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ACHIEVEMENTS AND PERSPECTIVES IN NANO MATERIALS AND NANOTECHNOLOGIES

IN

THE NATIONAL INSTITUTE FOR LASERS, PLASMA AND RADIATION PHYSICS

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HUMANE RESOURCES:

- number of working persons : 113 (~45%)
- number of scientists : 94
- referees in international journals: 8
- EU experts for FP7 NMP projects: 2
- number of young researchers (PhD students or Post Doc) with international grants: 18
- number of scientific papers published in the last five years: over 250

LABORATORIES:

LASER PHOTOCHEMISTRY	Dr. I. Morjan
NANOMETRIC POWDERS, QUANTUM DOTS AND NANOSTRUCTURES THIN FILMS	Dr. C. Grigoriu
NONLINEAR NANOPHOTONICS	Acad. V.I.Vlad
PHOTONIC PROCESSING OF ADVANCED MATERIALS	Dr. M. Dinescu
LASER-SURFACE-PLASMA INTERACTIONS	Dr. I.N. Mihailescu
PLASMA PROCESSES, MATERIALS AND SURFACES	Dr. G. Dinescu
PLASMA SURFACE ENGINEERING	Dr. C. Ruset
ELEMENTARY PROCESSES IN PLASMA AND APPLICATIONS	Dr. C. Lungu
LASER SPECTROSCOPY	Dr. M. L. Pascu
SOLID STATE LASERS	Dr. M. Zamfirescu

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LABORATORY OF LASER PHOTOCHEMISTRY

EXPERTISE:

1. *The synthesis of nanomaterials with controlled composition and structure by laser pyrolysis*
2. *Thin films production by LCVD*
3. *The characterization of nanomaterials produced by laser pyrolysis and LCVD*

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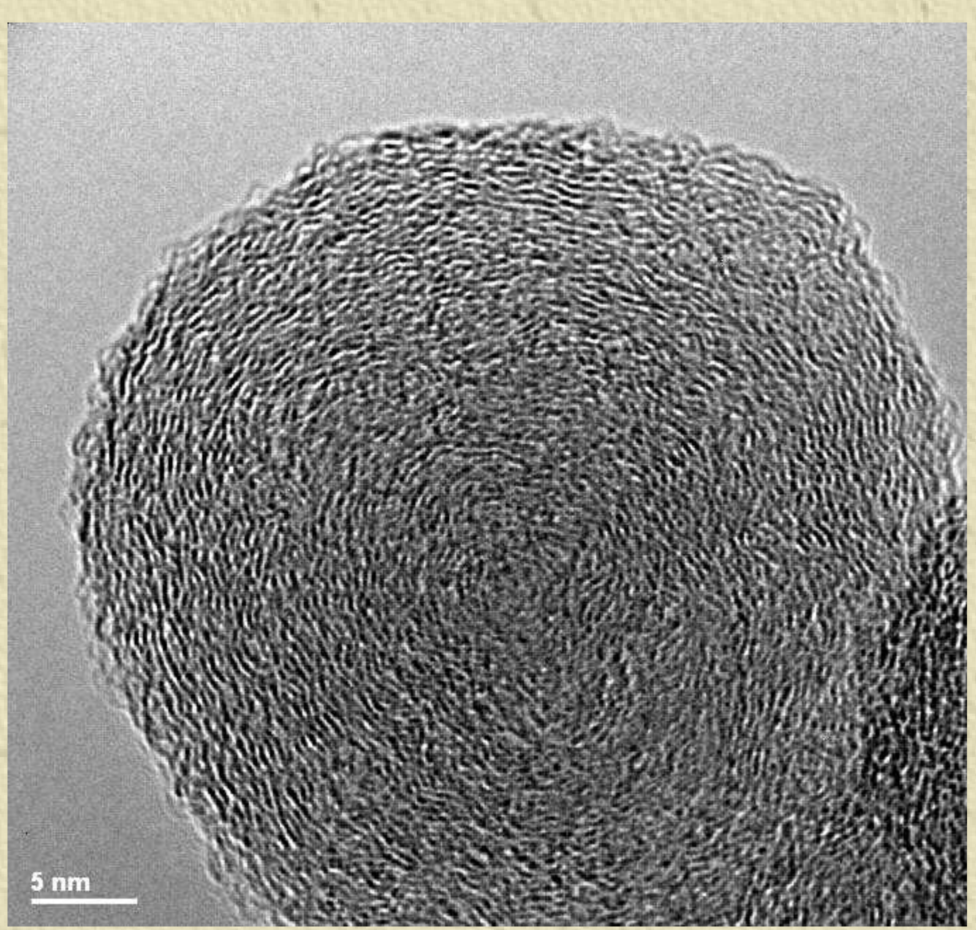
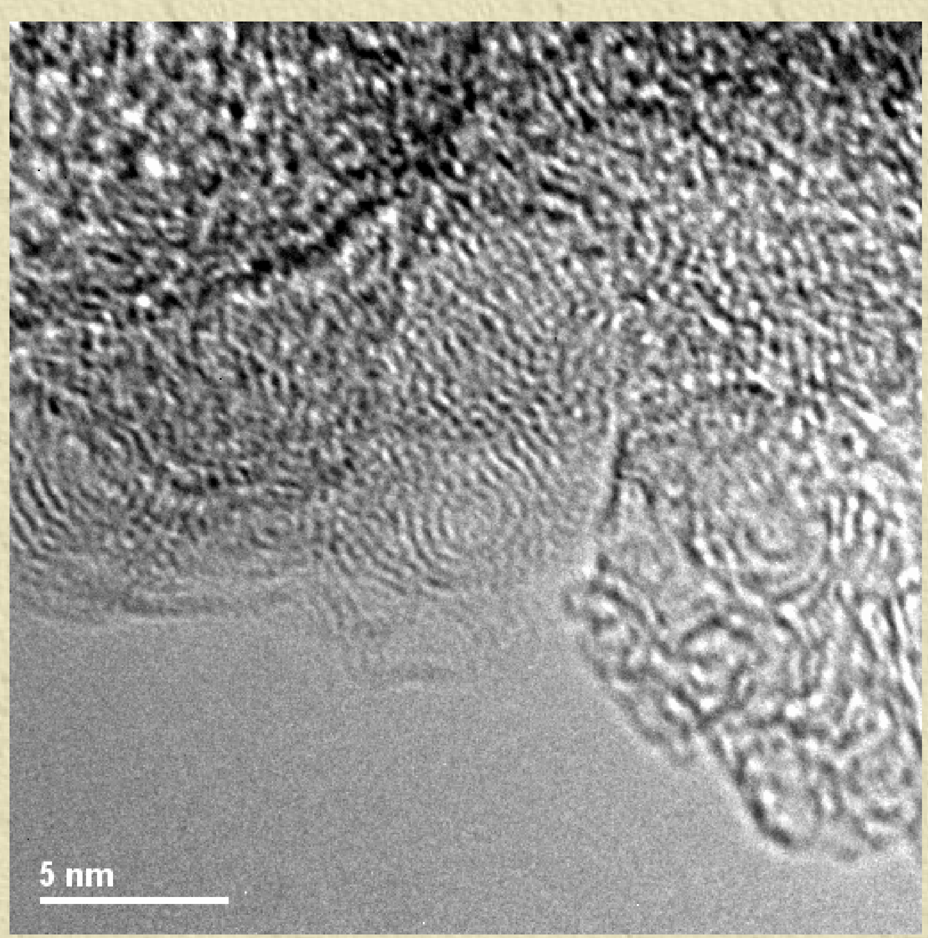
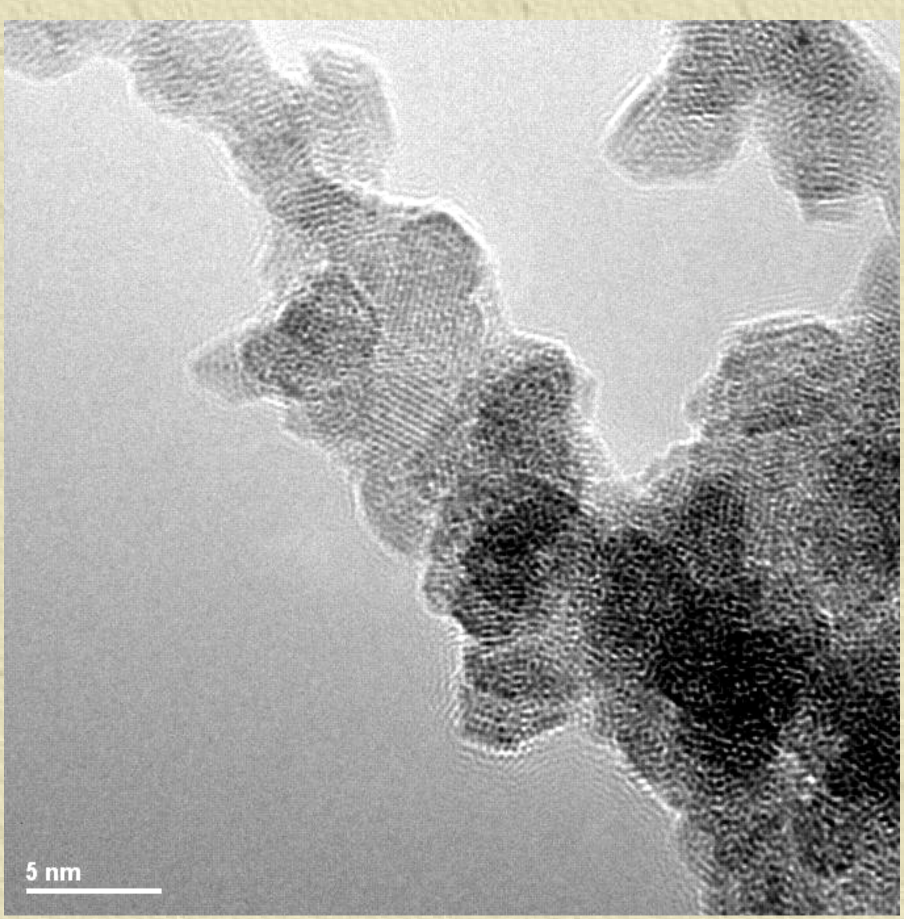
THE SYNTHESIS OF CARBON NANOMATERIALS

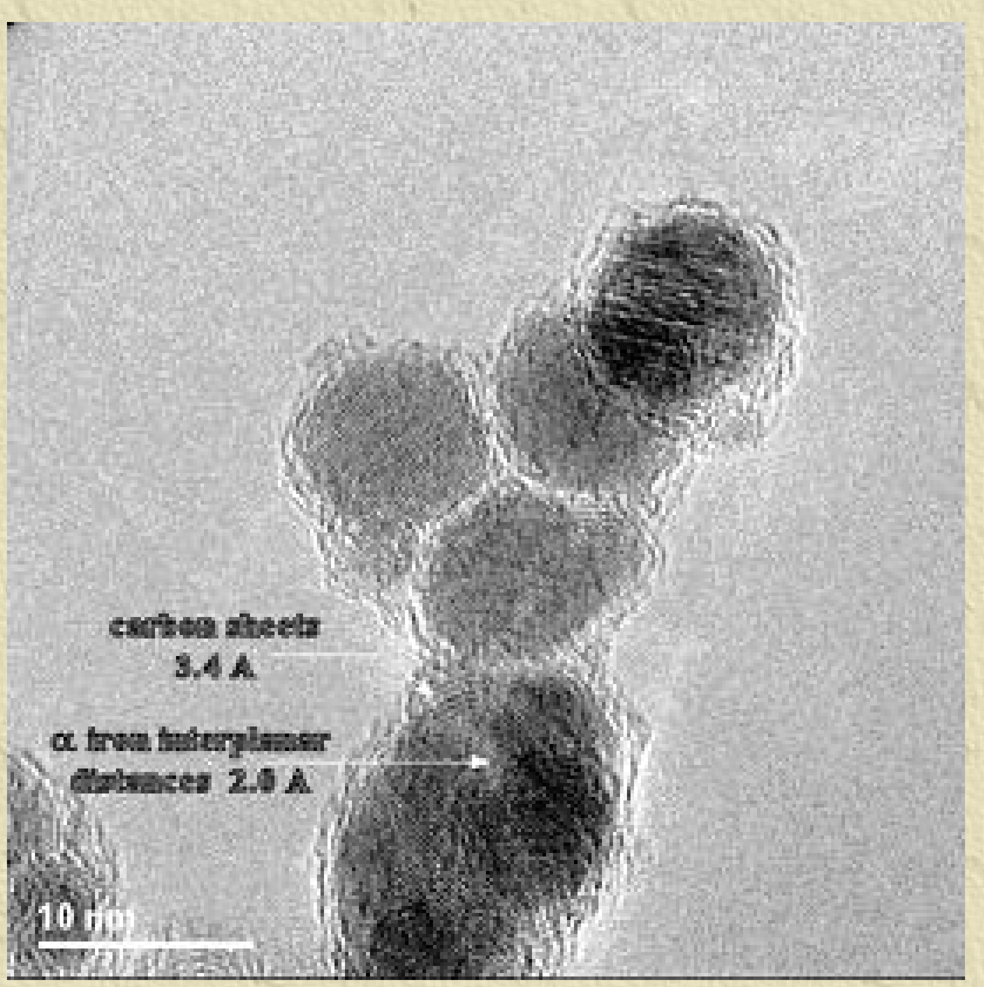




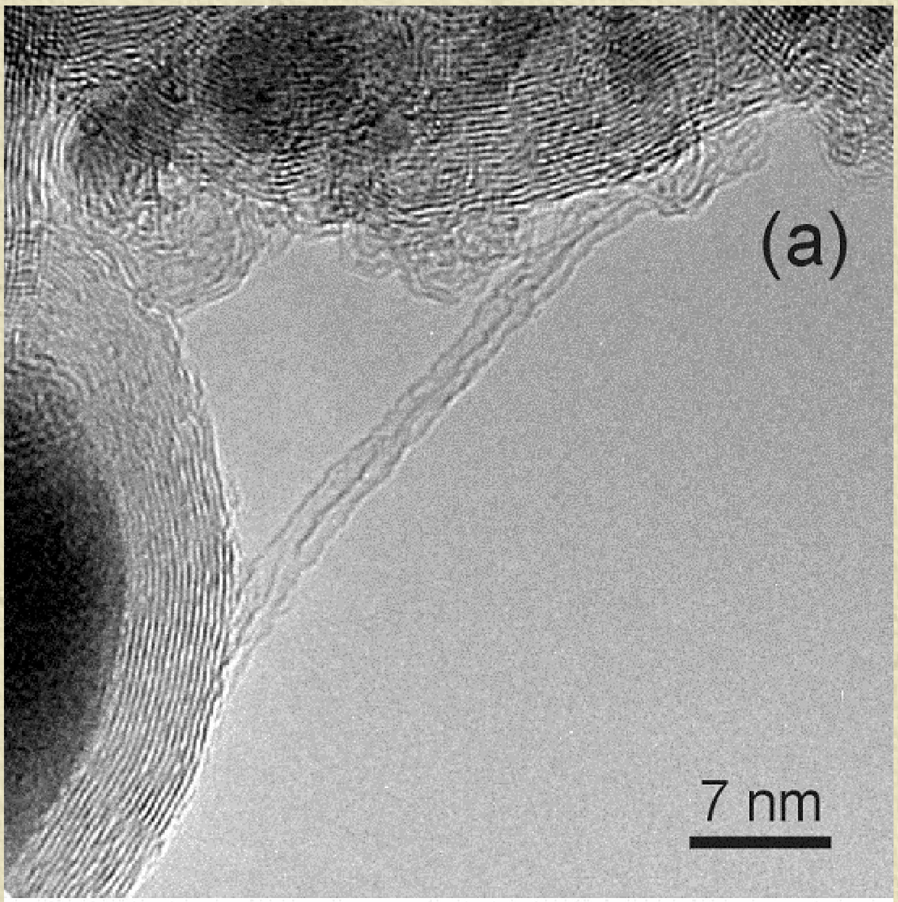
THE SYNTHESIS OF γ-Fe_2O_3 NANOPARTICLES

