Advancing Plasma-Based Technologies

PLASMIONIQUE

À l'Avant-Garde des Technologies Plasma

YOUR PARTNER IN RESEARCH AND INNOVATION

Plasma-Based Tools for Innovative Solutions to Engineering of Advanced Materials

Andranik Sarkissian & Plasmionique Team

About Us

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Plasmionique Inc. Founded in1999

<u>Location:</u>

Parc Scientifique de Varennes,
Research laboratory Installations on INRS premises

<u>Competencies:</u>

Complex System Integration

Plasma Technology

<u>Our mission:</u>

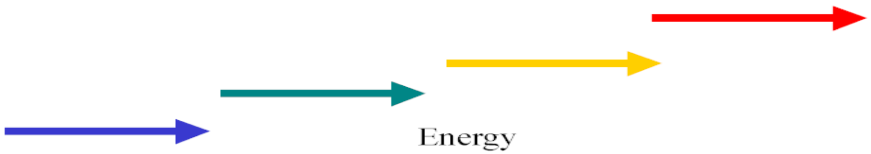
proliferation of the applications of plasma processes to surface engineering and Synthesis of advanced materials

<u>Clients & partners:</u>

Research Centres (university and governement)

What is a Plasma

- Plasma is the 4th state of mater
- (Over 99.9% of Universe is in Plasma State)
- States of Matter
  - Solid, Liquid, Gas, Plasma



- Mix of charged particles, neutral atoms, molecules, radicals and photons
- We Can speak of Plasma State when there are sufficient number of charged particles to change the electrical characteristics of the gas

Ionization Process:

A + e -> A + e + e

A + e -> A +A + e + e

Also Photoionization

Excitation /Fragmentation

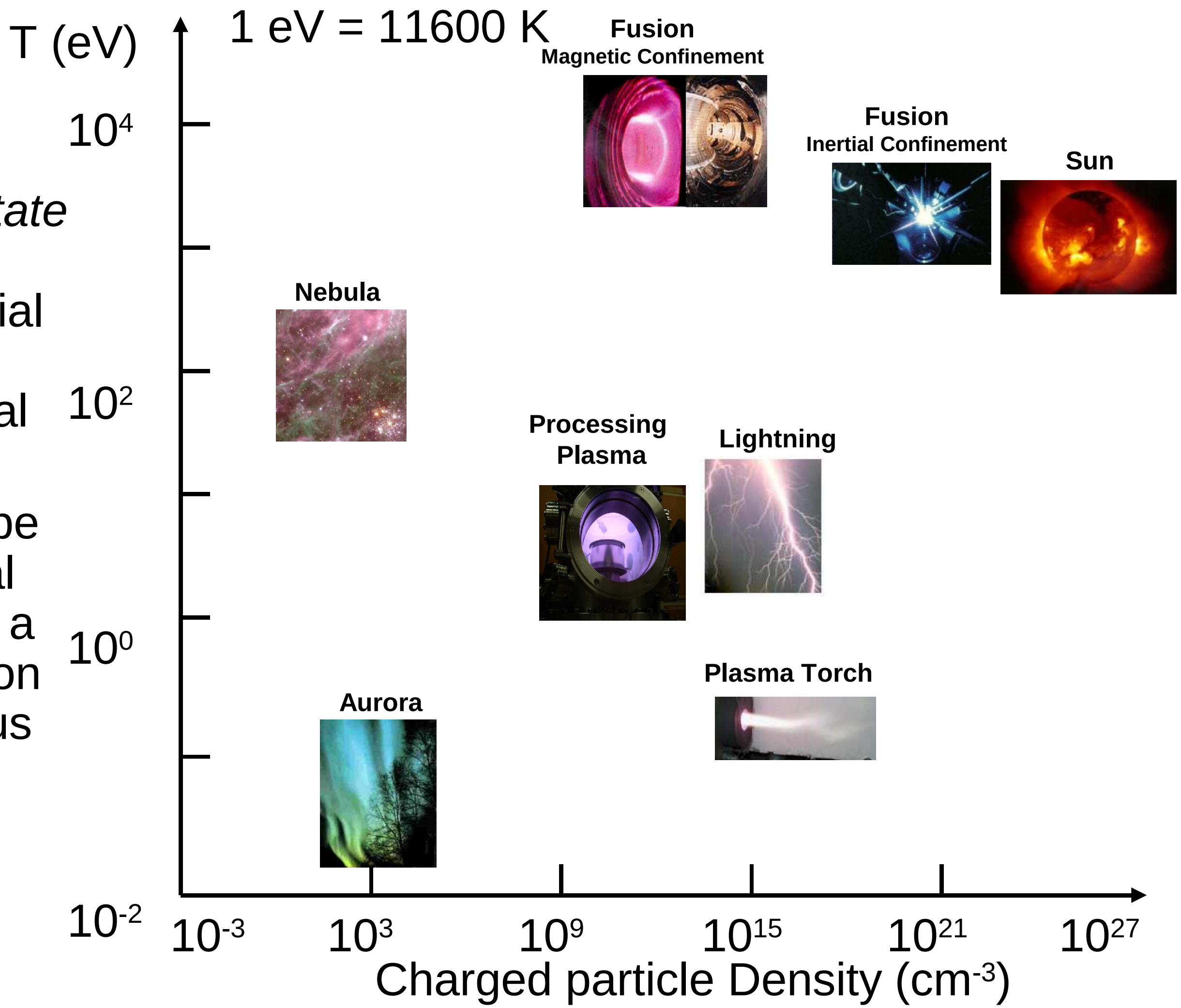
A + e -> A + e

A + e -> A +A + e + e

A* -> A + hν

Plasma Variety

- Plasmas are far from thermal equilibrium
  - Te > Ti > Tn
- The *Non-Equilibrium State of Plasma* allows synthesis of new material or coatings that are not possible by conventional means
- Charged particles can be manipulated by external fields in order to impart a predetermined energy on the material surface thus influencing the film characteristics.



Plasma-Surface Interaction

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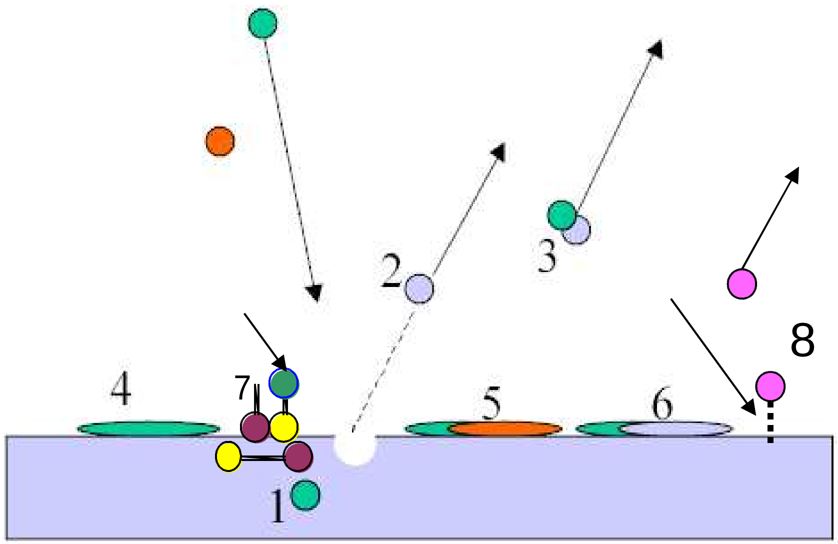
- Implantation (1) (E_k>10 keV)
- Sputtering (2)
  - Cleaning (8) (E_k<2 keV)
  - Deposition (4) (E_k<1 keV)
- Etching(3) (E_k ~ few eV)
- Deposition
  - Physical (4) (~ 0.5 to 50 eV)
  - Chemical (5,6)
- Surface Activation(7) (E_k ~ few eV)
  - Particles
  - Photons

