First HiPIMS activities at Politecnico di Milano

POLITECNICO MILANO 1863

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NanoLab

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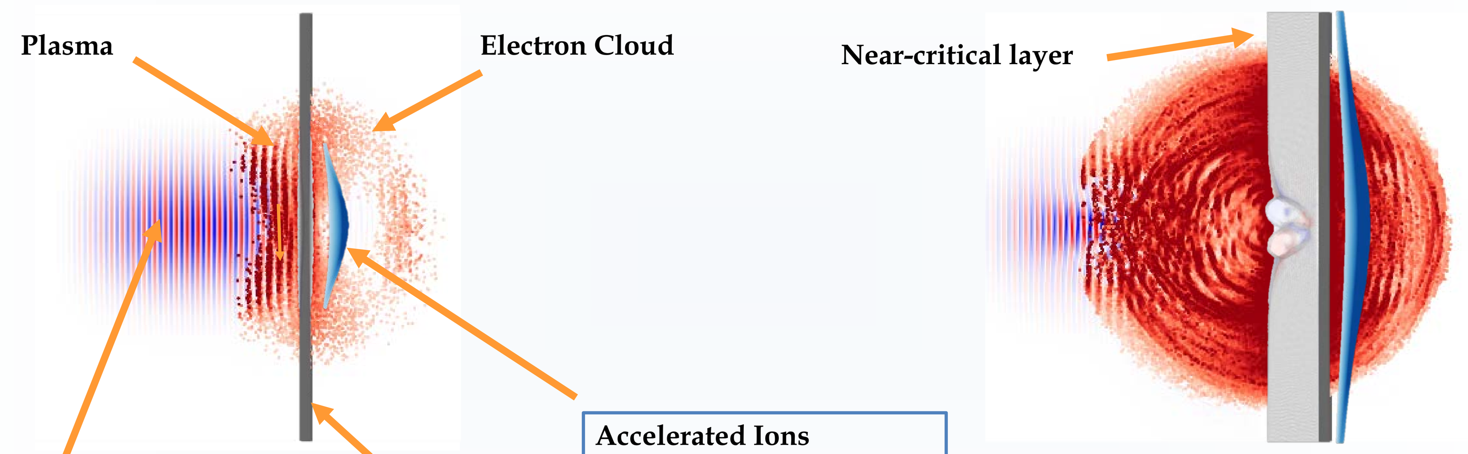
Innovative techniques of particle acceleration

Laser driven ion acceleration (TNSA): a non conventional technique to accelerate ions



Laser Pulse
- 10 fs -1 ps
- $> 10^{18}$ W/cm²

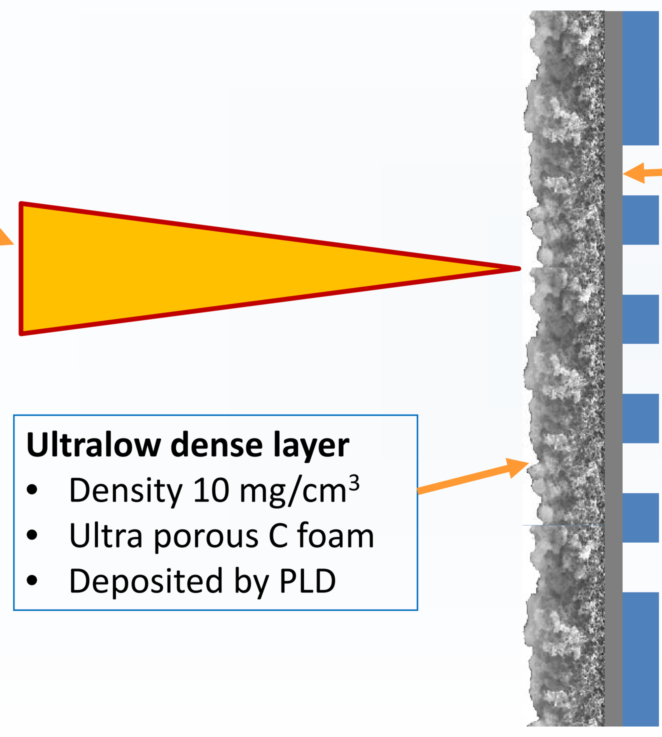
Target
- solid foil
- nm-µm

Accelerated Ions
- $E_{max} \approx 60$ MeV (H+)
- good collimation
- ps ion bunches
- 10^{11}-10^{12} ions/bunch