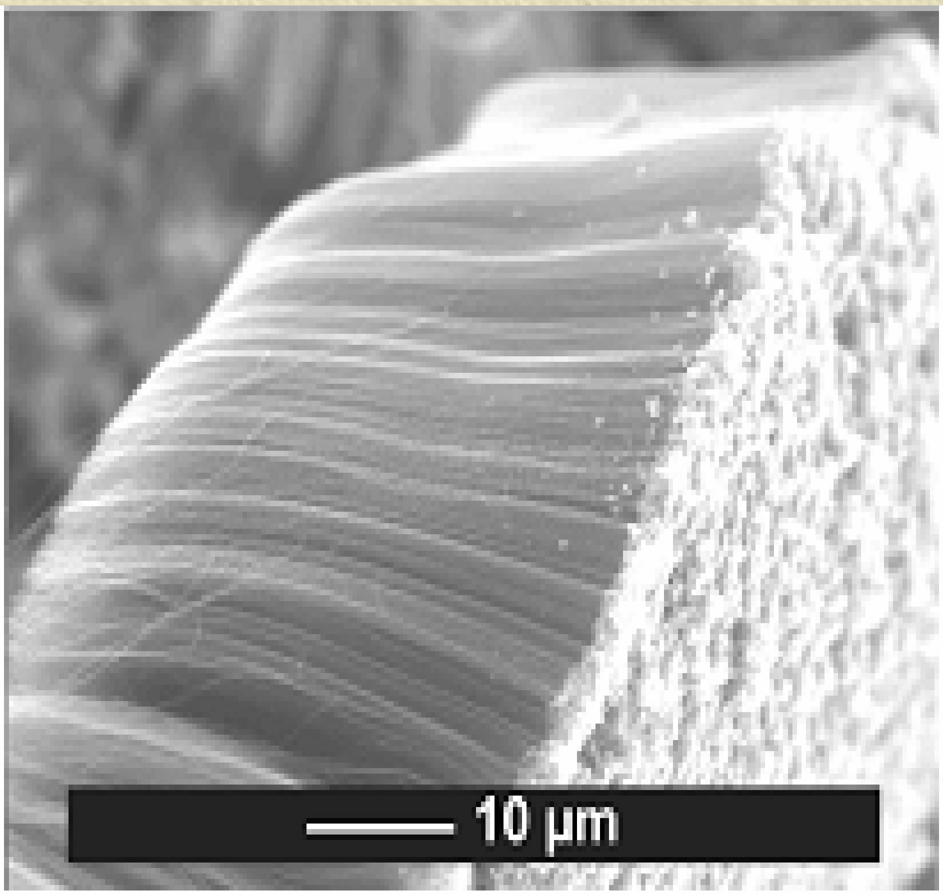


CORE-SHELL IRON-CARBON NANOCOMPOSITES



CARBON NANOTUBES





NANOMETRIC POWDERS, QUANTUM DOTS AND NANOSTRUCTURES THIN FILMS

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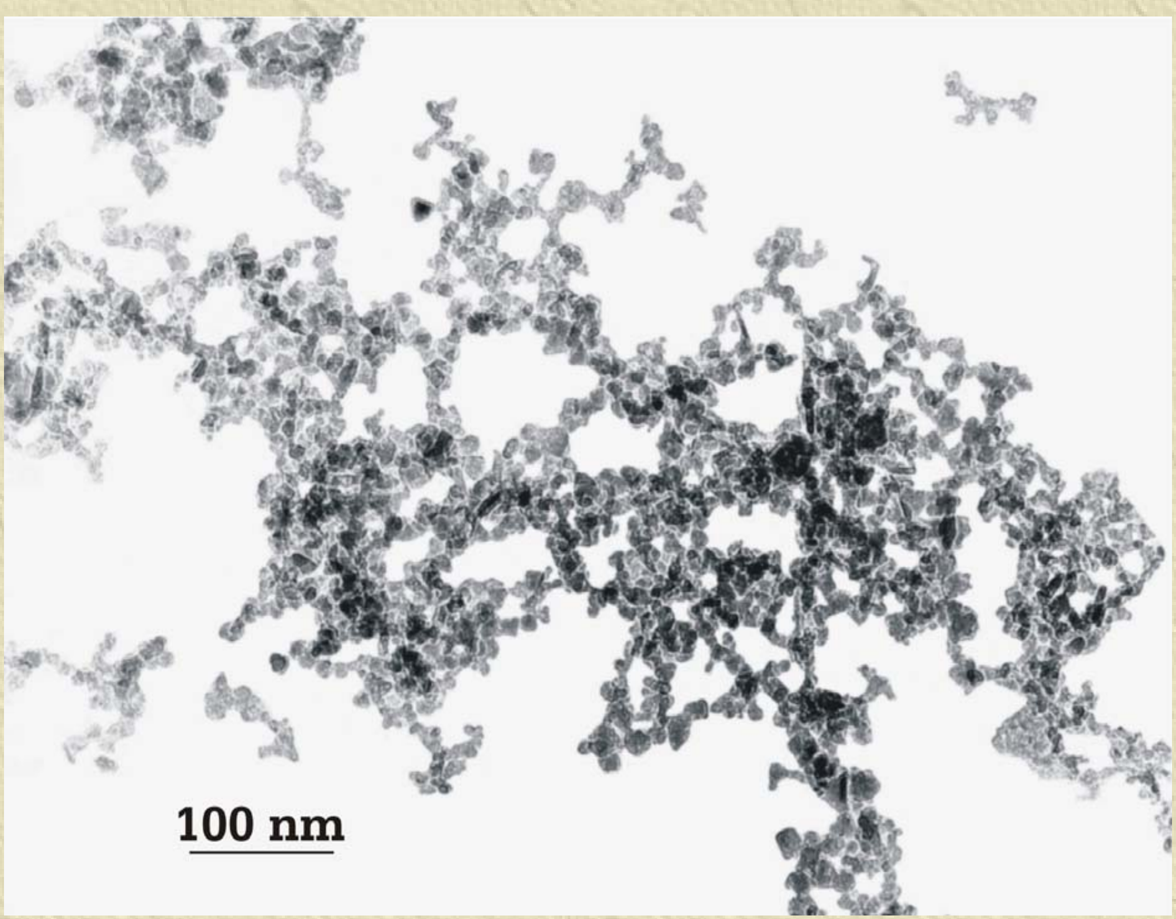
EXPERTISE:

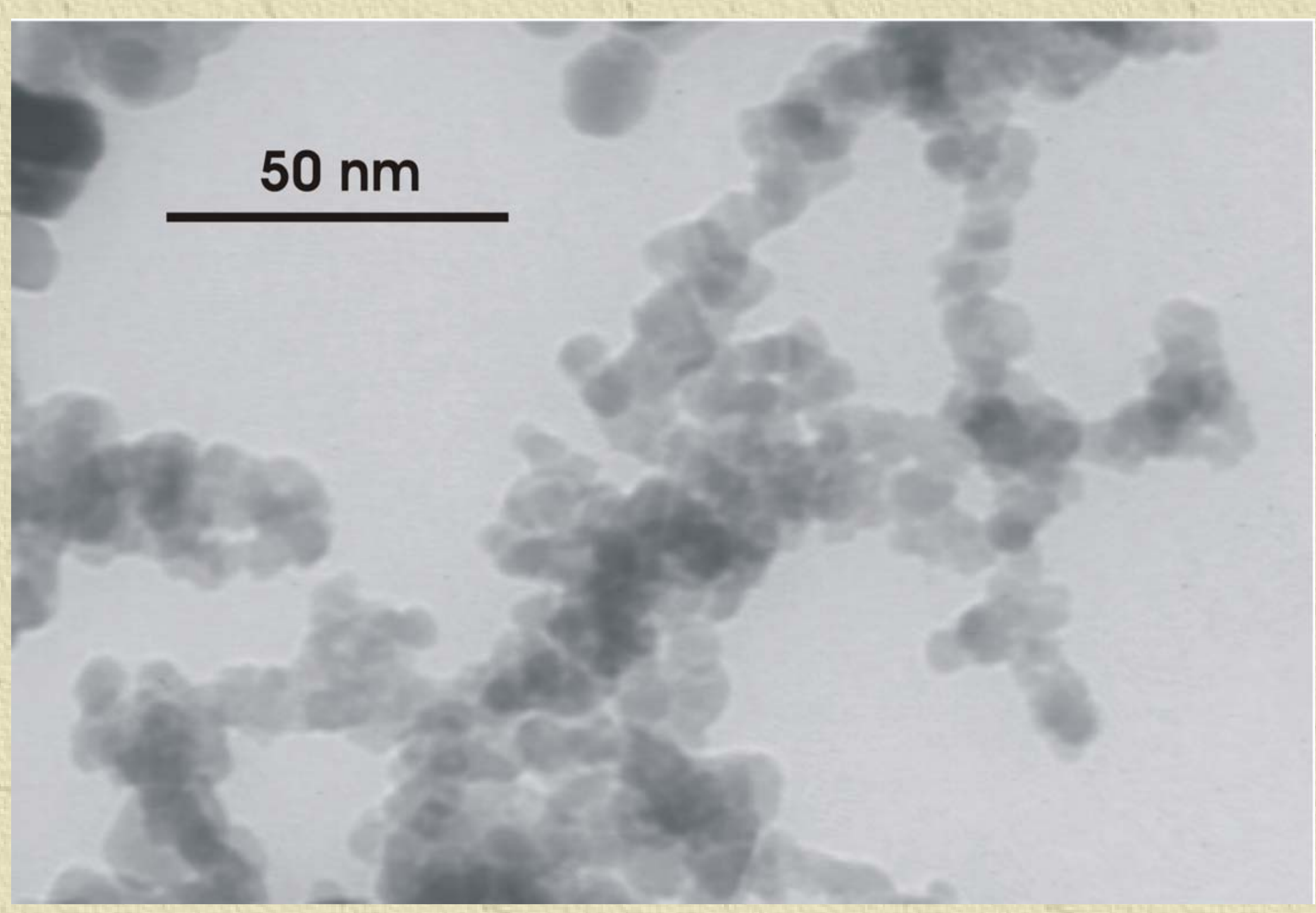
1. *Nanometric ceramic and metallic powder synthesis*
2. *Quantum Dots*
3. *Thin films for photonic crystals*