electrons > Plasma
Fragments > Processes



Our R&D

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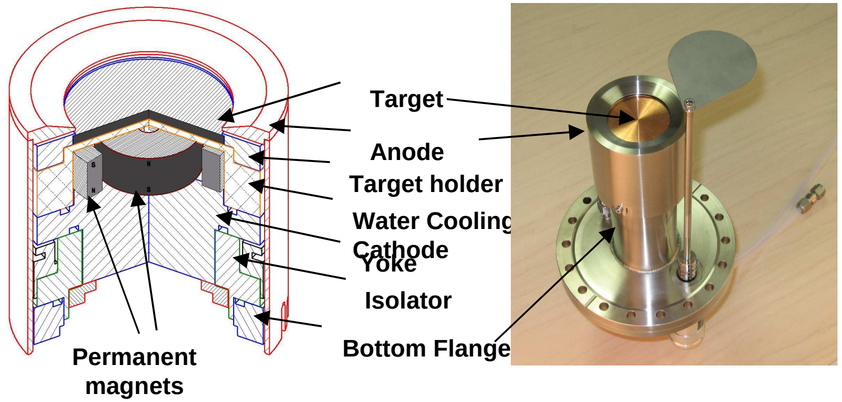
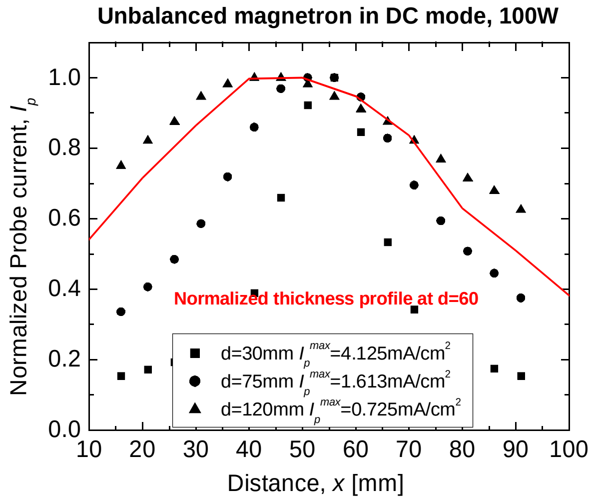
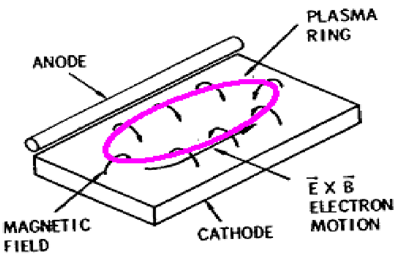
- Internal R&D
  - TOOLS and System Development
  - Process Development

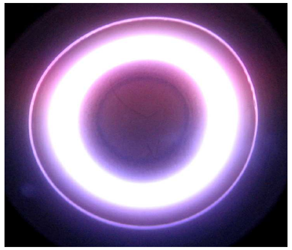
- Collaborative R&D
  - Applications
  - Process Development

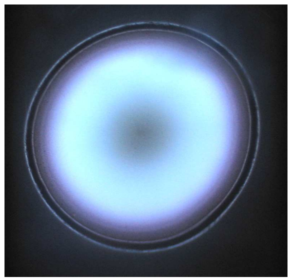
R et D internal

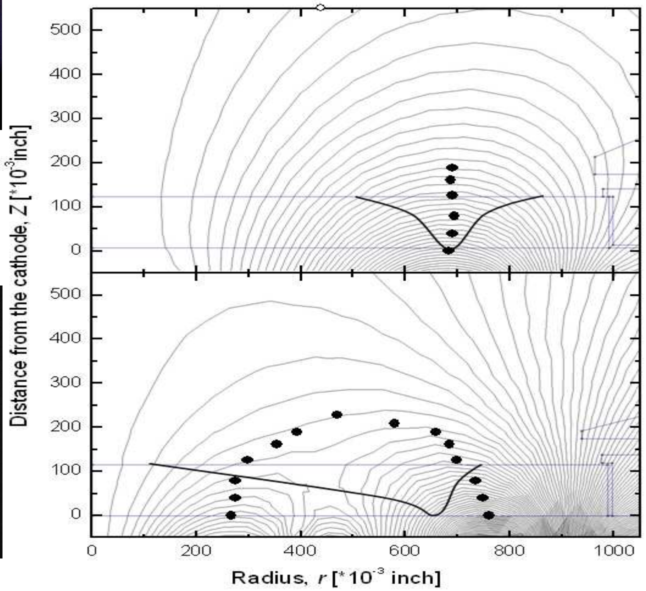


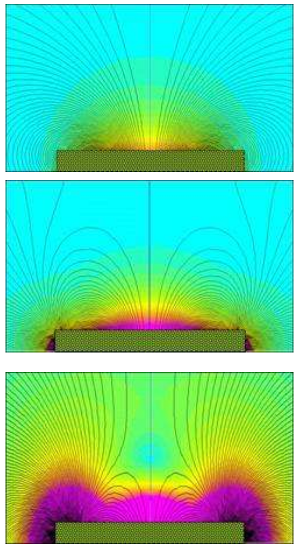












Collaborators

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INRS-EMT (since 1999, ongoing)

Prof. Claude Boucher (2001-2004) MRST, (Fusion)
Prof. François Martin (2003), NSERC-CRD
Prof. Federico Rosei (depuis 2005), NSERC-CRD
Prof. Barry Stansfield (depuis 1999) MRST, CRD
Prof. Alain Pignolet (depuis 2006)

Biomaterial Institute (Centre Hôpitalier de Université Laval)

Prof. Diego Mantovani (depuis 2000), CRD Project, NSERC-Strategic project (Biomaterial)
Prof. Gaetan Laroche (depuis 2000), NSERC-Strategic project (Biomaterial)

Université Laval (Dept. Adv. Mat., wood Science)

Prof. Bernard Riedl (NSERC-CRD)

Université de Montreal

Prof. A. Nanci (depuis 2005) , CRD (Dentistry)

Prof. Luc Stafford (depuis 2008), CRD (Physics)

McGill University

Prof. D. Perepichka (depuis 2005) NSERC-CRD

University of Saskatchewan

Prof. Akira Hirose (depuis 2001), NSERC-CRD
Prof. Chijin Xiao (depuis 2001), NSERC-CRD
Prof. Michael Bradley (depuis 2006)

University of Western Ontario

Prof. Andy Sun (depuis 2005)
Dr. James Noel (depuis 2006)

IREQ-HQ (1999-2001)

Dr. Alain Côté
Dr. Réal Décost

Groupe CTT (since 2000-2004)

Dr. Dominic Tessier

DRDC- Valcartier (2006)

Dr. Philppe Merel (depuis 2006)

FP-Innovation-FORINTEK (since 2008)

Dr. Vincent Blanchard
Dr. Pièrre Blanchet

ENEA- Frascati, Italy (1999 - 2003)

Dr. Riccardo de Angelis

CEA- Cadarache, France (depuis 2002)

Dr. James Gunn

Research Institute of Transplantology and Artificial Organs, Moscow- Russia (2002-2005)