Enhanced TNSA
- Near-critical layer (density of few mg/cm³) micrometer thick
- More and hotter relativistic electrons
- More ions at higher energy

M. Passoni et al. *Phys Rev Acc Beams* **19.6** (2016)
A. Macchi et al., Rev. Mod. Phys., 85 751 (2013)

Deposition of novel targets by HiPIMS

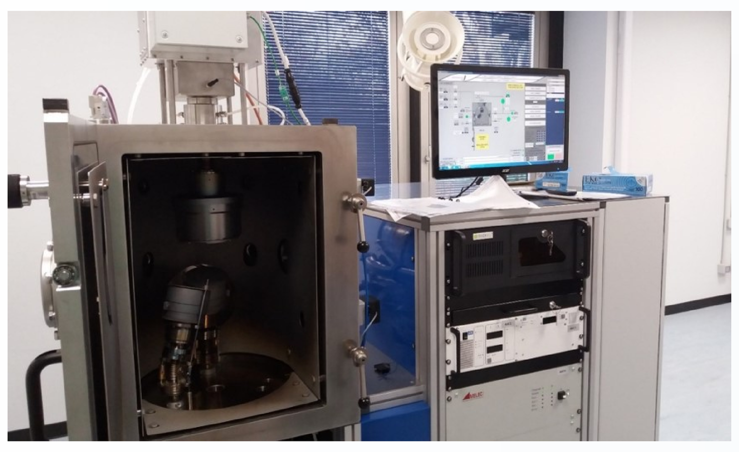


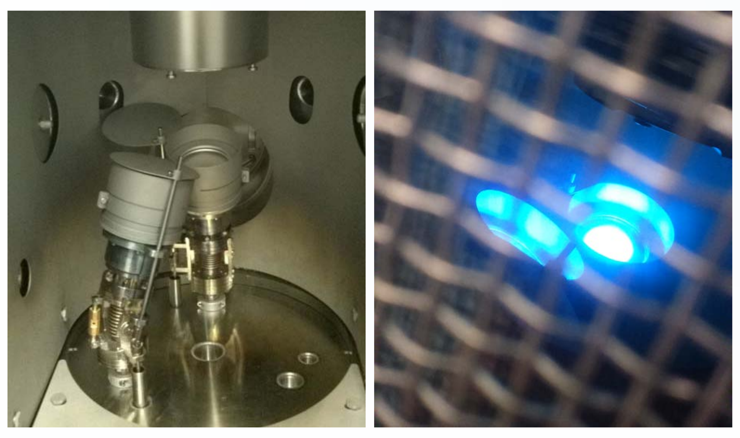
Solid free standing layer
- Usually a thin metallic foil (e.g. Al, Ti, etc.)
- Layer thickness (10s of nm up to 10 µm) influences max. energy of ions
- Roughness affects experiment reproducibility
- Possible presence of holes
- Need of carefull positioning

Ultralow dense layer
- Density 10 mg/cm³
- Ultra porous C foam
- Deposited by PLD

Deposit target by HiPIMS
- Wide variety of materials
- Different compositions
- Smooth films
- Direct deposition on the holder
- **Need of free-standing films on mm sizes**