SYNTESIS EQUIPMENT FOR NANOMETRIC POWDERS AND FILMS

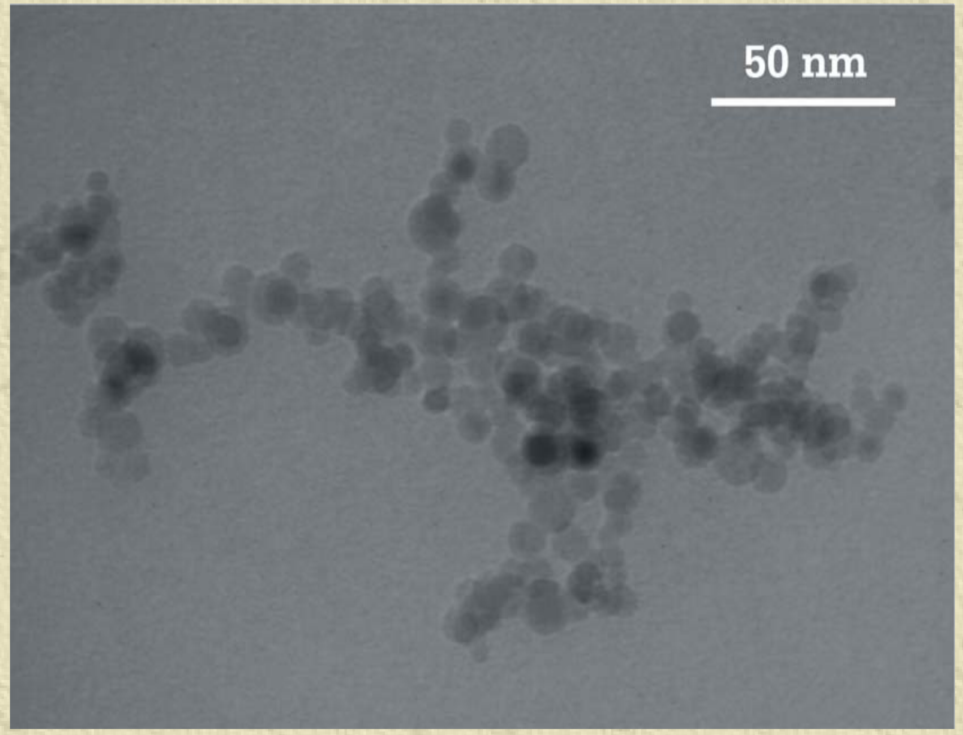
AlN NANOMETRIC POWDERS

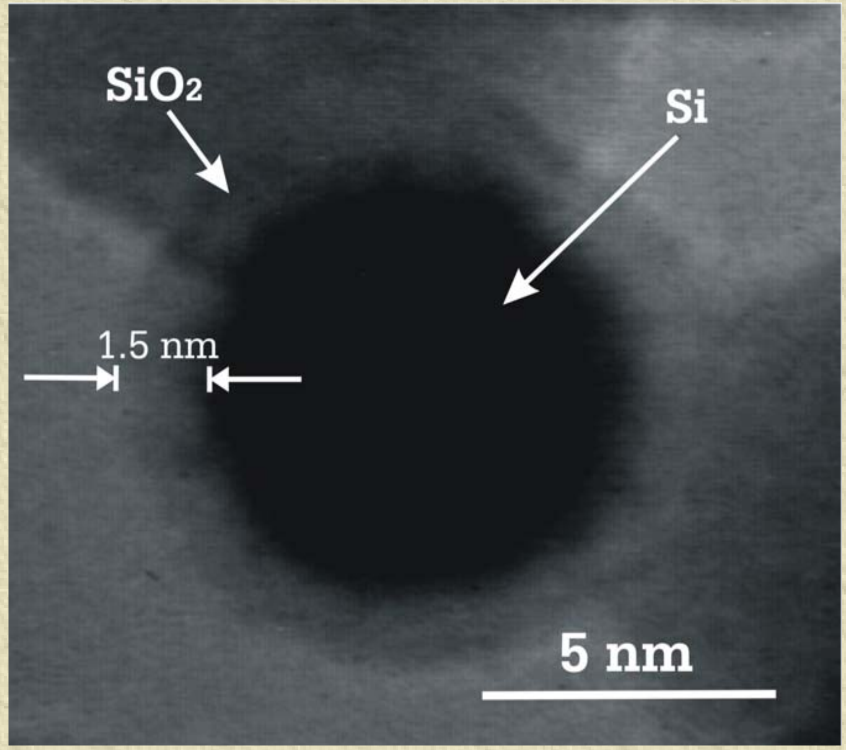


Cu NANOMETRIC POWDER

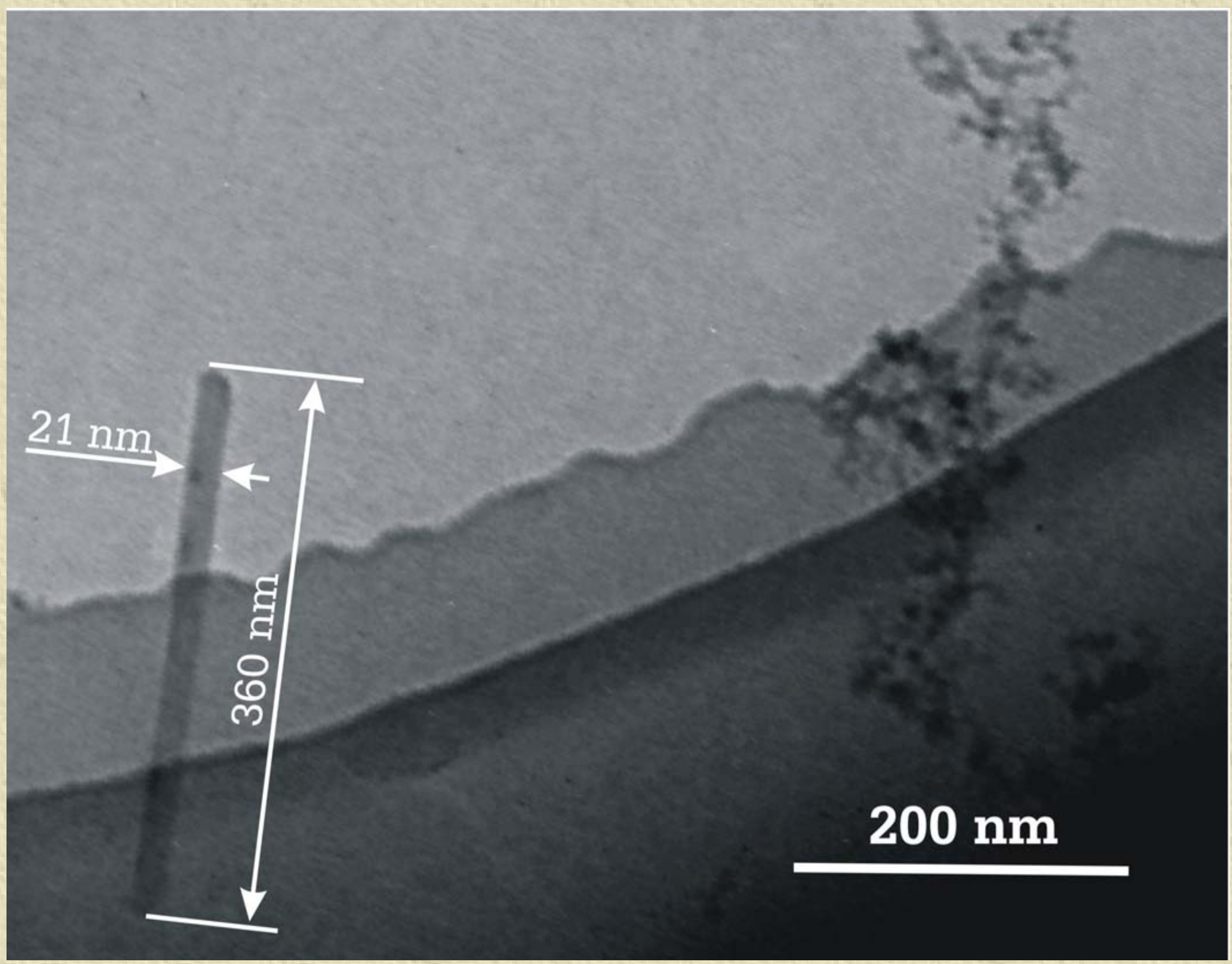


Si QUANTUM DOTS





Si NANOTUB



NONLINEAR NANOPHOTONICS

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1. Amplificarea puternica a raspunsului neliniar ultra-rapid al Siliciului-pe-Izolator (SOI) nano-structurat periodic masurata prin metoda RZ-scan cu un femto-laser

• Prima masurare cantit. a raspunsului neliniar de ord.3 a nano-structurilor SOI

• Elaborarea unei noi proceduri pentru discriminarea intre NLO de tip electronic si termic: **Dublu Z-scan (DZ-scan)** (colab. ENS, Paris si Univ. “La Sapienza” Roma)

2. Controlul raspunsului neliniar al Siliciului nano-poros prin porozitate

* Modelare (Brueggeman) simplificata

• Prima masurare cantitativa a raspunsului neliniar de ord.3 prin RI-scan si verificare a predictiei teoretice Bruggeman (colab. IMT)

3. Neliniaritatea de ordinul trei a “punctelor cuantice” (“quantum dots”, QD) in regim de confinare cuantica puternica

• Masurarea cresterii uriase a raspunsului neliniar al QD de CdTe in comparatie cu materialul masiv in regim de confinare cuantica puternica

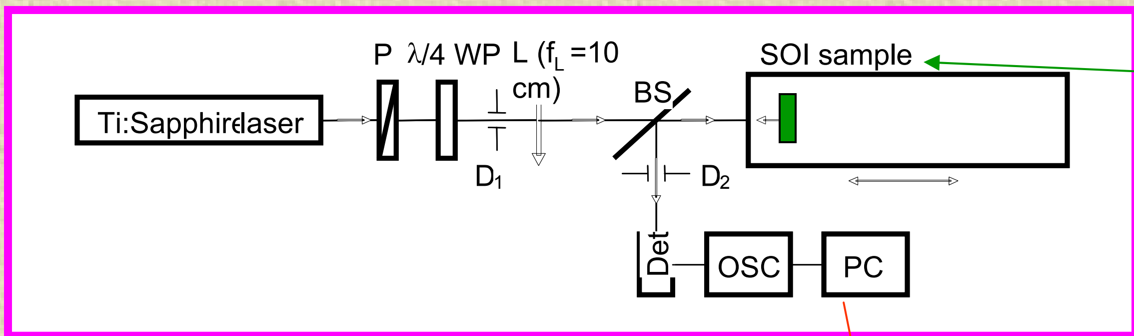
• **Controlul raspunsului optic neliniar prin dimensiunea QD** si a saturatiei acestuia la nivele mici de intensitate

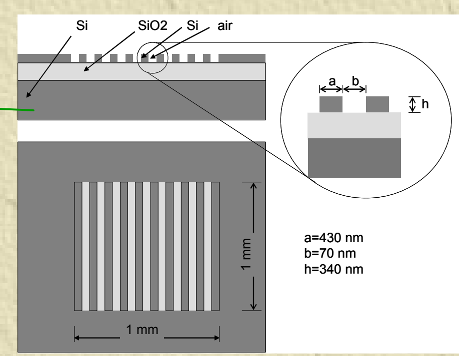
4. Nano-imaging

• **AFM+SNOM cu impulsuri laser cu durate de femtosecunde** – NL single QDs

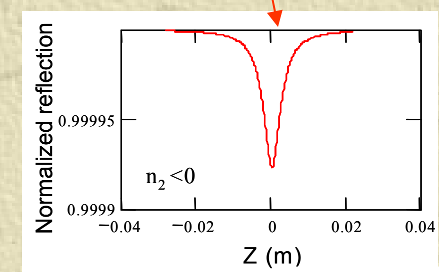
• Studiul proprietatilor structurale ale nano-starturilor de a-Se (depuse prin PLD) folosind metoda **extractiei diferential-evanescente** a luminii din ghidul format de nanostrat (colab. A. Peled – Holon Inst. Technol.,Israel si I. N. Mihailescu, G. Socol s.a.)

Amplificarea puternica a raspunsului neliniar ultra-rapid (femto-sec) al SOI nano-structurat periodic, masurata prin met. dublului RZ-scan





Laser Ti:Sapphire : λ=800nm
P_{av}=265mW, 75 fs, 76 MHz



SOI: Si (340 nm)-SiO_2(2 μm)-Si(0.5 mm)

Metoda si formula puterii reflectate Vlad et al:

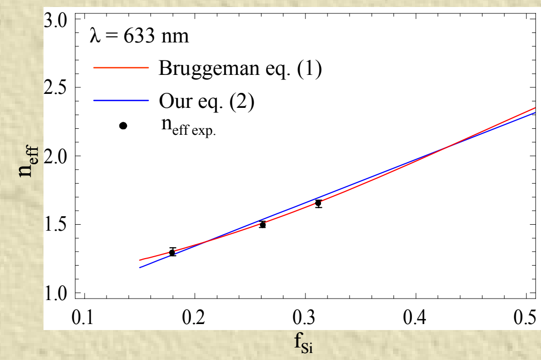
$$P(z) \sim 1 + \frac{2n_2 I_0}{n_0^2 - 1} \cdot \frac{1}{1+(z/z_0)^2} = 1 + \frac{2\Delta n}{n_0^2 - 1} \cdot \frac{1}{1+(z/z_0)^2}$$

Raspunsul neliniar electronic SOI nano-structurat ~ 20 x Raspunsul neliniar al Siliciului

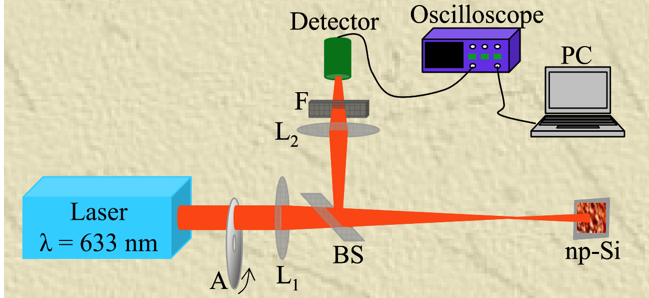
=> **Dispozitive fotonice neliniare ultra-rapide in tehnologia siliciului cu proprietati controlate prin nano structurare**

Colaborare INFLPR – Univ. “La Sapienza” di Roma si Ecole Normale Superieure Paris, in cadrul Retelei de Excelenta a UE PHOREMOST

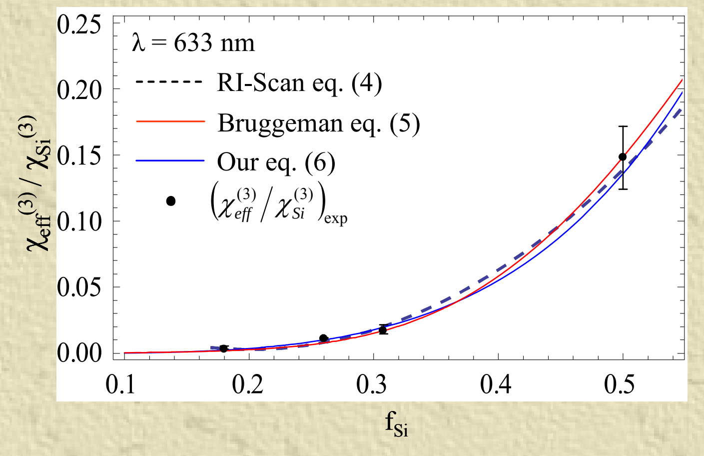
Optical linear and third-order nonlinear properties of nano-porous Si



$$n_{eff} \approx 3.19 \cdot f_{Si} + 0.73, \quad for\ \lambda = 633\,nm, \quad \varepsilon_{Si} = 15$$



$$R(I) \approx 1 + \frac{0.04}{n_{eff}^2} \cdot \frac{\chi_{eff}^{(3)} \cdot I}{(n_{eff}^2 - 1)}$$



Susceptibilitatea dielectrica de ord.3 in masuratori RI-scan (Vlad, Bazaru et al, JOAM, 2010):

$$\frac{\chi_{eff}^{(3)}}{\chi_{Si}^{(3)}} \approx \frac{R_{np-Si} - 1}{R_{Si} - 1} \cdot \frac{1}{209} \cdot (3.16 \cdot f_{Si} + 0.71)^2 \cdot \left[(3.16 \cdot f_{Si} + 0.71)^2 - 1\right]$$

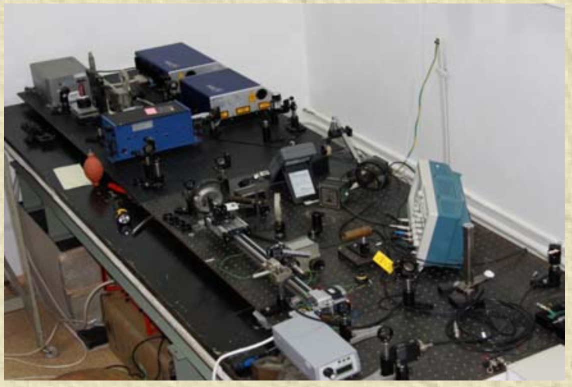
Controlul raspunsului neliniar electronic Si prin nano-structurat =>

Dispozitive fotonice neliniare ultra-rapide in tehnologia siliciului cu proprietati controlate prin nano structurare

Colaborare INFLPR – Actiunea COST MP0702 “Towards Functional Sub-Wavelength Photonic Structures” ; Colab. IMT Bucuretsi

Neliniaritati de ordinul trei uriase ale "punctelor" cuantice de CdTe in regim de confinare puternica (de sute de mii de ori mai mari decat in volumul cristalelor)

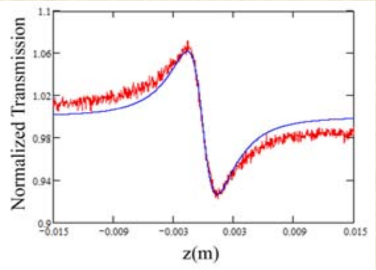
Raza "punctelor" cuantice ("atomi" artificiali) sintetizati special pentru a avea nivelele excitonice rezonante cu lungimea de unda a laserului utilizat este:
R_{QD}=2 nm < $R_{BohrCdTe}$=7.5 nm ⇒ Confinare cuantica puternica