Prof. Victor N. Vasilet

Cleaning Optical Networks

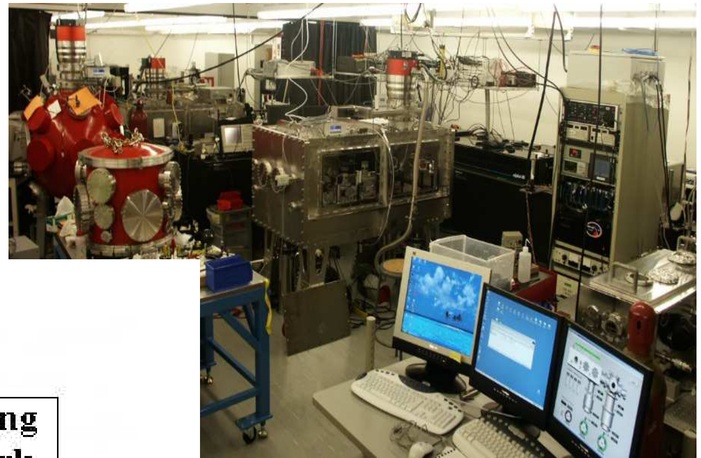
Motivation

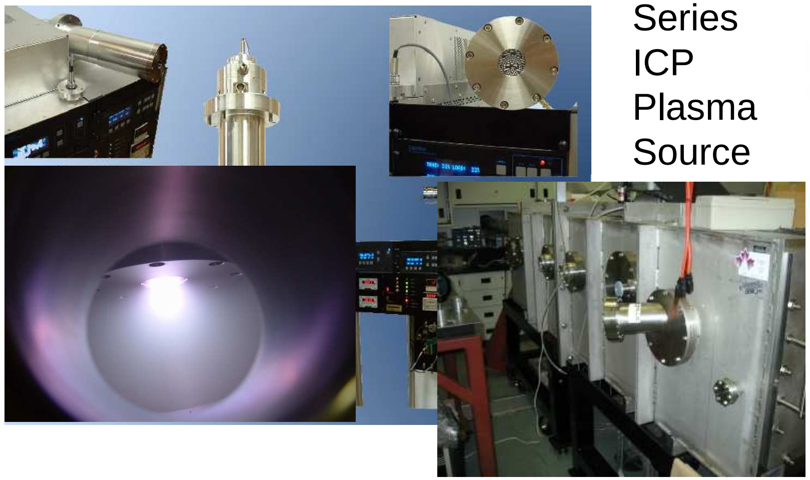
- A typical Problem on High power femtosecond laser infrastructures (200 TW) is the Contamination of Compressor Gratings and Mirrors
- Similar problem for Synchrotrons

Objective

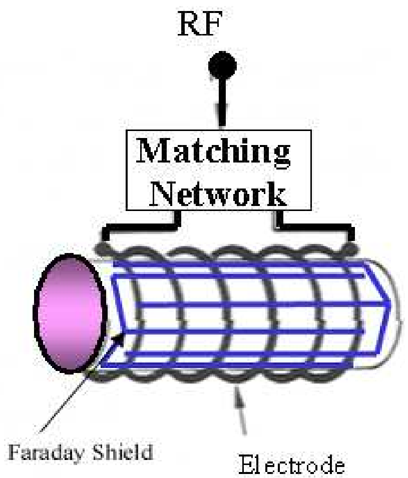
Develop Solution for in-situ cleaning

Collaboration with ALLS (prof. F. Martin et al.)

