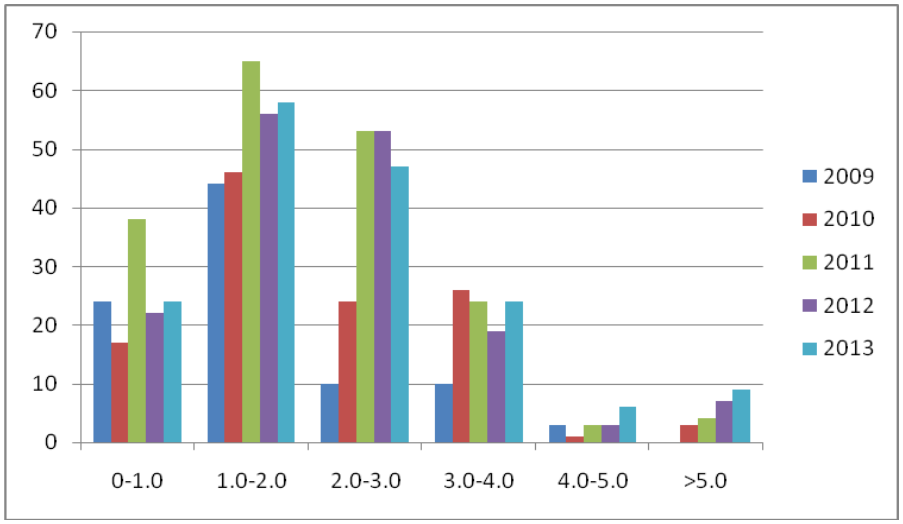






W ca material structural prin compozite lamelare

SUMMARY



Impact factor distribution for papers published by NIMP researchers between 2009 -2013

An increased number of articles published in journals with high impact factor

An increased attractiveness for young researchers (around 30 new employees in the last 4 years, including from Diaspora)

New opportunities for international collaborations (NIMP had become partner in new FP7, Euratom, EUROCORE, COST, SCOPES, etc. projects); researchers from abroad start to come and work at NIMP (e.g. stages of PhD students from Latvia, France, Turkey, post-docs from UK, India, China)

NIMP had become an important player not only at national level, but also at European level