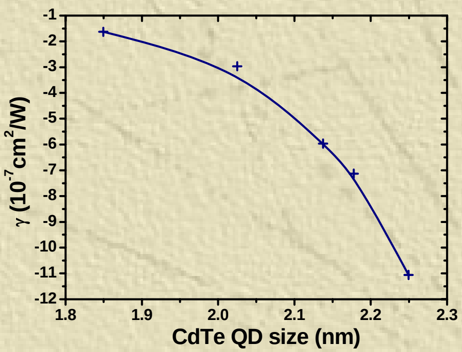
Montajul experimental de Z-scan

Am masurat neliniaritati uriase (la concentratii ale "punctelor" cuantice infime ~ $10^{-4}cm^{-1}$): de x10^5 ori marimea neliniaritatilor din cristalele masive de CdTe:

$$n_{2e} = -5.3\times10^{-8}\,\frac{cm^2}{W}$$



Aceste neliniaritati pot fi controlate prin dimensiunea "atomilor" artificiali, avantaj fata de neliniaritatile oferite de materialele optice naturale si au un mare potential in obtinerea unor **comutatoare fotonice ultra-rapide (femto-secunde) la scara nano-metrica**
(Dancus, Vlad et al, Optics Letters, 2010)



Colaborare INFLPR – TU Dresden in cadrul Retelei de Excelenta a UE PHOREMOST

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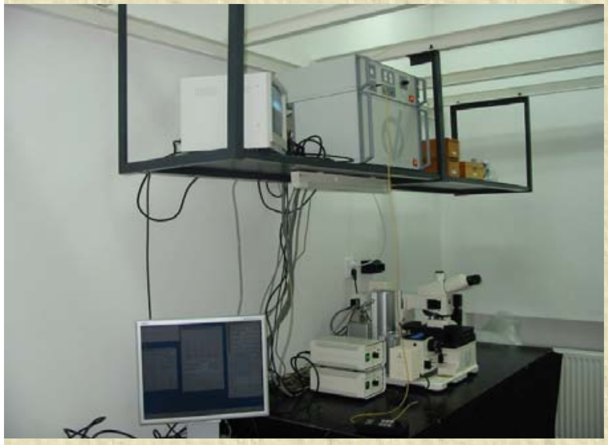
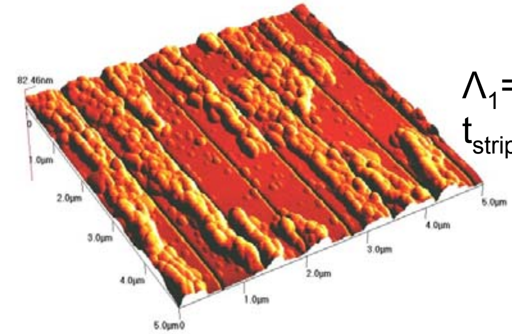
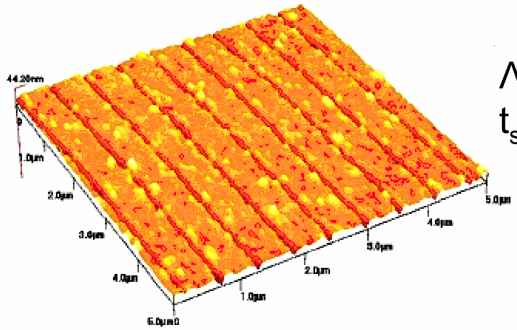
Caracterizarea SOI nanostructurat folosit pentru cresterea raspunsului optic neliniar cu AFM/SNOM si SEM



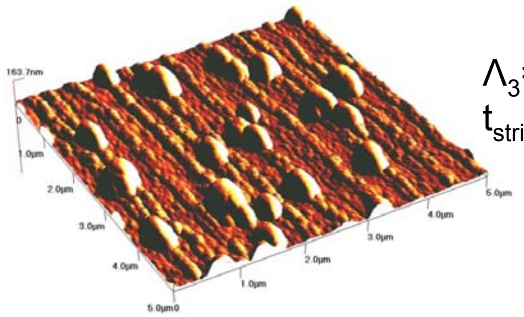
Imagini AFM/SNOM



Λ_1= 0.5 μm
$t_{stripes}$=0.43 μm

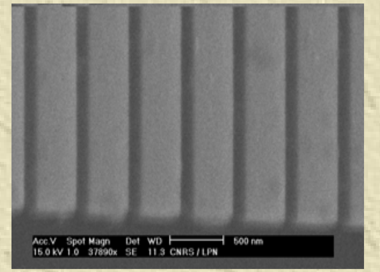


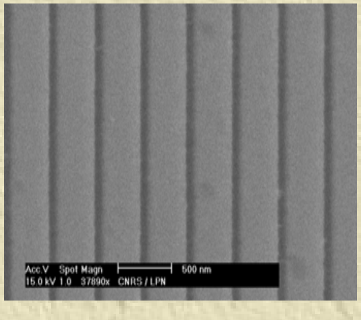
Λ_2= 0.53 μm
$t_{stripes}$=0.43 μm

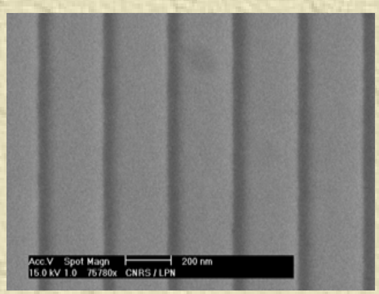


Λ_3= 0.35 μm
$t_{stripes}$=0.3 μm

Imagini SEM







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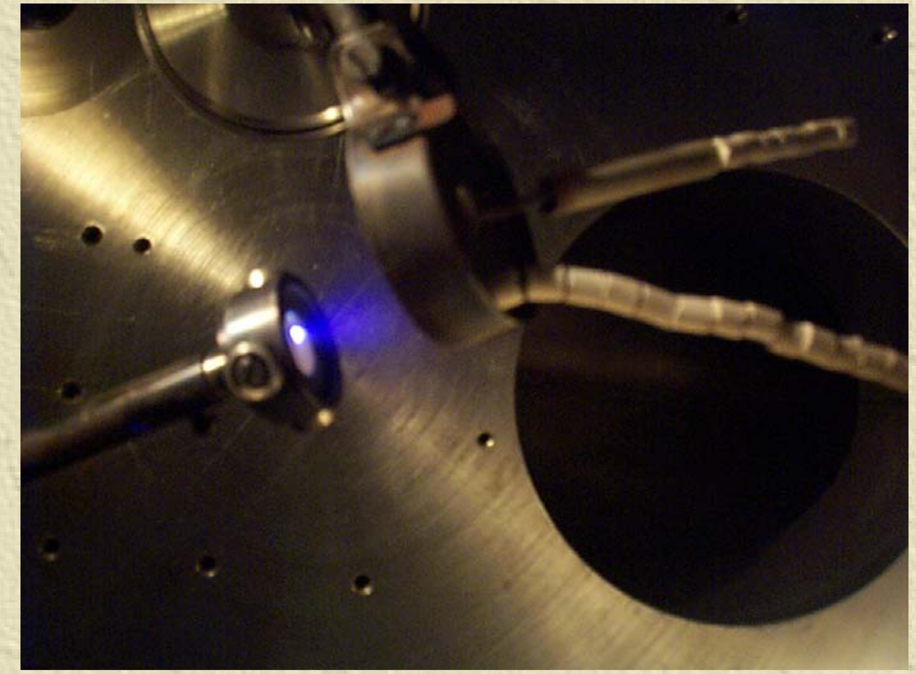
LASER-SURFACE-PLASMA INTERACTIONS

EXPERTISE:

1. *Pulsed laser deposition of thin layers in chemically-active media*
2. *Laser radiation interaction with metals and semiconductors in chemically –active atmospheres*
3. *Nitriding, carbiding and oxidation of metals and semiconductors in coherent radiation field.*



PHOTONIC PROCESSING OF ADVANCED MATERIALS

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The group was organized starting with 1996 and in present contains 17 qualified scientists and 2 technicians.

Topic

The activity is focused on laser processing of matter, with applications in thin films and nanostructures with functional properties, functional polymers, protein and cell transfer for tissue engineering, chemical sensors for the detection of warfare agents.

Expertise:

Thin films and heterostructures obtained by PLD and RF-PLD for different electronic applications :

-Ferroelectrics, piezoelectrics and relaxors for electronic, microwave and optoelectronic applications: titanates (PZT, La doped PZT, BTO, BST, etc), niobites (SBN, PMN, NKN), tantalates (SBT, BZT, NBT).

-Zinc oxide (ZnO): piezoelectric, n-type semiconductor, p-type semiconductor- ZnO/MgxZn1-xO and MgxZn1-x/ ZnO /MgxZn1-x

-III-V compounds: AlN, InN, GaN and their combinations.

-Heterostructures: PMN/LSCO; PZT/TiN; CN/SiCN/SiC; SBN/STON.

-High-k dielectric materials: ZrO2, ZrSixOy, HfO2, HfSixOy, Nb2O5, NbSixOy, Ta2O5, TaSixOy.

-Wide band gap semiconductor metallic oxide: WOx.

Nanomaterials for catalytic and biological applications:

- catalytic systems and porous materials fabrication by laser and conventional techniques.
- nanomaterials for drug delivery.

132 papers in nanoscience and nanotechnology field, published in **ISI journals and 4 contributions in Springer and Wiley & Sons's published handbooks.**

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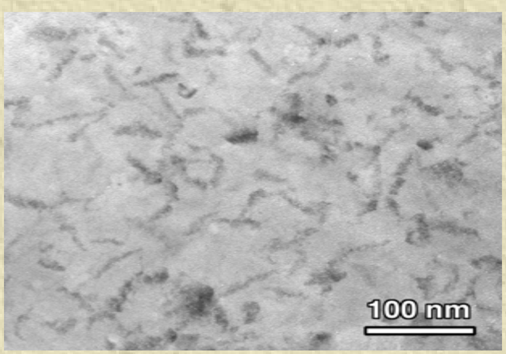
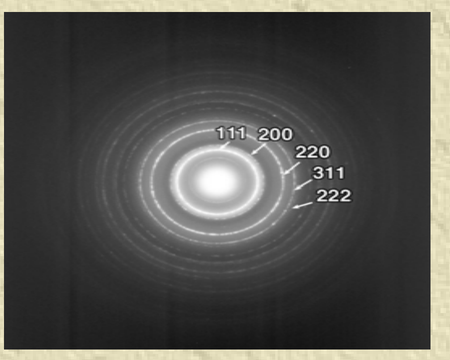
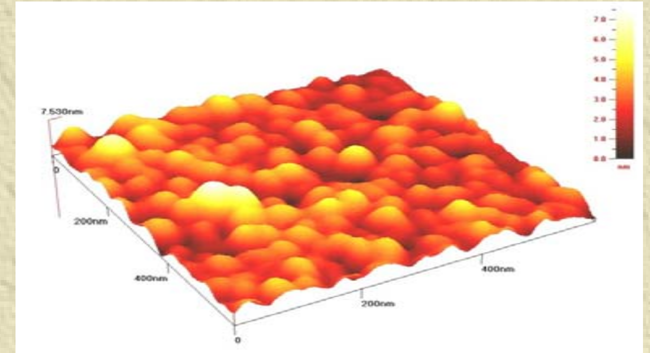
Nanostructured zirconia thin films grown by Pulsed Laser Deposition (PLD)

•ZrO_2 thin film on Si (100) deposited at room temperature, at $5x10^{-2}$ mbar oxygen, 6 J/cm^2 laser fluence: it can be observe a mixture of amorphous ZrO_2 and nano-crystallites; cubic crystallization phase (a=0.5135) even it is known that at room temperature the stable crystallization phase is monoclinic.

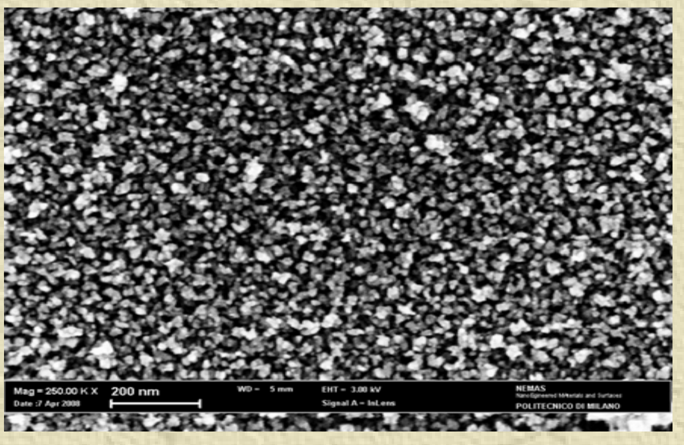


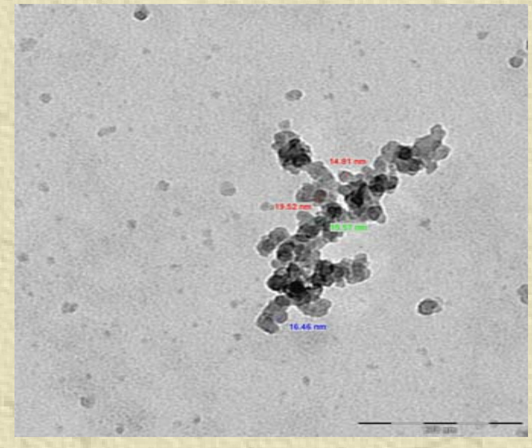




WO_3 nanoclusters obtained by PLD

- Surface microstructure of a film WO_3 deposited at 9 mbar oxygen pressure and substrate temperature at 873 K





-M. Dinescu, M. Filipescu, P.M. Ossi, N. Santo,, Thin Solid Films (2009)

-M. Filipescu, P.M. Ossi, N. Santo, M. Dinescu, Applied Surface Science 255 (2009) 9699–9702

-Filipescu M, Scarisoreanu N, Craciun V, Mitu B, Purice A, Moldovan A, Ion V, Toma O, Dinescu M, APPLIED SURFACE SCIENCE 253 (19): 8184-8191 (2007);

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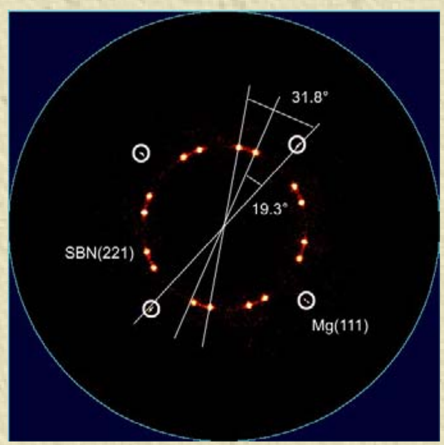
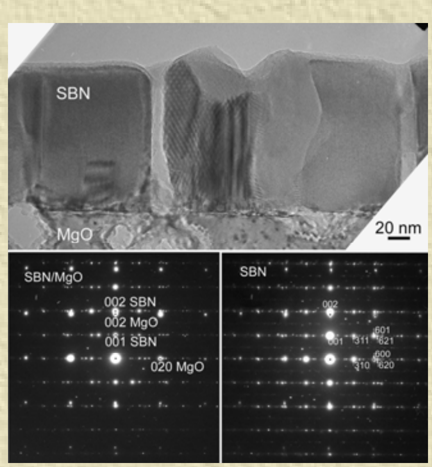
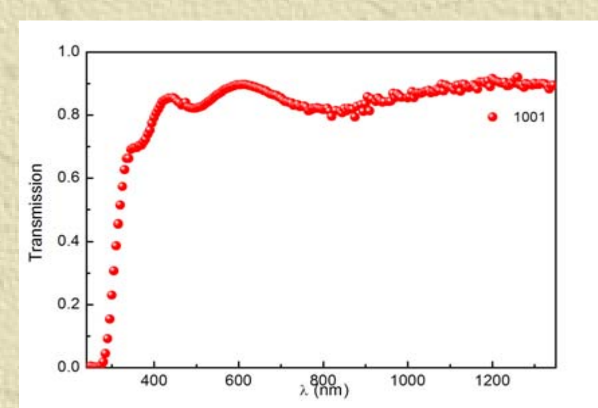
Electro-optic and ferroelectric properties of lead-free ferroelectric $Sr_xBa_{1-x}Nb_2O_6$ (SBN) thin films obtained by PLD and RF-PLD.