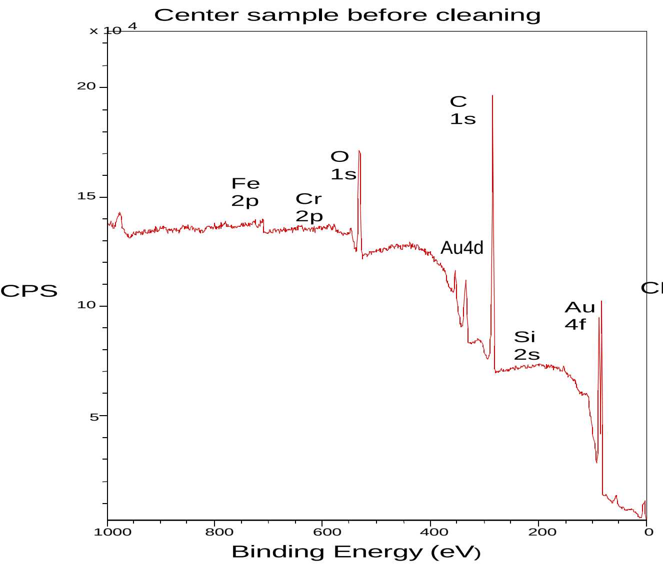


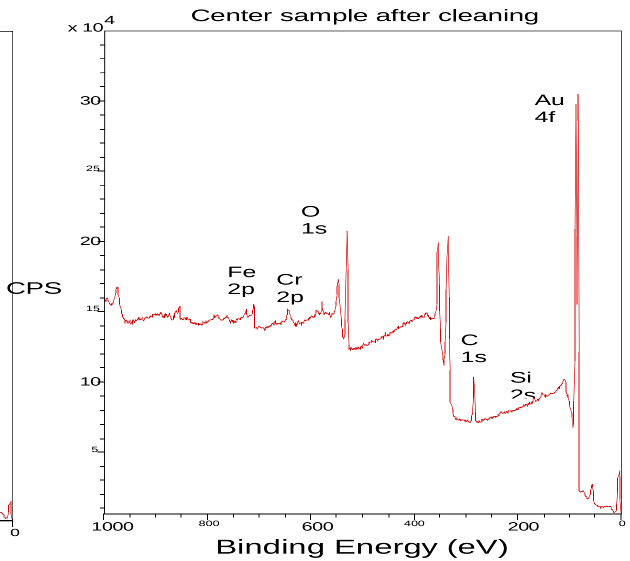


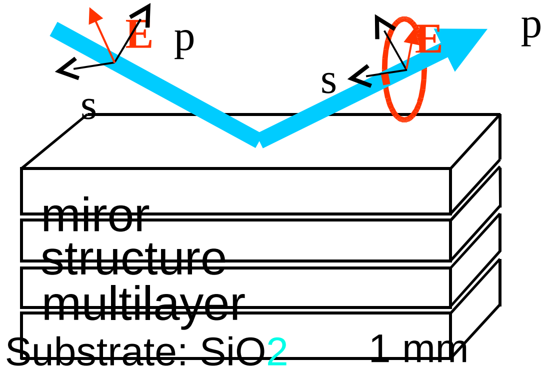
PLUME
Series
ICP
Plasma
Source



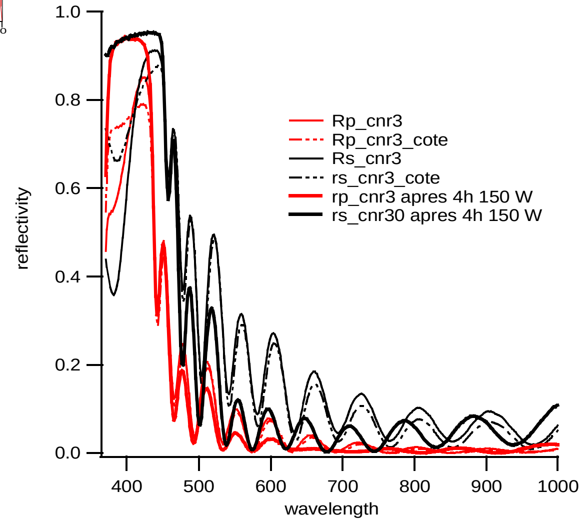
XPS and Reflectivity Measurements





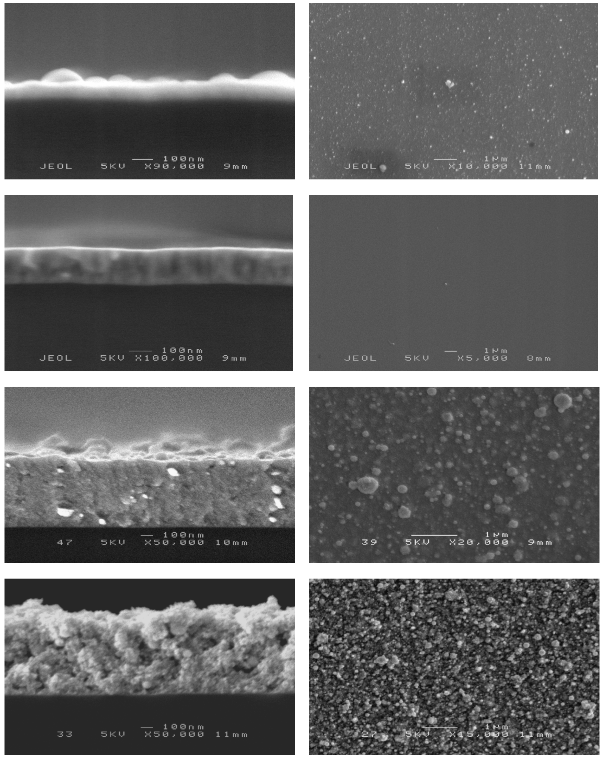


	New		Edge		Centre	
XPS peak	Before	After	Before	After	Before	After
Au4f	54	40	14	29	5	24
C1s	31	33	60	27	80	33
O1s	8	19	20	32	13	30
Fe2p	-	-	2	2	0.8	4



Synthesis of Thin Film by Pulsed Laser ablation

Collaboration with ALLS (prof. A. Pignolet)



Laser Pulse: 20 fs to 20 ns

Laser Energy: 4.5 mJ to 45 mJ

All other parameters were constant

Rotary Target: ZnO

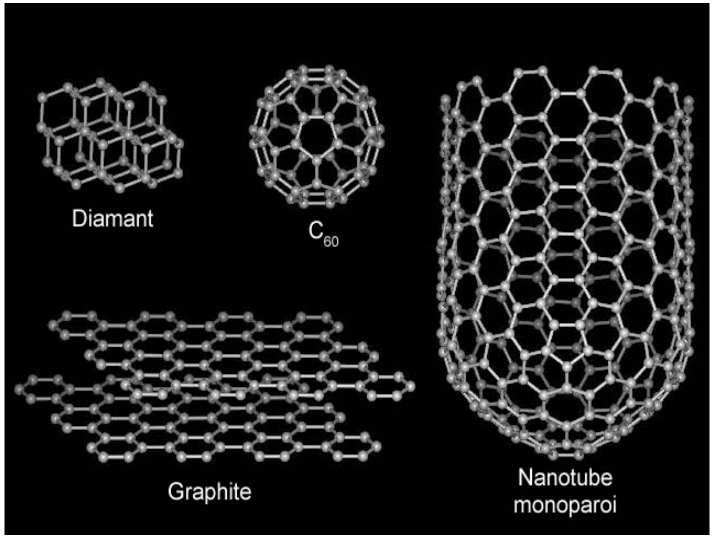
Substrate Temperature: RT

ZnO

Magnion Series SPLD-421

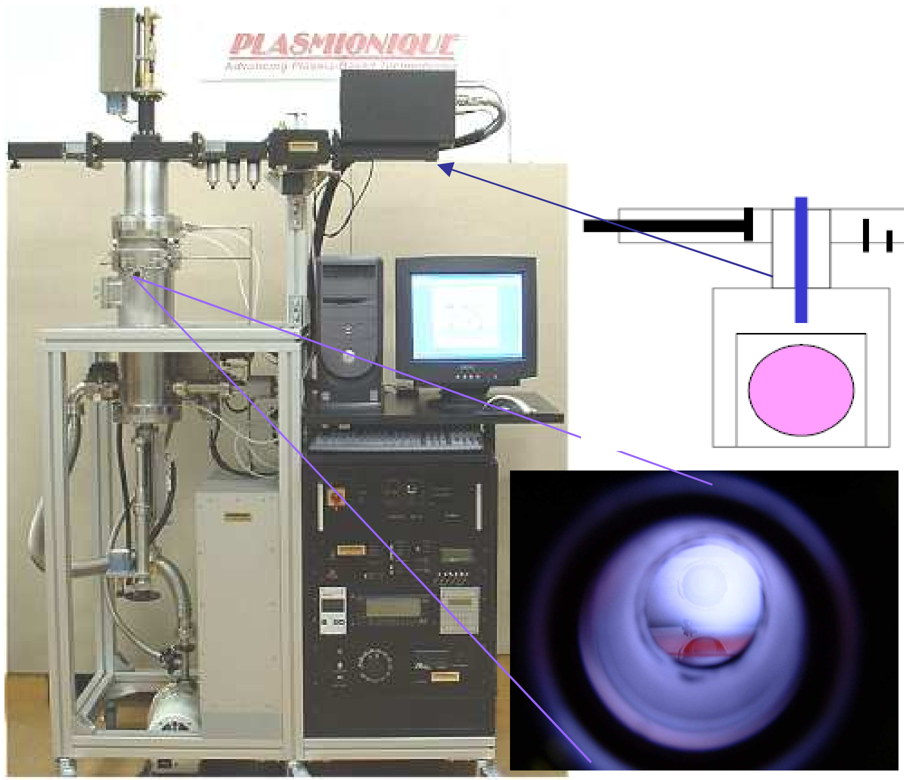
Synthesis of the Allotropes of Carbon and DLC

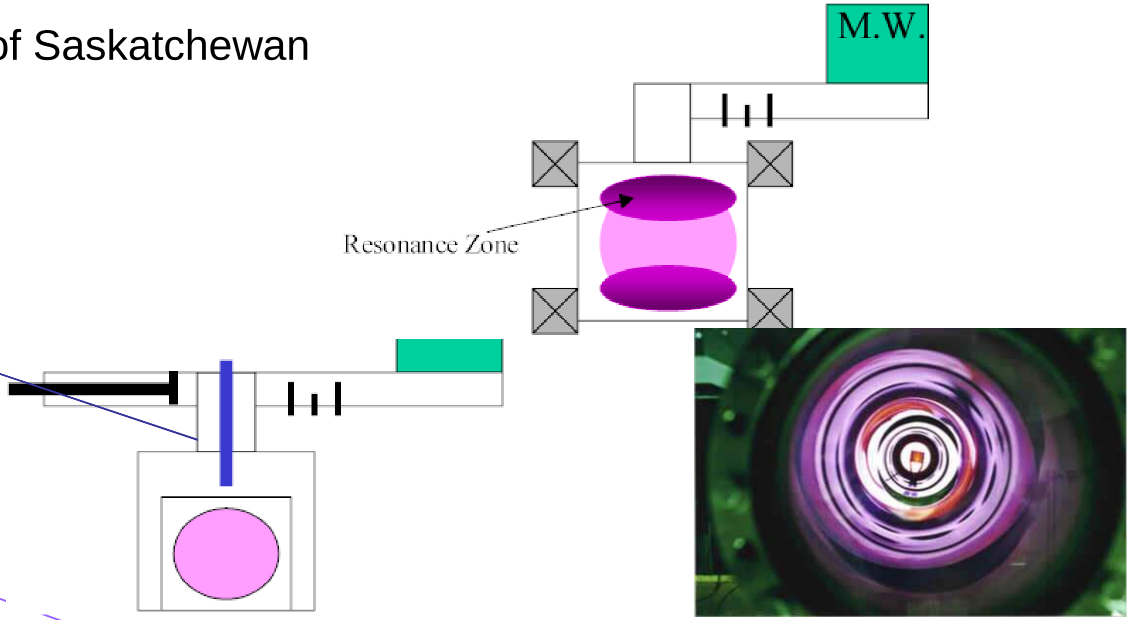
- The arrangement of carbon atoms determine the chemical and physical characteristics of the material
  - Graphite - sp2
  - Nanotube - Rolled Graphite
  - Diamond - sp3
  - etc