HiPIMS apparatus @ POLIMI

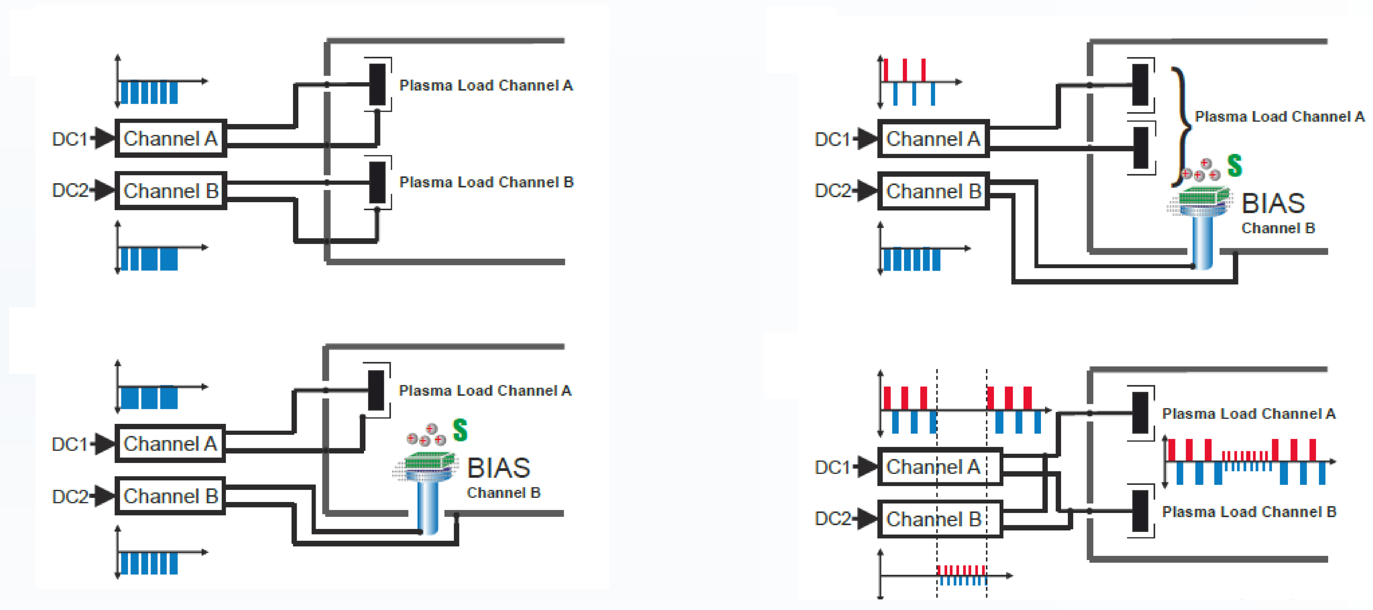




Apparatus Features
- Two 3 inch cathodes in sputter up configuration
- Two generators with positive and negative polarity output
- Four inch anode as substrate holder
- Substrate heater up to 400° C
- Three process gas lines
- Four channel oscilloscope for monitoring of pulse current
- 1200 l/s TMP reach high and fast vacuum conditions

Pulse genetator features	Channel A 6 kV	Channel B 1.5 kV
Pulse output voltage	+/- 1 kV	+/- 1 kV
Pulse Time Conditions	UP+; UP-; BP	UP+; UP-; BP
HiPIMS ON time	T_{on} +/- ≥ 20 µs	T_{on} +/- ≥ 20 µs
HiPIMS OFF time	T_{off} +/- ≥ 20 µs	T_{off} +/- ≥ 20 µs
HiPIMS freq. conditions	$\Sigma (T_{on} + T_{off}) \geq 500$ µs (2 kHz)	
MF ON and OFF times	$T_{on/off}$ +/- ≥ 5 µs	$T_{on/off}$ +/- ≥ 5 µs
MF Frequency conditions	$\Sigma (T_{on} + T_{off}) \geq 20$ µs (50 kHz)	

Different HiPIMS configurations

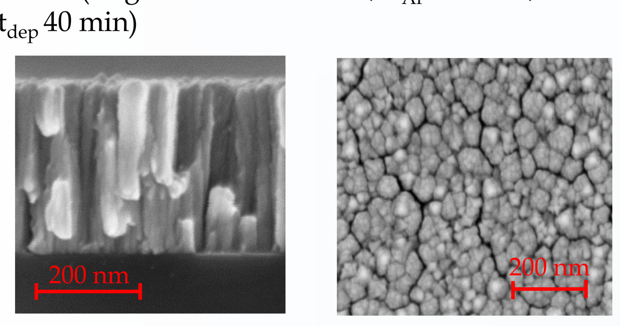


1. Two independent unipolar HiPIMS source
2. Unipolar HiPIMS source + Bias (properly synchronized)
3. Bipolar HiPIMS source + Bias (properly synchronized)
4. Superimposed Bipolar HiPIMS source + MF