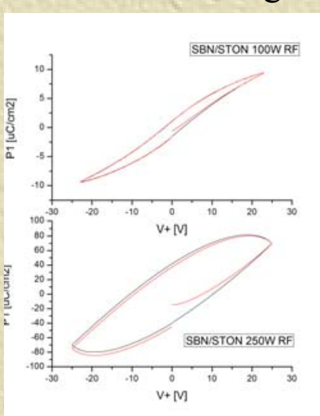
-SBN/MgO – highly crystalline structure , reproducibility and transmission.

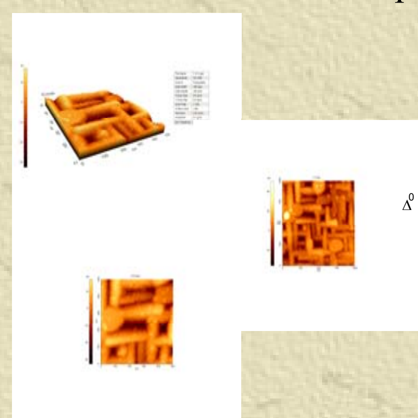


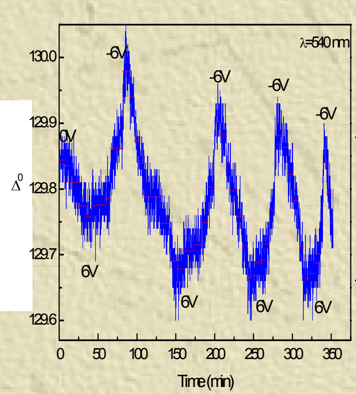


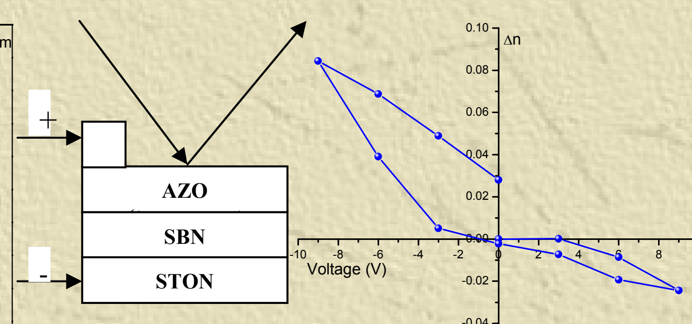


-SBN/STON – good dielectric and ferroelectric properties, high electro-optic behavior: r_{33}=36.5 pm/V .









N. D. Scarisoreanu, G. Dinescu, R. Birjega, M. Dinescu, D. Pantelica, G. Velisa, N. Scintee and A. C. Galca,, APPLIED PHYSICS A-MATERIALS SCIENCE & PROCESSING, 93 (3), 795-800, 2008

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PLASMA PROCESSES, MATERIALS AND SURFACES

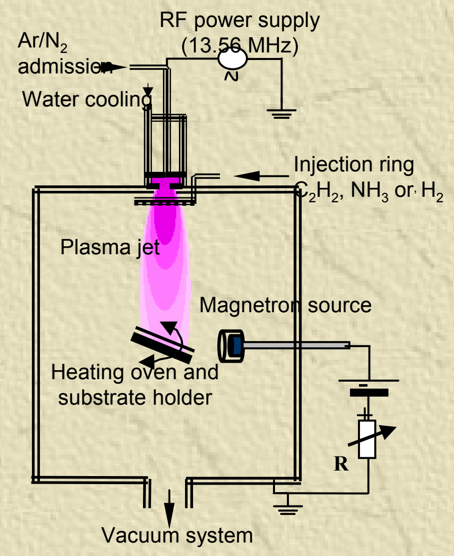
EXPERTISE:

- ***functional and nanostructured materials (polymeric composites, carbon nictride, carbonaceous structures, ceramic oxides) obtained by plasma assisted chemical vapor deposition;***
- ***protective thin film deposition for application in optics, microelectronics, and biology;***
- ***surface functionalisation of polymer-in plasma materials for the modification of hydrophilic, adherent and porosity properties***
- ***carbon nanowalls, nanotubes, nanofibers obtained***

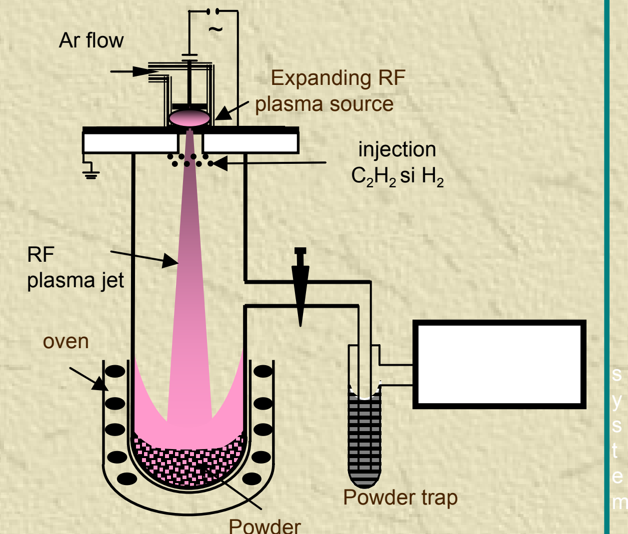
by plasma techniques and their applications

Techniques developed for carbon nanostructures synthesis

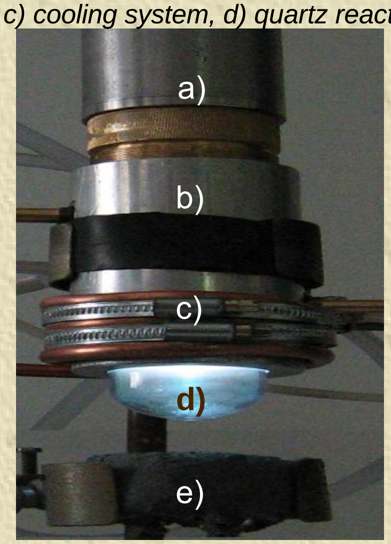
Combined RF jet for PECVD with DC magnetron sputtering



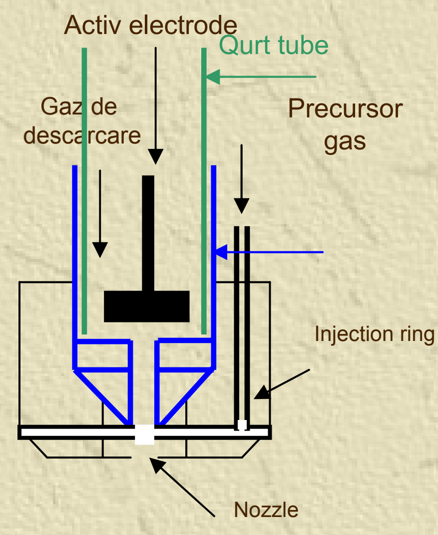
RF expanding plasma & fluidized bed reactor

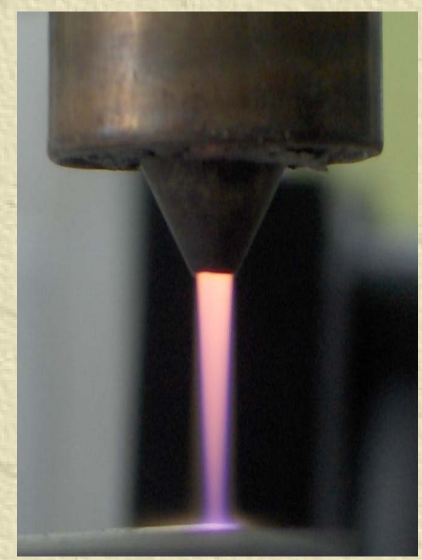


a) plasma source, b&e) oven,
c) cooling system, d) quartz reactor

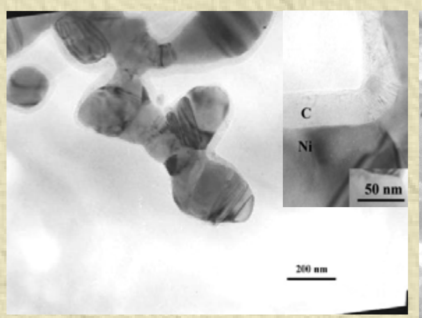


Atmospheric pressure plasma jet



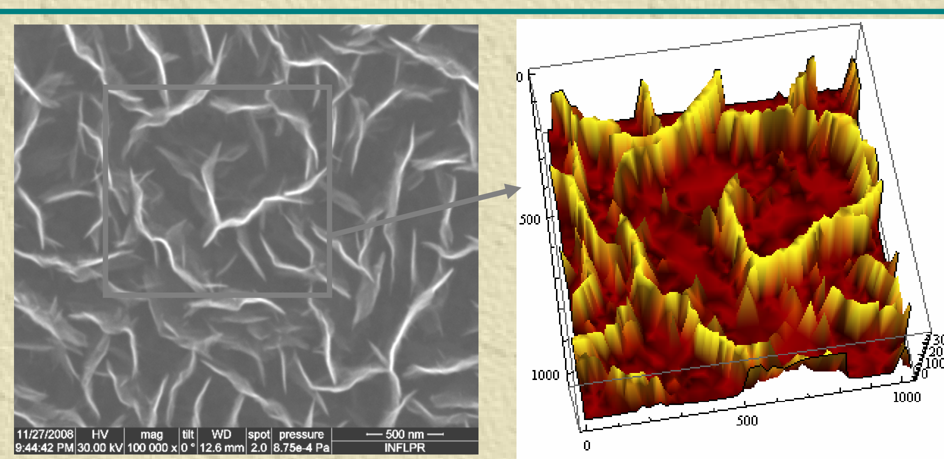


Obtained carbon based nano-materials



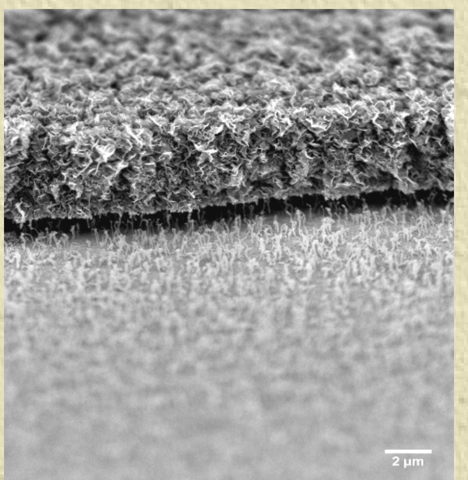
Core-shell nanoparticles
embedded in graphitic layers

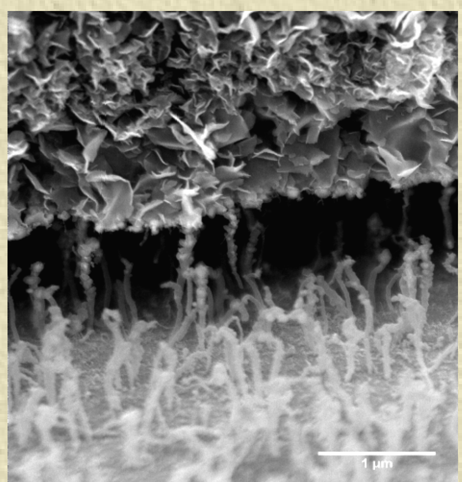
Carbon nanofibers (CNF)

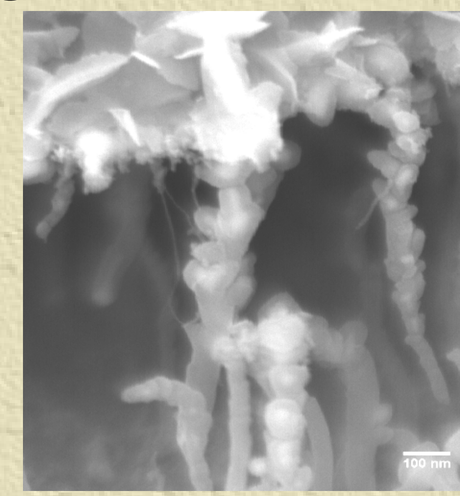


Carbon nanowalls (CNW)

Combined CNT and CNW growth



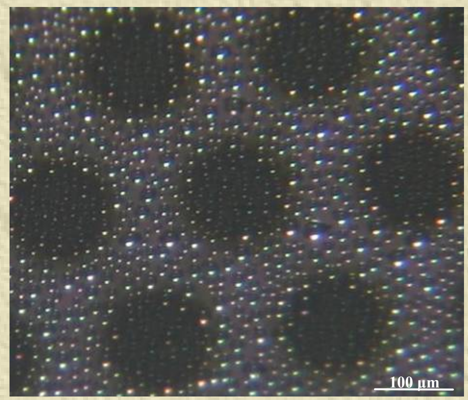




Applications

✓CNW superhydrophobic materials

Optical Image of water drop on CNW



water vapor condensation on a cold patterned Si/SiO_2/CNW

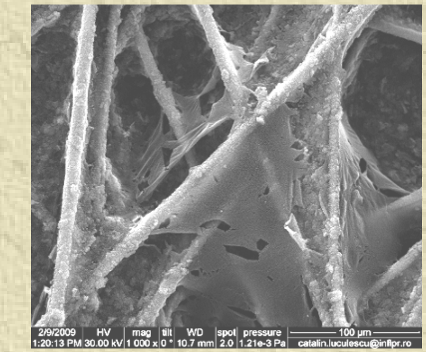
✓CNW- inhibitors of cell growth

L929 fibroblast cells 2 days after seeding on

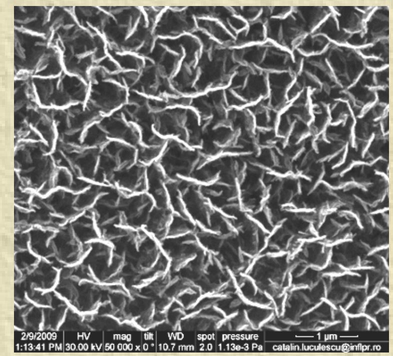
Si/SiO_2 witness (a) *Si/SiO_2/CNW patterned films (b)*