Microwave-PECVD Synthesis

Collaboration: A. Hirose et al., U of Saskatchewan





Motivation

- **Tribological application**
- **High power windows**
- **Sensors**
- **HT power electronics**
- **etc**

Graphite and Diamond Coatings

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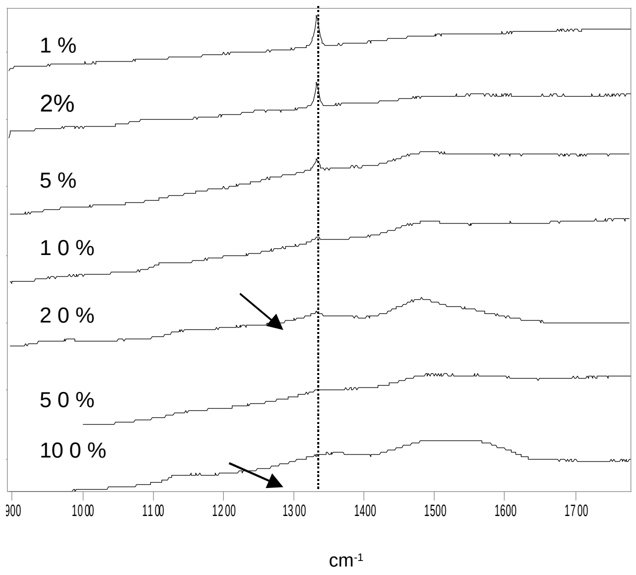
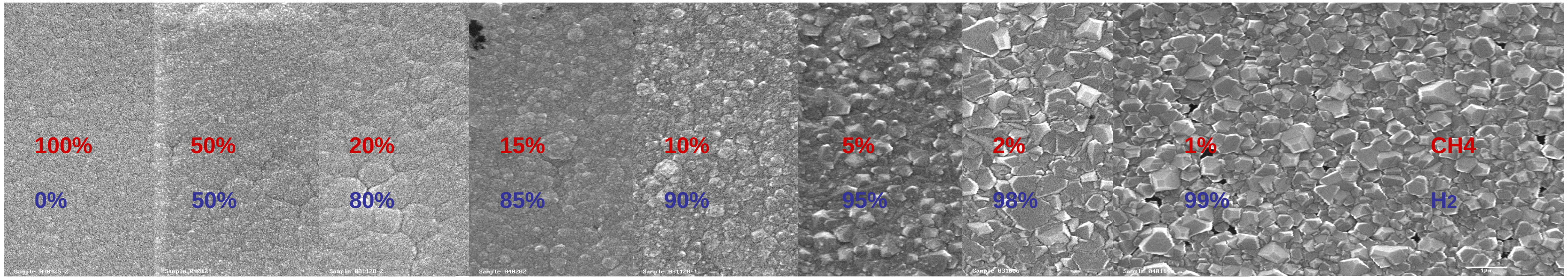
Substrat:
P-type (100) Si
Sample Preparation:
Ultrasonically scratched in diamond powders containing solutions
Operation Condition Microwave power: 1000 W,
Operation Pressure: 30 Torr,
Total Gas Flow rate: 50 sccm
Time: 2-8 h

Substrate temperature: 520 C



- Various Mixture of H2 and CH4
- Substrate Temperature ~ 550 degree C
- Increased ratio of sp3/sp2 with decreasing ratio of CH4/H2



Synthesis of CNT

Collaboration: Dr. P. Merel, et al., DRDC & Prof. A. Sun, et al., U. Western Ontario

Motivation

- **Interesting Physical Properties**
- **Variety of Applications**
  - **Hydrogen Storage**
  - **Field emission**
  - **Nanoelectronics/ optics**
  - **Sensors**
  - **Composite**
  - **etc**

Objectives

- **Simplifying Synthesis**
  - **Reduced Temperature**
- **Controlled Synthesis**
  - **Selectivity of Physical properties**

Using PECVD and PVD Processes

Typical Process Steps

1- Buffer Layer (Magnetron sputtering)

2- Deposition of Catalyst (Magnetron sputtering)

3- Heat Treatment (nano particle formation)

4- Reduction of Oxide (H2 plasma assisted)

5- Synthesis from Hydrocarbon gas mixture: PECVD

Advantage of PECVD vs CVD: Lowers Synthesis Temperature

Synthesis of CNT
RF-PECVD

In situ deposition of :