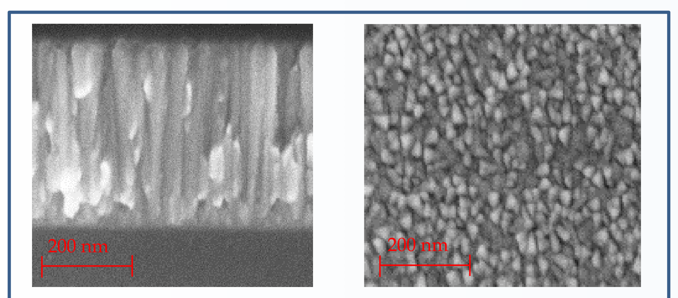
Role of process parameters and deposition schemes

As a first attempt deposition of stainless steel investigating the role of process parameters

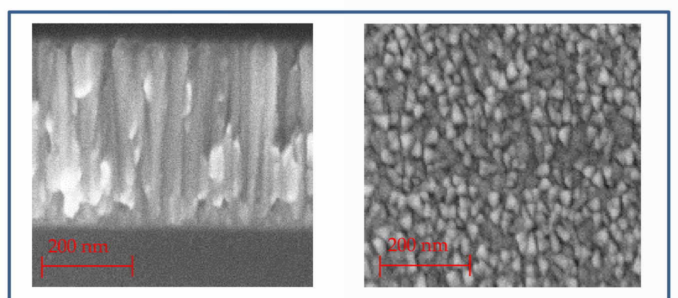
dcMS (target = Stainless Steel, P_{Ar} = 1.3 Pa, t_{dep} 40 min)



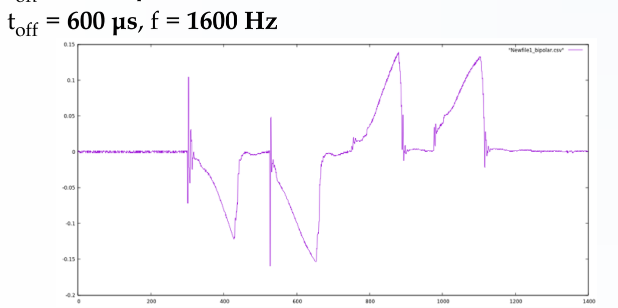
V1 = 550 V



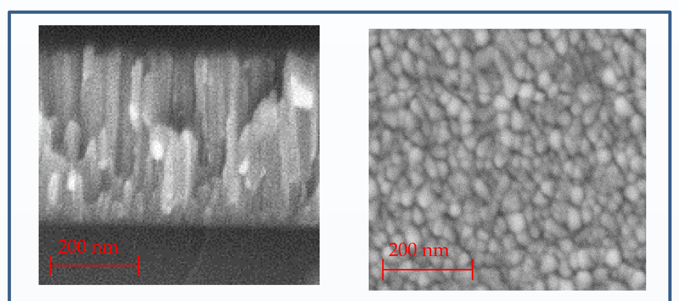
V1 = 800 V, V2 = 50 V (bias), t_{on} = 25 µs, t_{off} = 600 µs, f = 1600 Hz



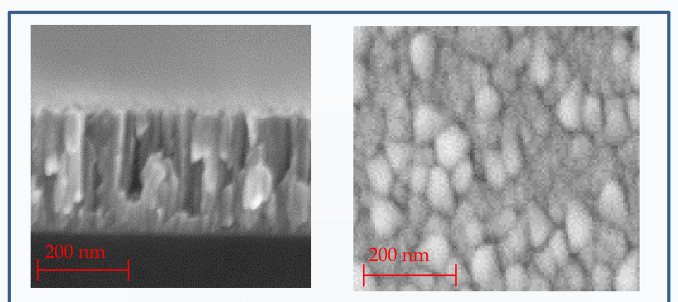
V1 = 800 V, V2 = 50 V (bias), t_{on} = 4 x 25 µs BIPOLAR, t_{off} = 600 µs, f = 1600 Hz