Under investigation:

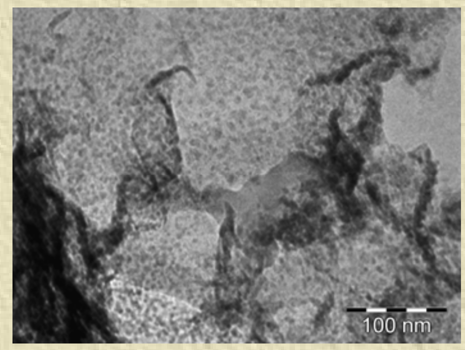
✓Support for fuel cell catalyst



CNW on Carbonic paper as support



Magnifications of CNW growth between CP fibers



Ni nanoparticles grown onto CNW surface

✓Field emission & gas sensors

PLASMA SURFACE ENGINEERING

Nano-structured W coatings - from research to production

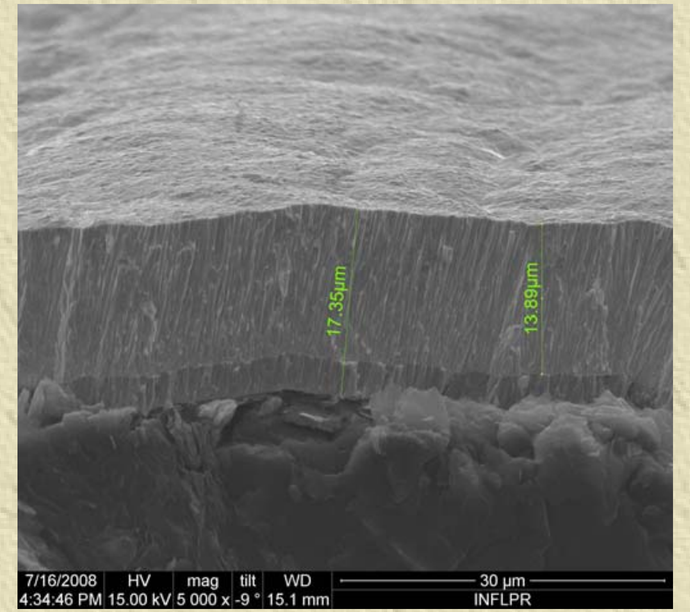
➢ Coating technology: Combined Magnetron Sputtering and Ion Implantation (CMSII)

➢High energy ion bombardment
U_{HV} = 30-70 kV; τ ~ 20 μs; f = 25 Hz
- increase the surface mobility
- high densification of the coating

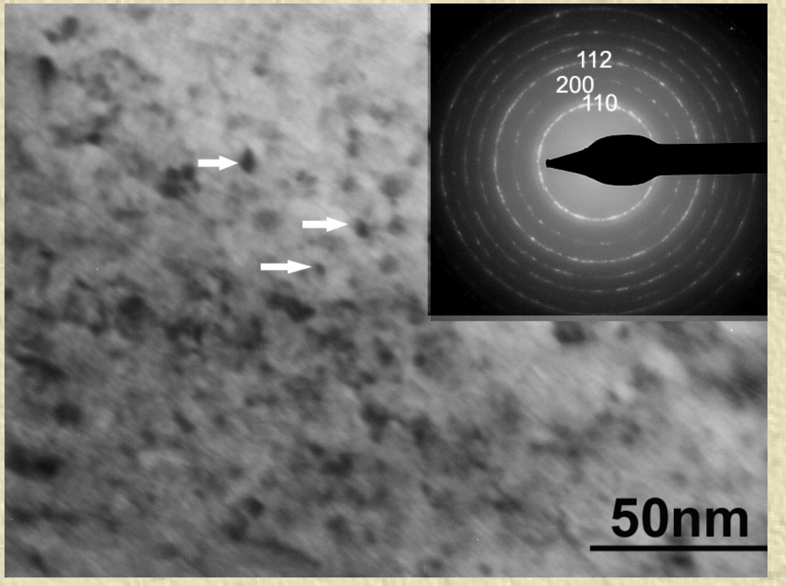
➢ Nano-crystalline structure

➢ A Mo interlayer is used to adjust the mismatch of thermal expansion coefficients between CFC and W

➢ Due to the high energy ion bombardment a stress relief occurs into the coating and consequently relative thick coatings (10-50 μm) can be produced.



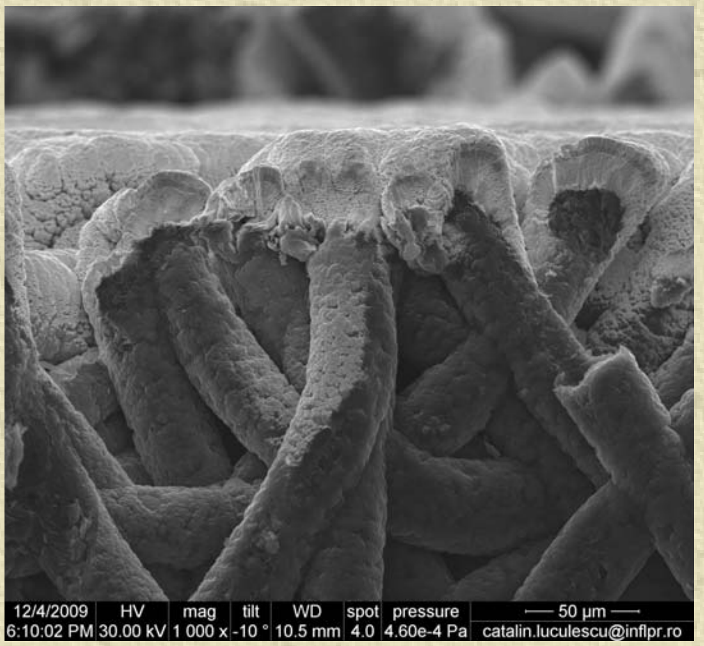
SEM micrograph

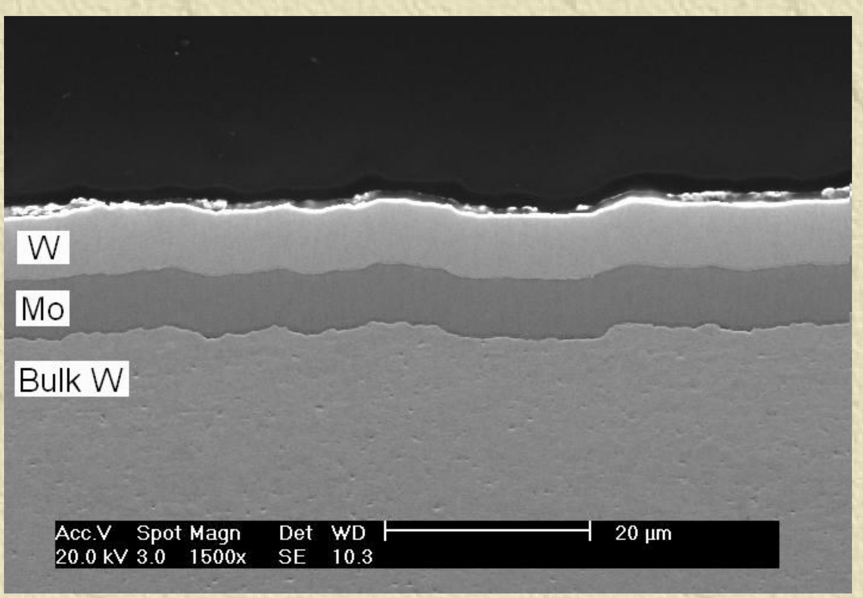


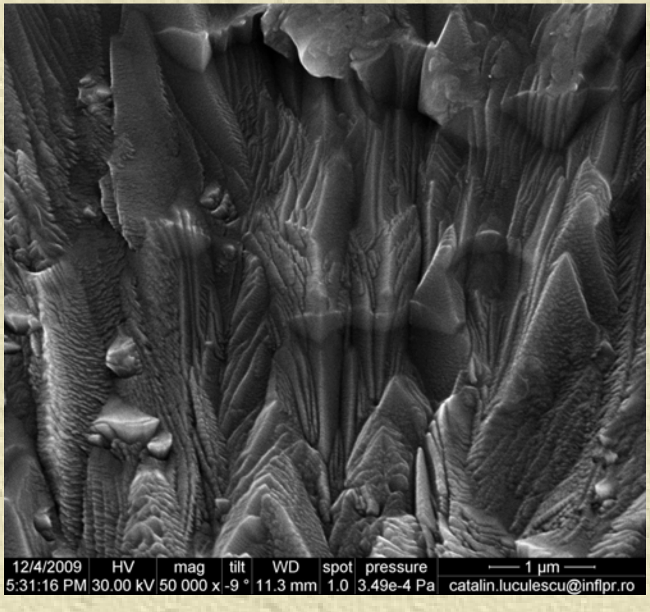
TEM micrograph

Specific characteristics of CMSII coatings

- W coating penetrates into the gapes between fibers, surrounding the fibers → very good adhesion
- The W coating appears to be more compact than bulk W

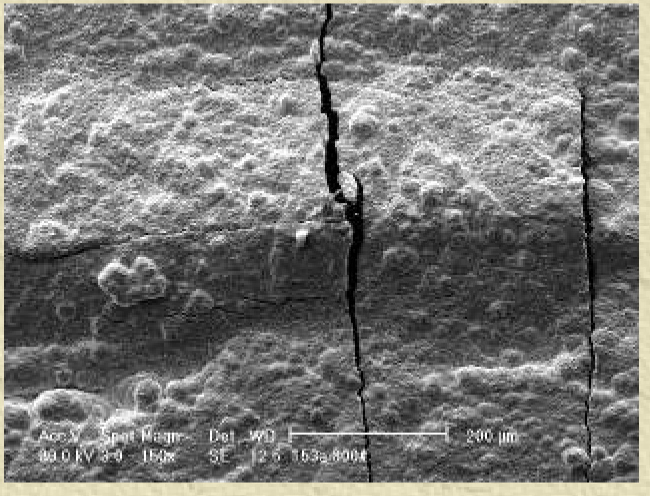


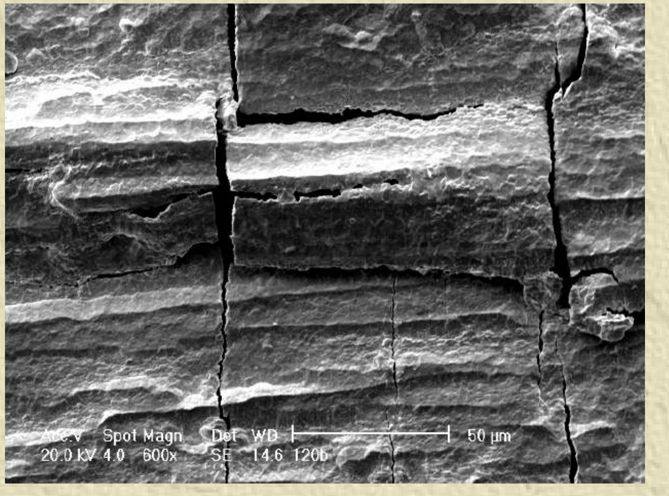




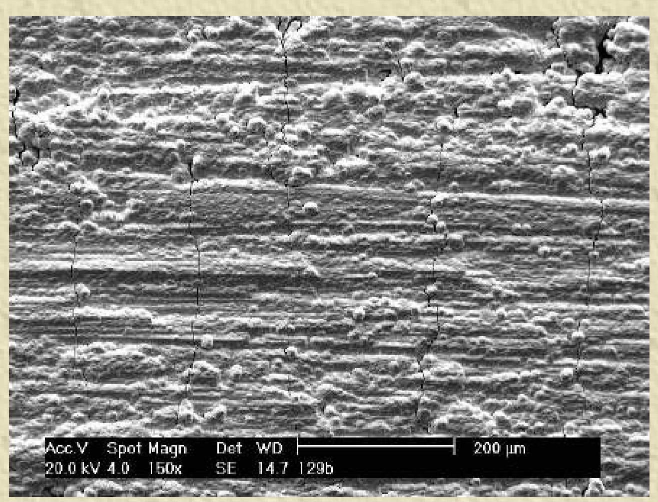
SEM micrograph, high magnification

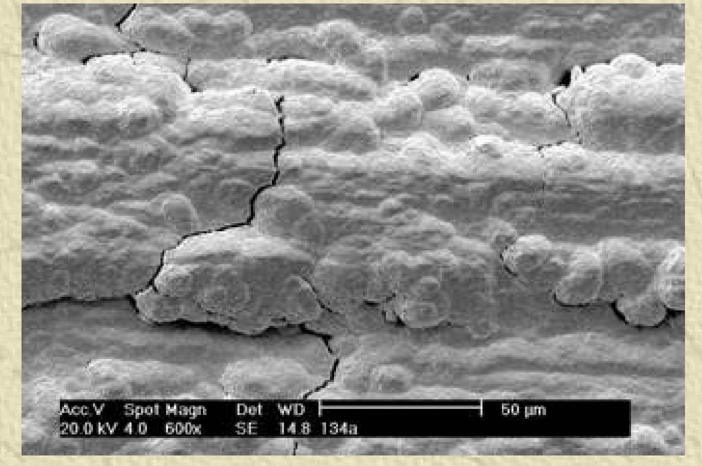
After High Heat Flux tests (T ~ 2,000 °C)





Coatings deposited by conventional PVD or CVD techniques





Nano-structured coatings deposited by CMSII technology (there is no detachment of the coating from the substrate)

W coated CFC tiles for JET (Joint European Torus)

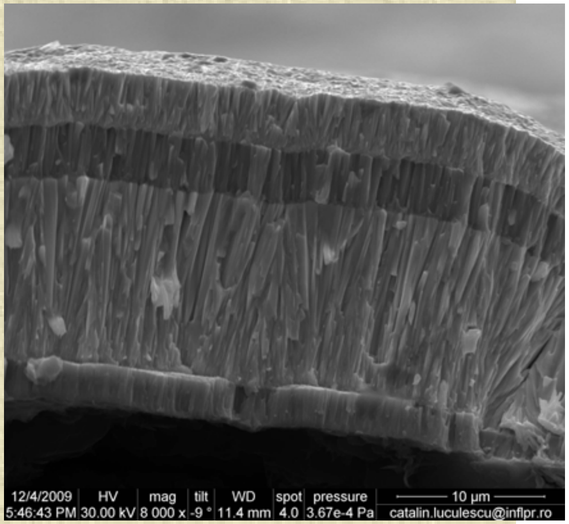
G 1 and G8 divertor tiles coated with 20-25 μm W in series production