1) Buffer layer

2) Catalyst

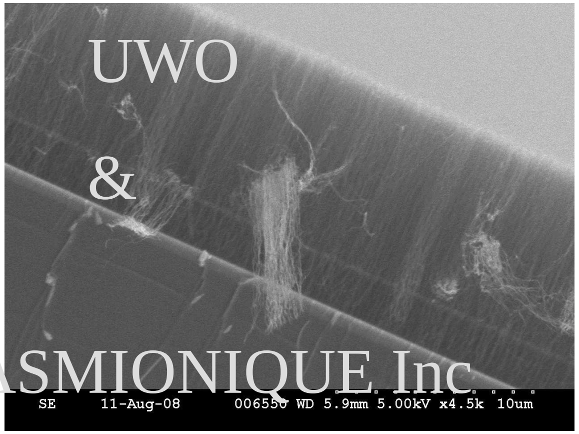
Followed by

3) Pre treatment

4) Synthesis

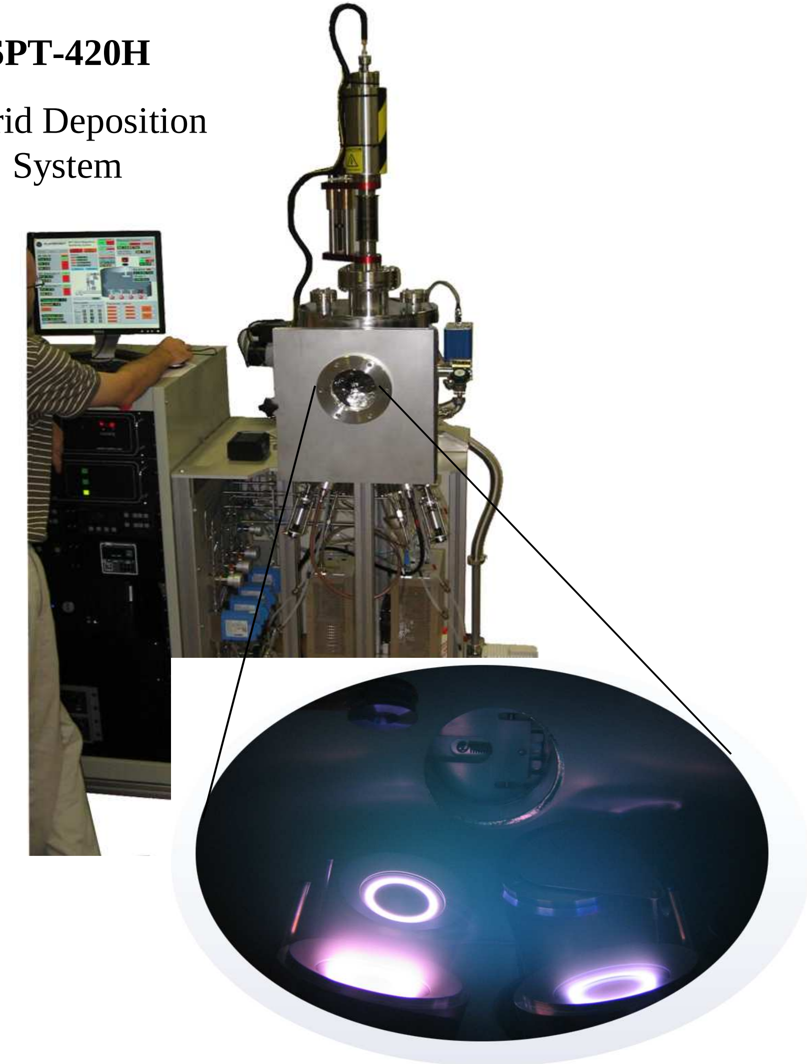
without exposing system to air

LOW Temperature Synthesis

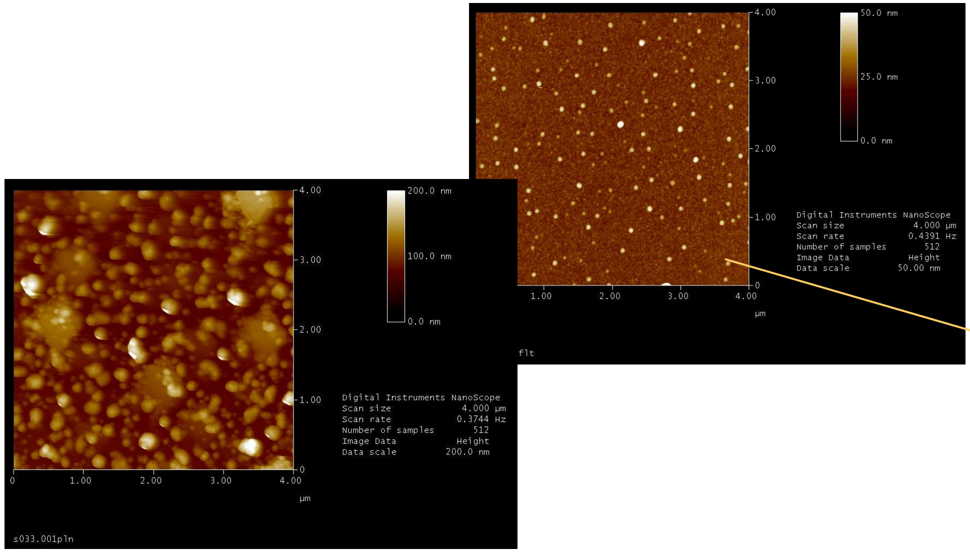


SPT-420H

Hybrid Deposition System



Synthesis of CNT (MW-PECVD)



20 min growth

Ni thickness

2.7 nm

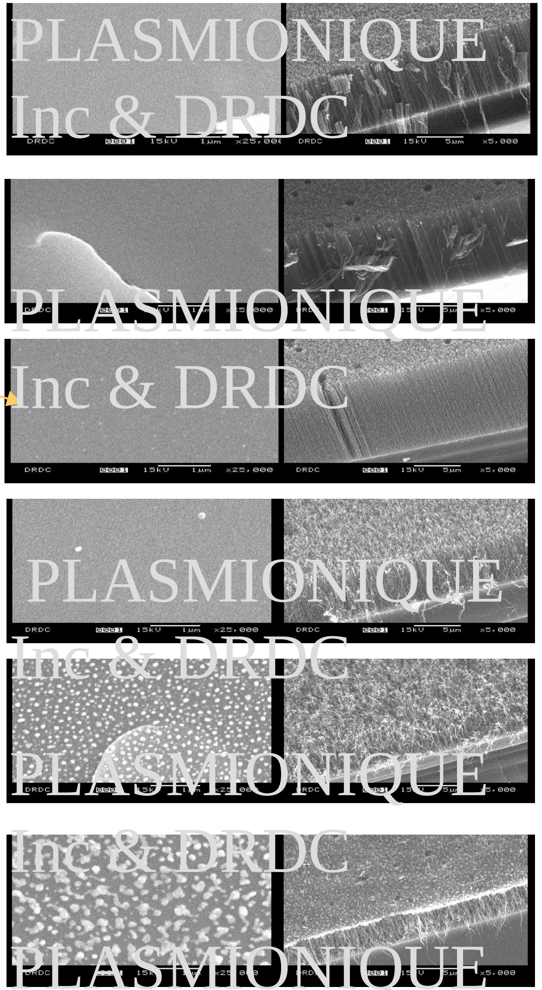
3.4 nm

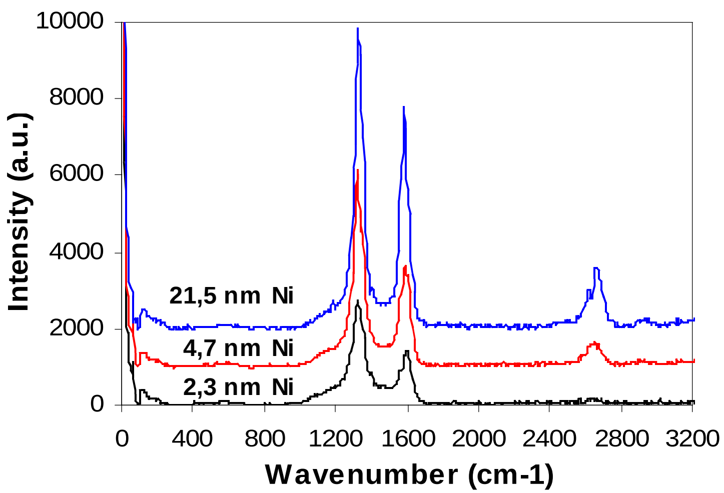
3.9 nm

4.7 nm

9.1 nm

21.5 nm





Improving Haemocompatibility of PTFE (Teflon)

Motivation

Collaboration with l'Université Laval (profs. Mantovani et al. (U Saskatchewan), Hirose, et al., Vasilet (Moscow)

- PTFE is currently a material of choice for vascular prosthesis

- After implantation, thrombosis and restenosis, are often observed

- 65% of synthetic prostheses must be replaced in the 10 years following implantation, usually due to thrombosis

Objectives

Carbon-based coating of PTFE, using plasma-based deposition techniques, has been studied as a possible route to improve the bio- and haemocompatibility of PTFE implants

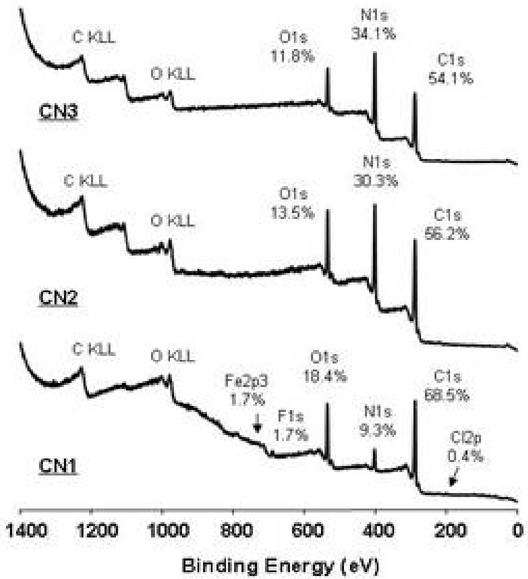
Coating on PTFE

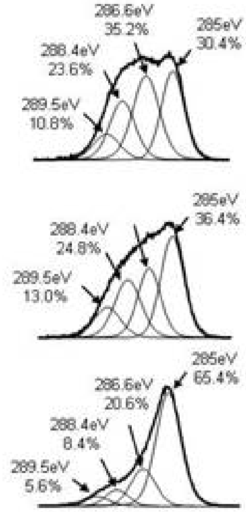
- Reactive Magnetron Sputter Deposition Technique

- Graphite targets

- Sample temperature <50℃.