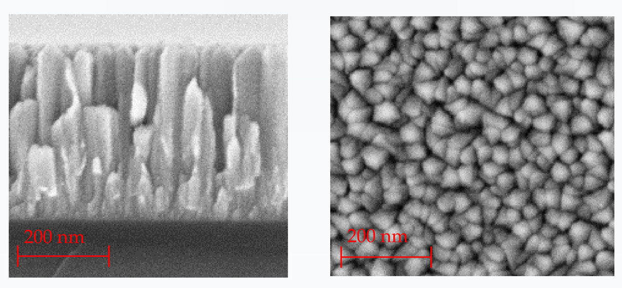
HiPIMS (target = Stainless Steel, P_{Ar} = 1.3 Pa, t_{dep} 40 min)



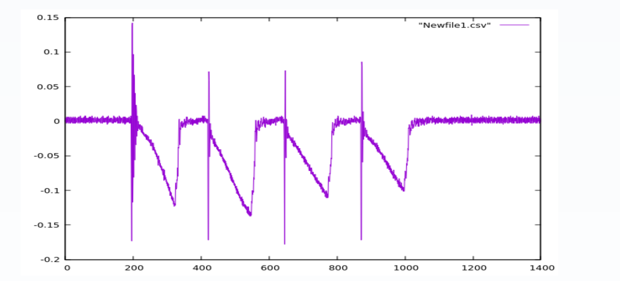
V1 = 800 V, V2 = 50 V (bias), t_{on} = 100 µs, t_{off} = 2400 µs, f = 400 Hz



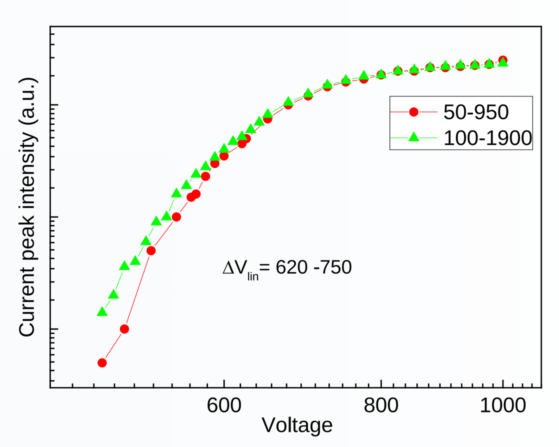
V1 = 800 V, V2 = 50 V (bias), t_{on} = 4 x 25 µs UNIPOLAR, $t_{off,1}$ = 20 µs, $t_{off,2}$ = 2340 µs, f = 1600 Hz

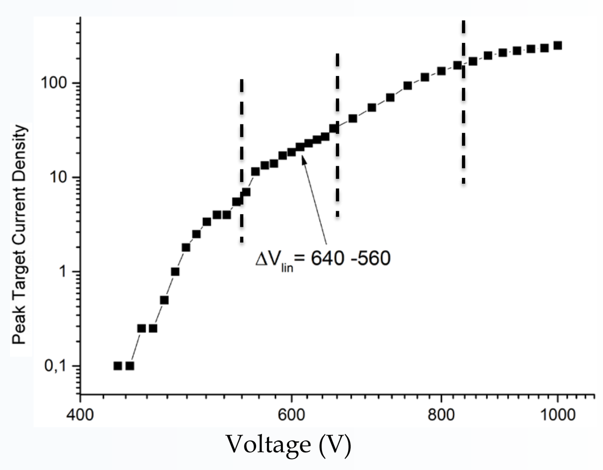


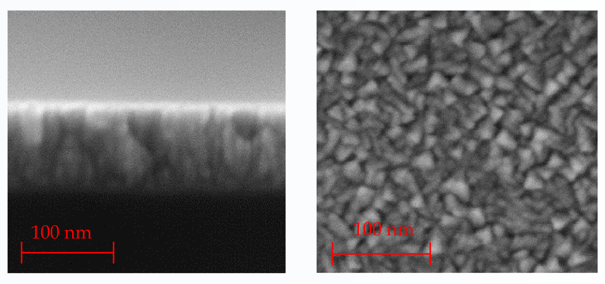
V1 = 1000 V, V2 = 200 V (bias), t_{on} =4 x 25 µs UNIPOLAR, $t_{off,1}$ = 20 µs, $t_{off,2}$ = 2340 µs, f = 1600 Hz