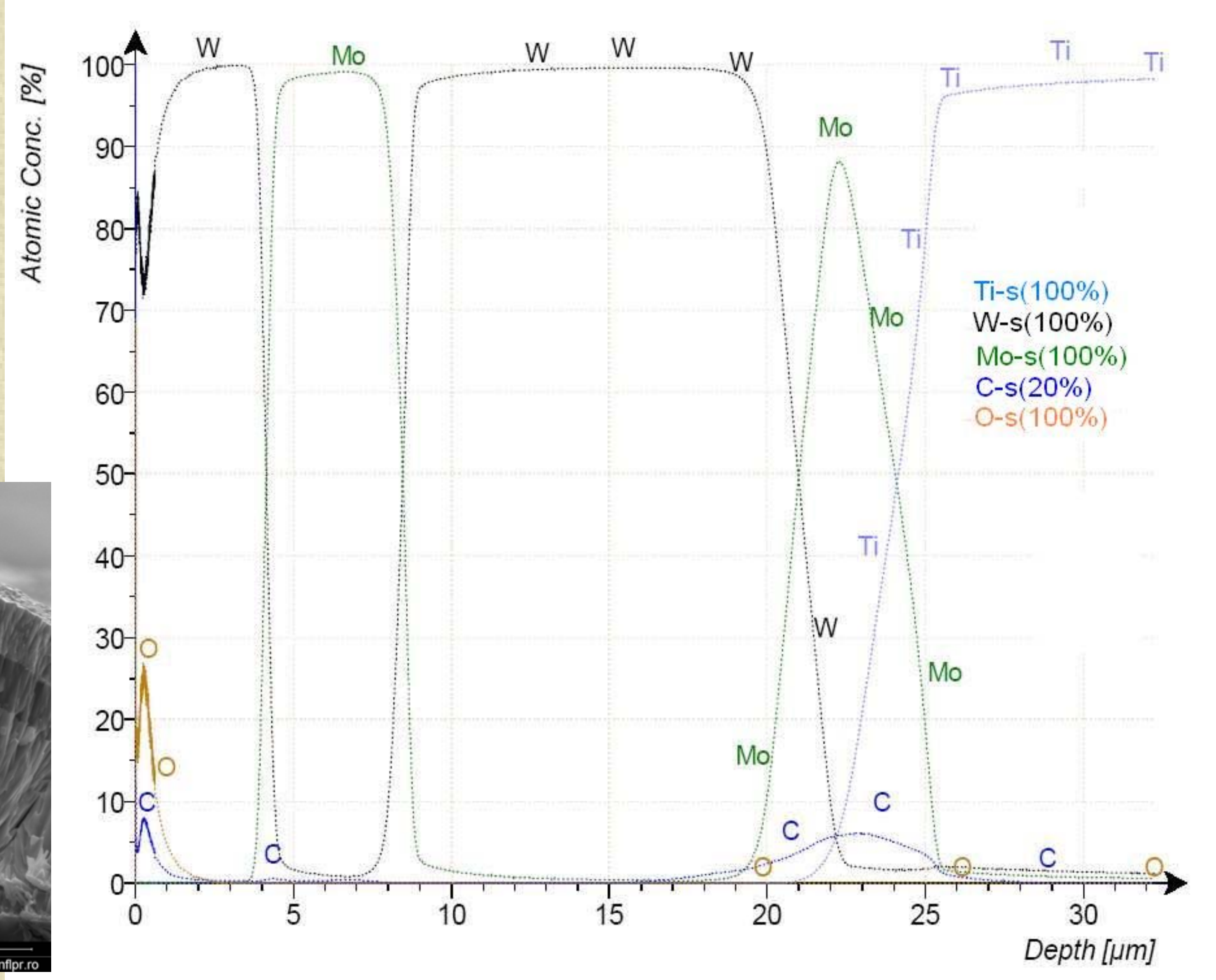
G 6 and G7 divertor tiles coated with 20-25 μm W in series production

Approx. 2,000 tiles have to be coated. More than 1,300 tiles were already coated

W/Mo markers for measurement of W erosion in JET divertor

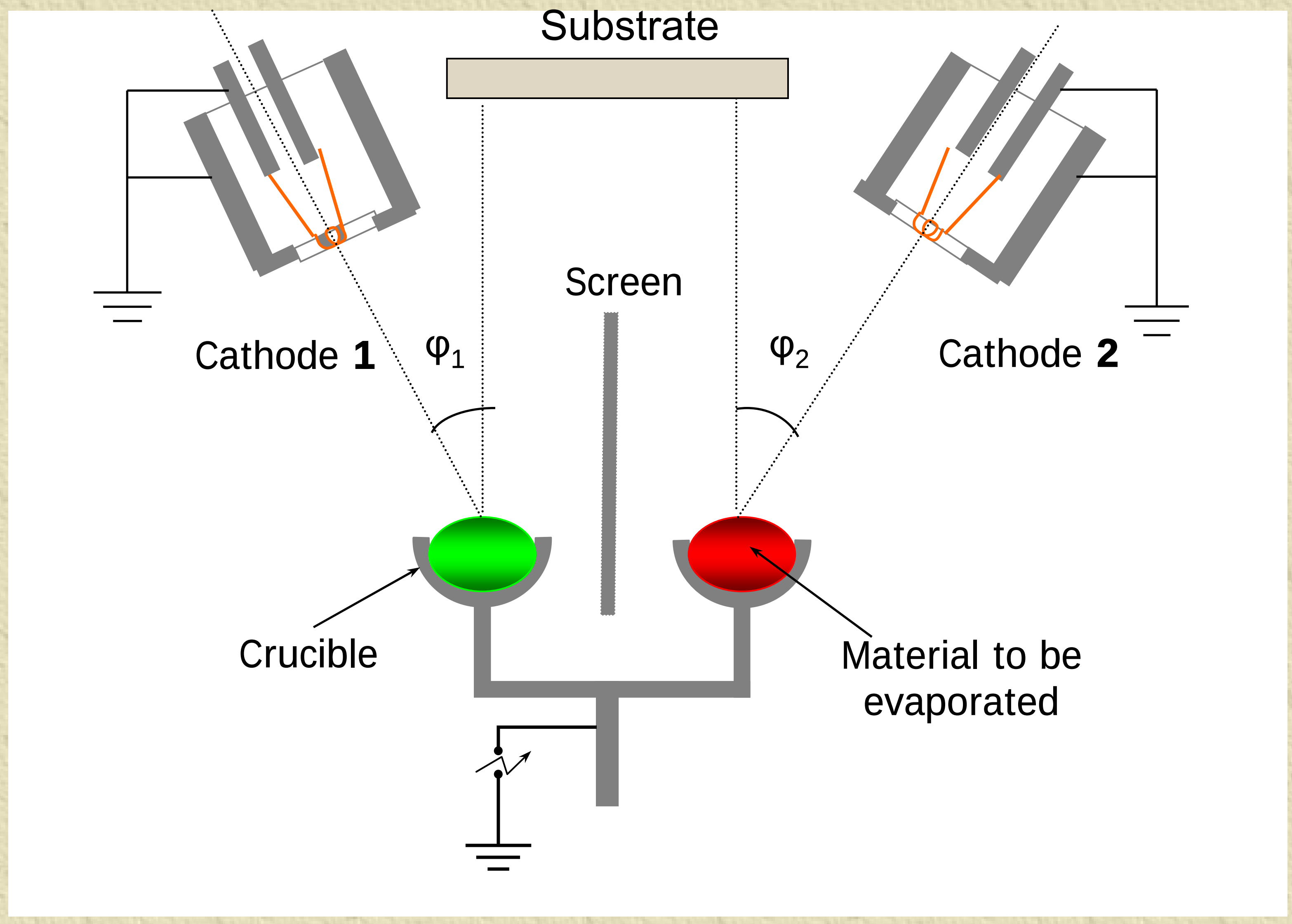
- Structure of markers:
  - 2-3 μm Mo
  - 12-14 μm W
  - 3-4 μm Mo
  - 3-4 μm W
- Applied on particular G6, G7, G1 and G8 tiles



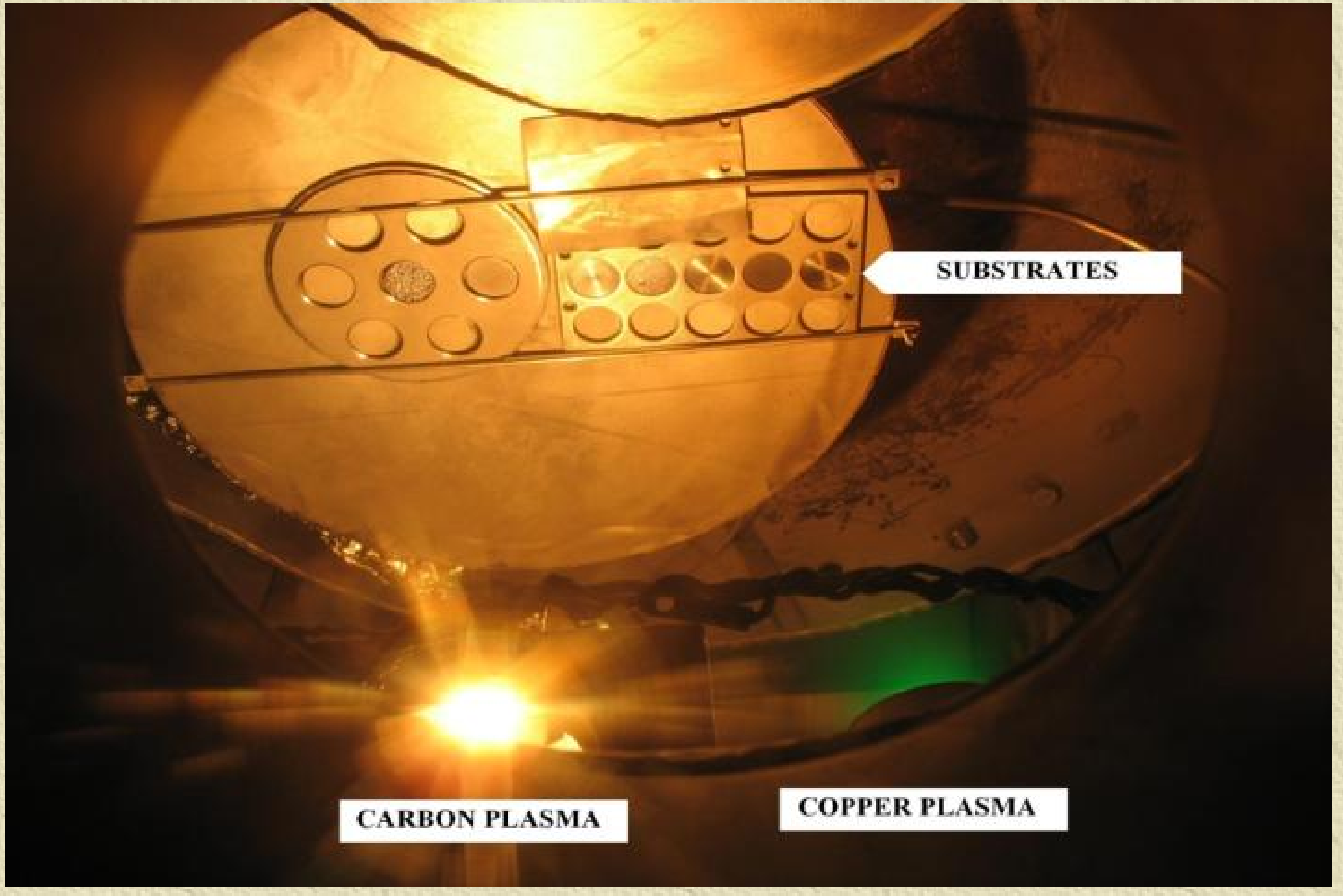


GDOS depth profiles for coating constituents measured on a witness sample

Mixed layer formation




Heinzinger Power Supply
PERICOL


SUBSTRATES
CARBON PLASMA
COPPER PLASMA

NILPRP

LASER SPECTROSCOPY GROUP

MICRO/NANODROPLETS BEHAVIOUR WHEN EXPOSED TO LASER RADIATION FIELD

MAIN OBJECTIVES

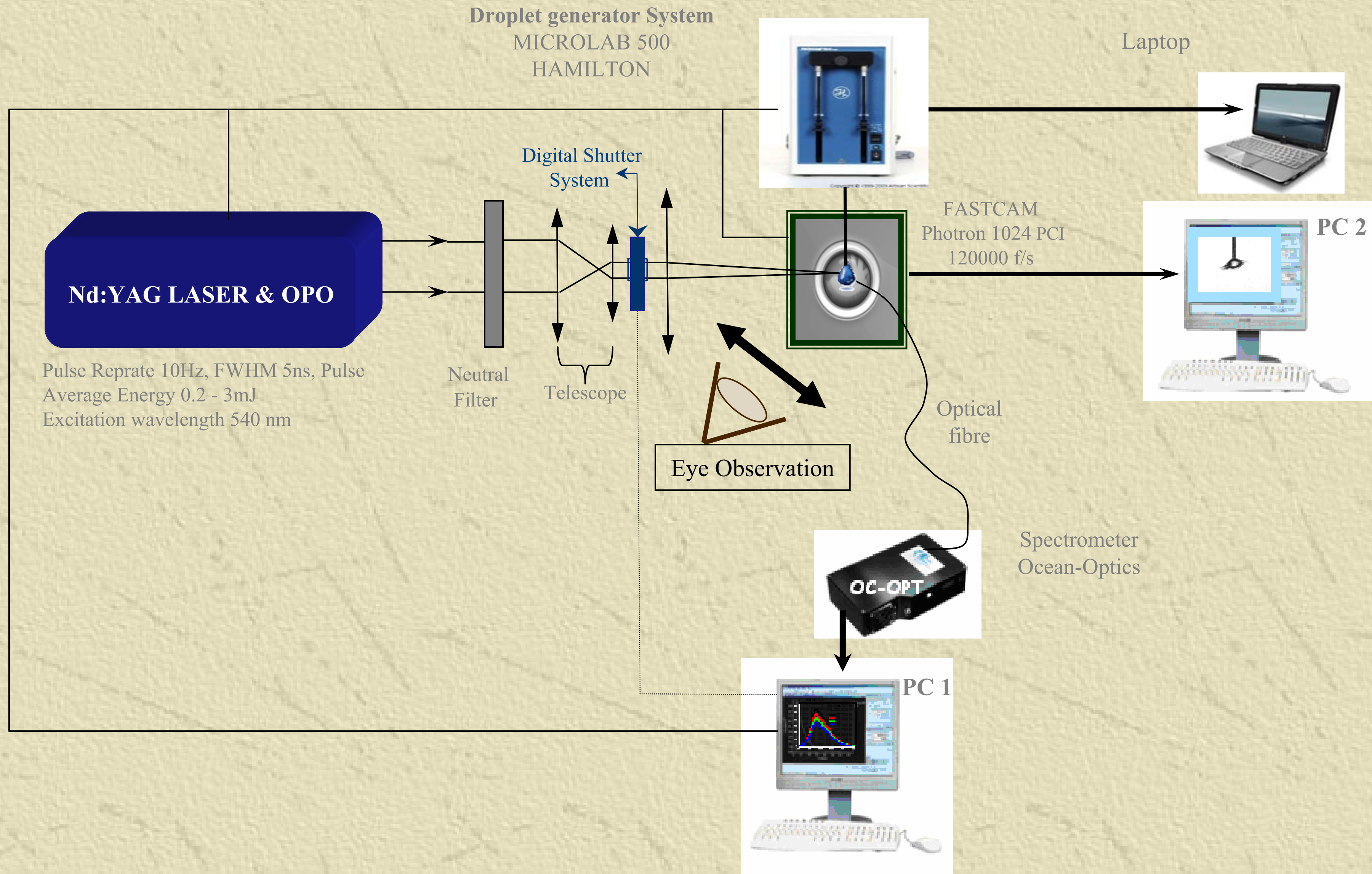
DEVELOP A MEAN TO TRANSPORT THE MEDICINES TO THE TARGETS WITHOUT DESTROYING THEM DURING TRANSPORT