Improving Hemocompatibility of PTFE (Teflon)

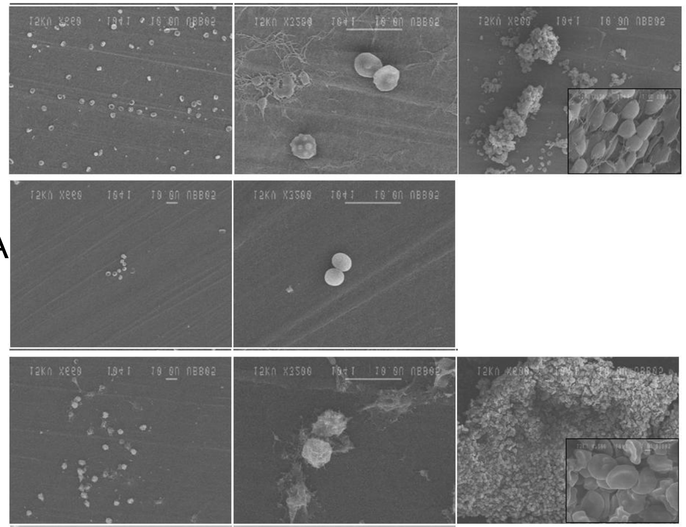


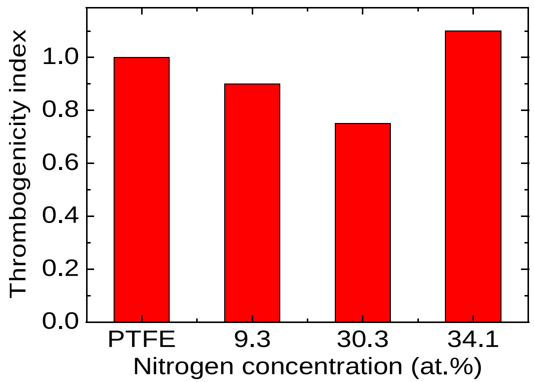


PTFE

Treatment A

Treatment B





Surface After Contact with Whole Blood

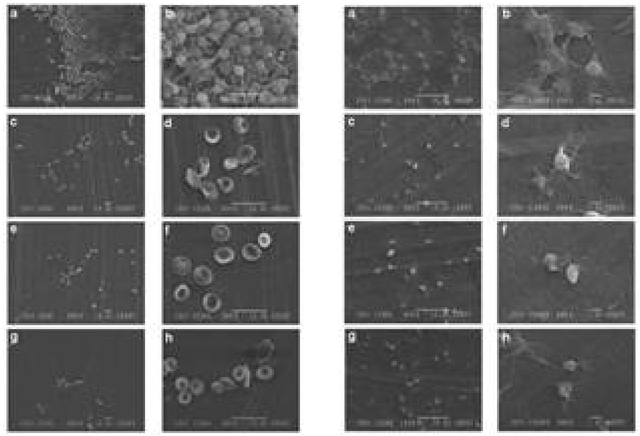
Platelet adhesion

PTFE

9.3% N

30.3% N

34.1% N



Improving Osseointegration

Objectives

Modification of the surfaces of Ti an Ti-based alloys for improved osseointegration of medical implants

Motivation

- Titanium and its alloys are a material of choice for implants used in dental or hip replacement procedures

- Bone adhesion is a critical issue

Collaboration with INRS-EMT,McGill and UMontreal (profs. Rosei, Prepichka, Nanci)

Surface Treatment Methods

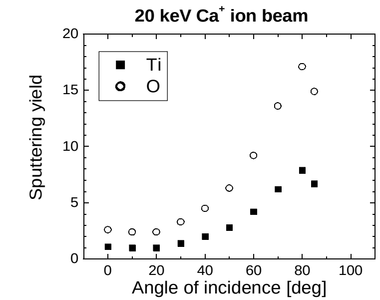
- Surface Coating
- Selective Surface

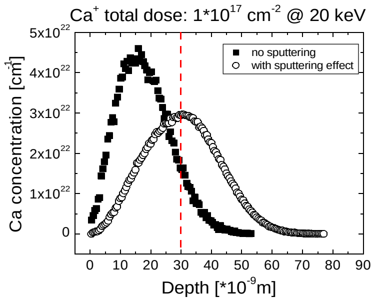
Nanotexturing

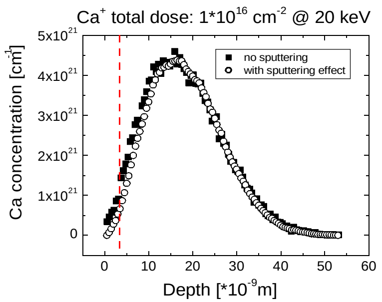
- Surface Doping
- Hybride Techniques

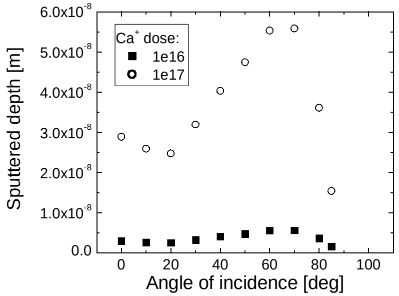
Improving osseointegration

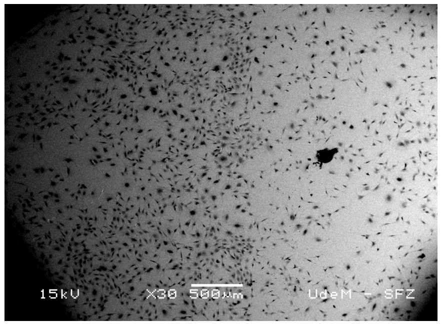
Ca Ion Implantation





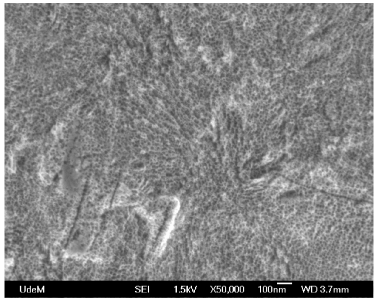




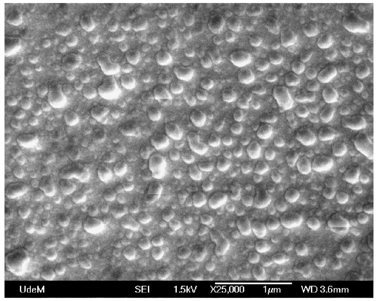


Ca Sputter deposition and ion mixing

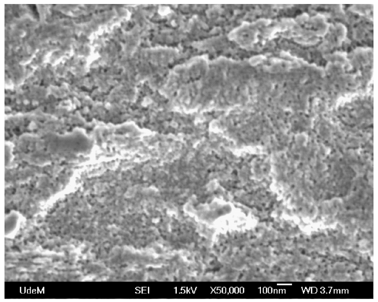
Reference Nanostructured Surface



Ca Sputter deposition Case 1



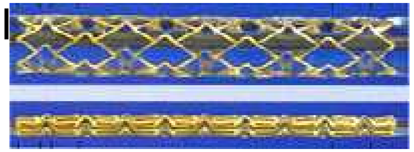
Ca Sputter deposition Case 2

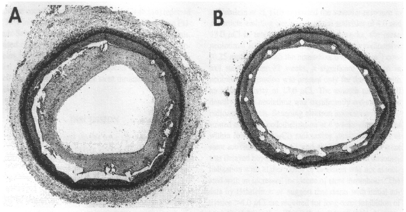


Surface Modification
Cardiovascular Stents

Objectives

- Improving Treatment of Artery Bl
  - Balloon Angioplasty
  - Stenting





- Endovascular brachytherapy (stents)
  - Radioactive stents
    - ^{32}P: pure beta-emitter
    - E_{max} = 1.7 MeV
    - Path in biological tissues: 2-4 mm
    - Half-life: 14.2 days