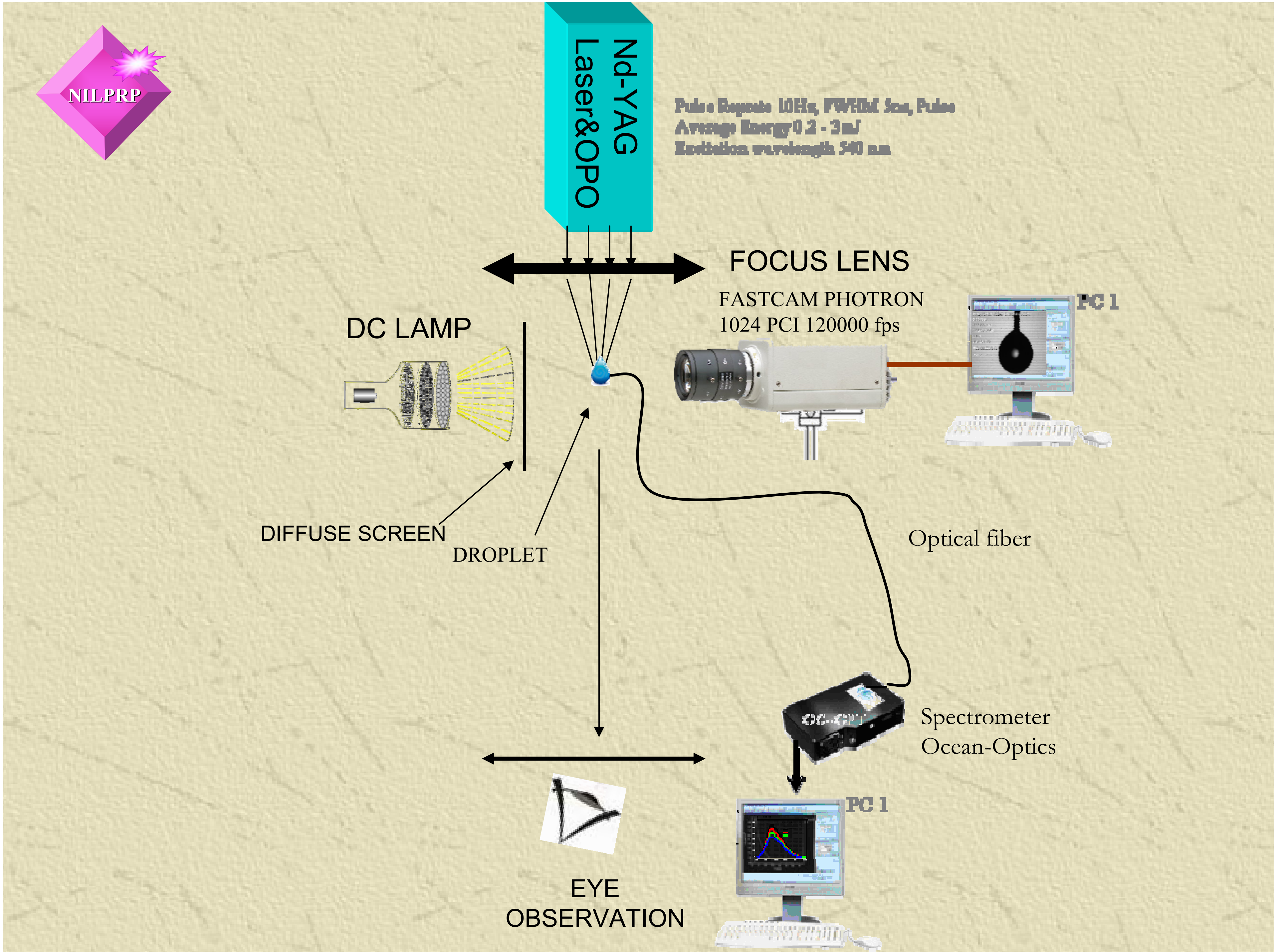
- Generate micro/nano-droplets which contain different substances: ultrapure water, modified medicines (antibiotics, cytostatics) to better fight Multidrug Resistance to treatment, laser dyes.

- Characterize the micro/nano-droplets: superficial tension, contact angles, spectral properties.

- Interaction of microdoplets with laser beams.

EXPERIMENTAL SET - UP



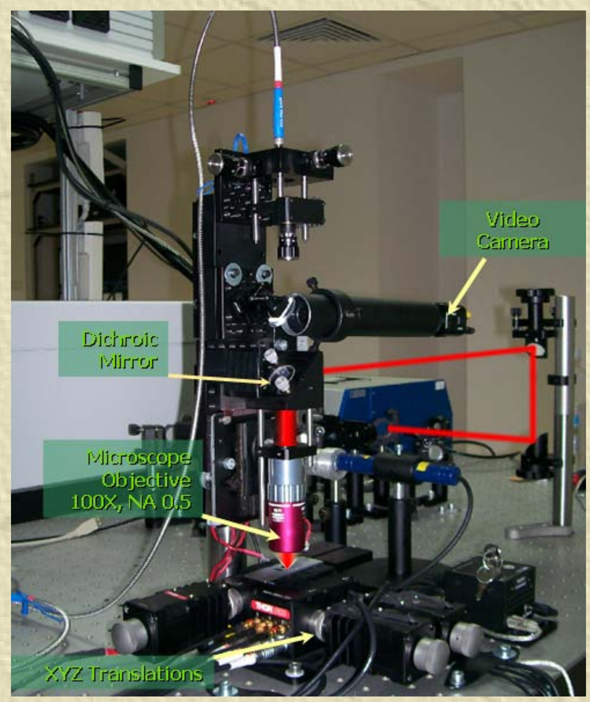


NILPRP
Nd-YAG
Laser&OPO
Pulse Repeate 10Hz, FWHM 5ns, Pulse
Average Energy 0.2 - 3mJ
Excitation wavelength 540 nm
FOCUS LENS
FASTCAM PHOTRON
1024 PCI 120000 fps
PC 1
DC LAMP
DIFFUSE SCREEN
DROPLET
Optical fiber
Spectrometer
Ocean-Optics
PC 1
EYE
OBSERVATION

SOLID STATE LASERS

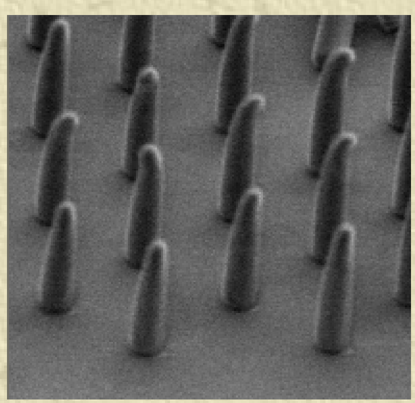
Applications connected with Nanosciences and Nanotechnologies

- Direct Laser writting (DLW) with femtosecond pulses for nanopatterning

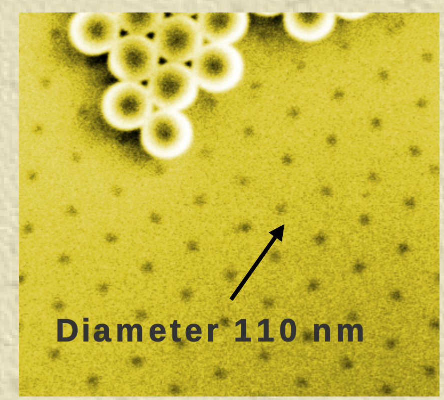


Workstation for DLW

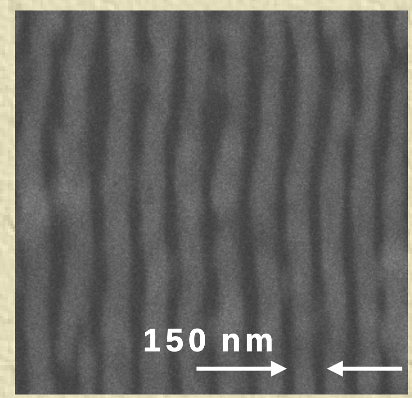
Two-Photon Photopolimerization (TPP)
J. Optoel. Adv. Mat. (2009).



Optical Near-field Enhancement for Laser Ablation
J. App. Phys. (2009).



Laser induced periodical surface structures (LIPSS)
J. Laser Micro/NanoEng. (2009).

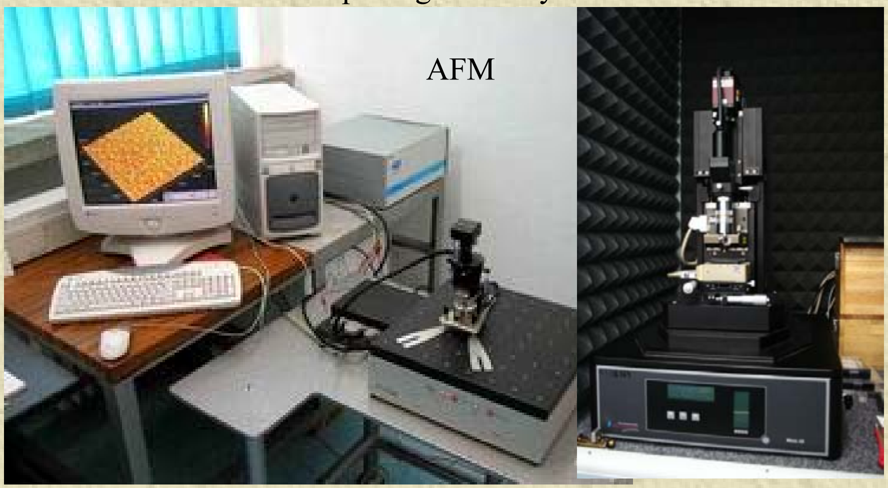


Applications:
photonic crystals, metamaterials, plasmonics

PHOTONIC PROCESSING OF ADVANCED MATERIALS

Characterization Equipments

Morphological analysis



AFM

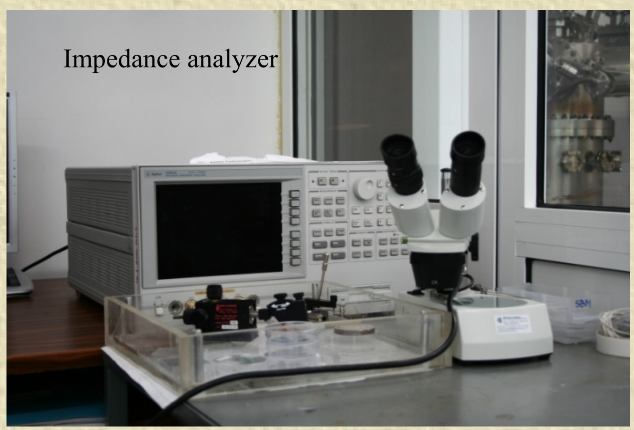
Structural analysis

XRD

Optical analysis

Spectroellipsometer

Dielectric and ferroelectric analysis



Impedance analyzer

Chemical analysis

SIMS

NILPRP

INTERNATIONAL COOPERATIONS

PROGRAMUL	DENUMIREA PROIECTULUI	SUMA	PERIOADA FINANTARII
PHOREMOST UE	Nanofotonica pentru realizarea de tehnologii la scara moleculara IST-511616	73.619 EUR	2005-2008
FUNMIG UE	Fundamental processes of radionuclide migration 516514/2005	53.300 EUR	2005-2009
FORBEST UE	Increased service lifetime of forging tools by combined surface treatments COOP-CT-2004-508710	58.500 EUR	2005-2007
EMDPA STREP UE	New elemental and molecular depth profiling analysis of advanced materials by modulated radio frequency glow discharge time of mass spectrometry STRP032202	263.498 EUR	2006-2008
3 DEMO UE	Single strep 3d depositionb of complex nanopatterned multifunctional oxidex thin films STRP033297	253.000 EUR	2007-2009
BONSAI UE	Bio-imaging with Smart Functional Nanoparticles FP6/LSHB-CT-2006-037639	249.700 EUR	2006-2009
CURARE UE	Computer-aided laser surface treatment and combined nitriding of forging dies with the objective of a lifetime increase Grant No. 222317/2008	150.000 EUR	2008-2010
EURATOM UE	Manufacturing and testing of W-coated CFC tiles for installation in JET for the ITER-like Wall project 1EU-1/2008	804.000 EUR	2007-2010
MagPro2Life	Advanced **Mag**netic nanoparticles deliver smart **Pro**cesses and **Pro**ducts for **Life**	235 000 EUR	2009-2012

NILPRP

PROGRAMUL	DENUMIREA PROIECTULUI	SUMA	PERIOADA FINANTARII
FP7 –ICT-2009-4-247868, e-LIFT	Laser printing of organic/inorganic material for the fabrication of electronic devices	195.000	2010-2012
NATO-SfP 982671	Polymers based piezoelectric sensor array for chemical warfare agents detection	243.000	2007 - 2010
FU06-CT-2007-00064	Deposition of Be-C&W films by TVA method and retention study	100.000	2009-2011
WP09-PWI-07-01/PS	Study of the substrate temperature influence during film deposition; formation of the stable alloys Be/C, Be/W	100.000	2009-2011
WP09-PWI-07-02/PS	Study of the ternary system formation Be-C-W using Thermo-ionic Vacuum Arc method; influence of oxygen on the process	100.000	2009-2011