Motivation

- Restenosis Rate (about 30%-40%)

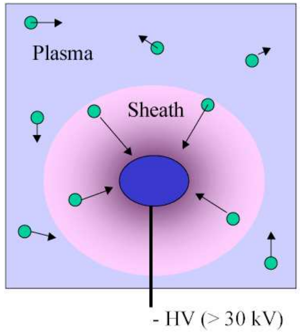
Approach

Surface Modification of Stents

- Coating (Polymer, Drugs)
- Ion Implantation of Radioisiotopes

PBII Application

- Efficient
- Compact
- Minimize Contamination



Gold deposited cardiovascular stent

PBII of Radioisotopes

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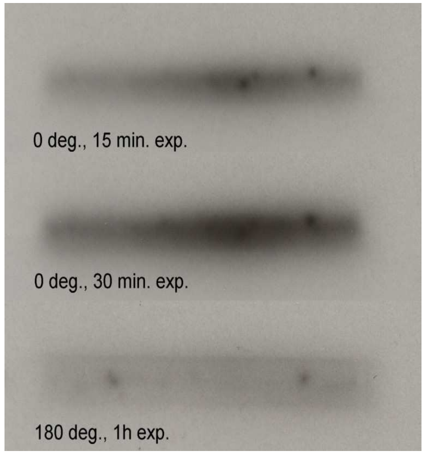
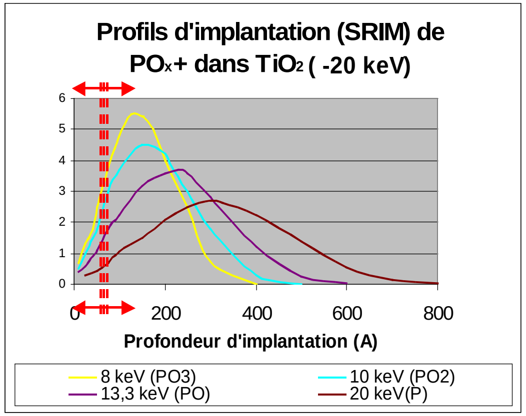
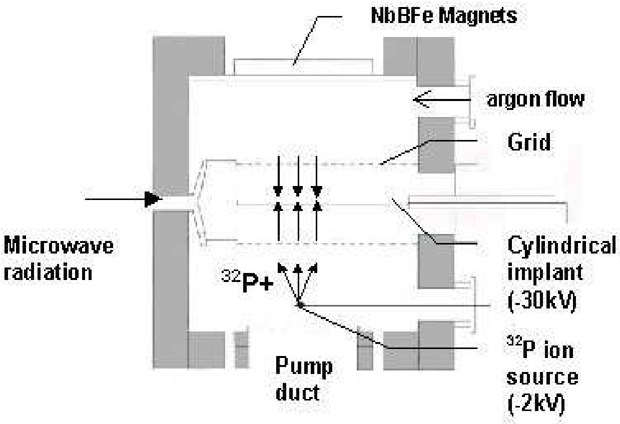
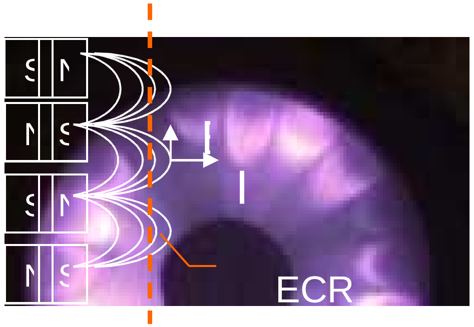
Process Steps

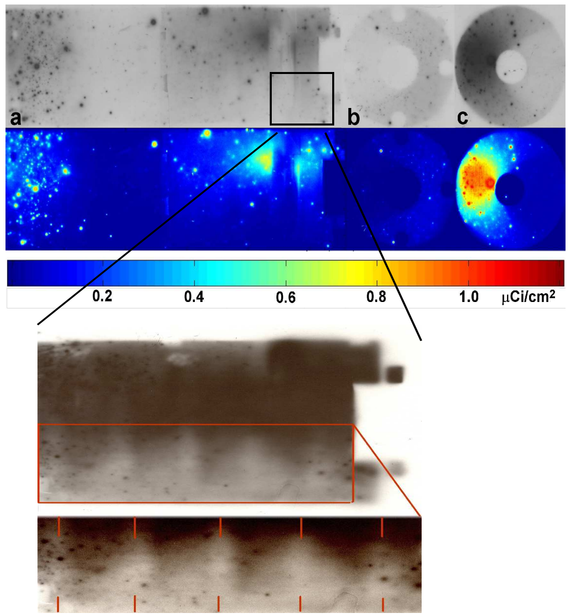
- Sputtering for P injection in Plasma
- Ionization of P by Ar Plasma for
- Extraction and Implantation in Stents











PBII of Radioisotopes

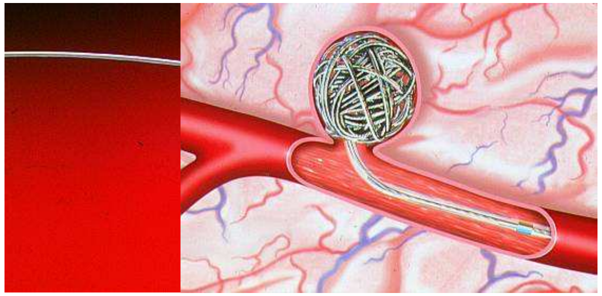
Radioactive Stents DO NOT WORK

- Accelerate Restenosis at Tips

↓

Other Applications

- Occlusion of aneurysms
  - J. Raymond, P. Leblanc, A. C. Desfaits et al., Stroke **33** (2), 421 (2002)

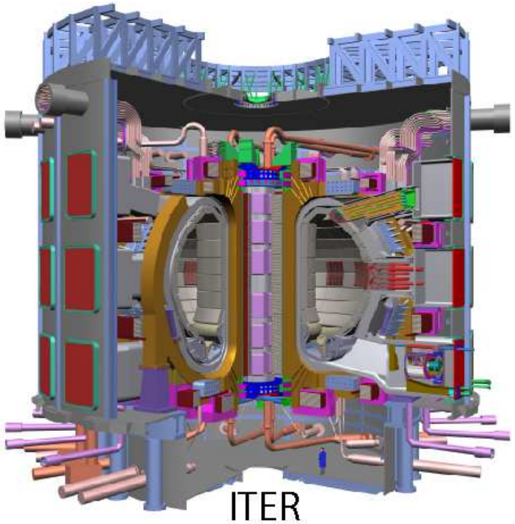


ß-emitting Short life-time radioisotopes are POWERFUL TOOLS to study PLASMA TRANSPORT

↓

Other Applications

- Material Erosion, Transport and Redeposition Study in a Nuclear Fusion Reactor



Conclusions and Comments

- The plasma state of matter, and in particular, the nonequilibrium plasma offers interesting opportunities for Surface Engineering and Advanced Material Synthesis

- The Plasma-Assisted processes impacts variety of field

- The environmental concerns and the requirements for improved products are the driving forces for the proliferation of Plasma Technology