I-V characteristics







V1 = 650 V, P_{Ar} = 0.9 Pa, t_{on} = 25 µs, t_{off} = 475 µs, no bias

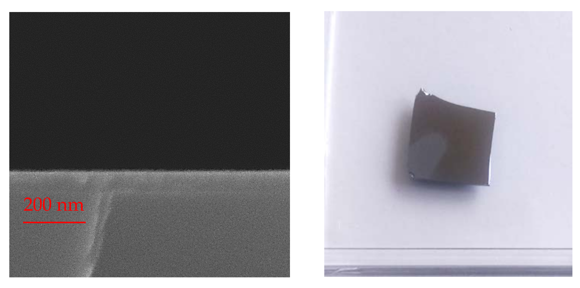
Preliminar Analysis
- Film morphology affected both by pulse voltage and bias
- Bipolar mode seems to have little effect compared with unipolar one
- Check of the I-V characteristics is a possible route to determine the different deposition regimes

Comparison with Pulsed Laser Deposition

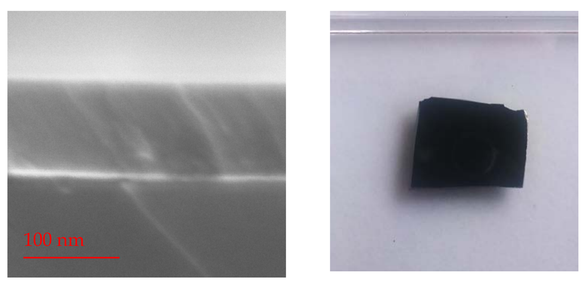
Deposition of compact carbon coatings with two different high energy PVD techniques: HiPIMS and Pulsed Laser Deposition.

HiPIMS process parameters
target = Carbon,
P_{Ar} = 0.9 Pa,
t_{dep} 40 min
V1 = **900 V**, V2 = **0 V** (no bias),
t_{on} = **4 x 25 µs UNIPOLAR**,
$t_{off,1}$ = **20 µs**,
$t_{off,2}$ = **2340 µs**, f = **1600 Hz**

Pulsed Laser Deposition process parameters
Target: Carbon
Laser wavelength: 532 nm,
Pulse energy: 300 mJ, 10 Hz,
Laser fluence: 2.5 J/cm²,
Atmosphere: vacuum

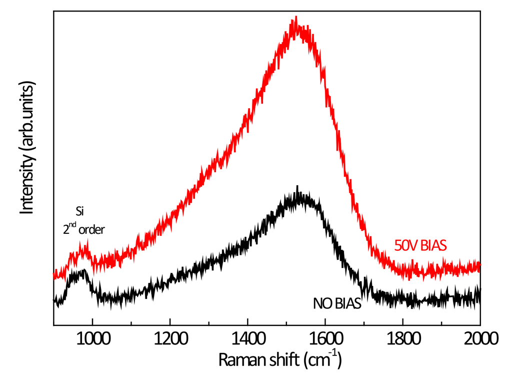


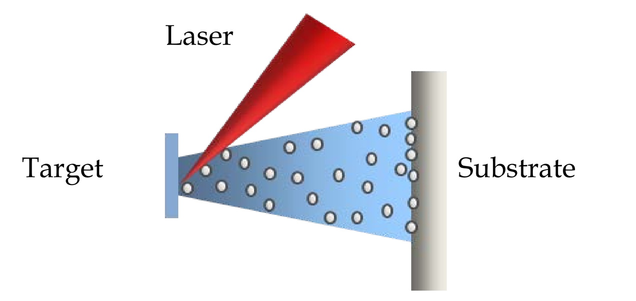
V2 = **0 V** (no bias)

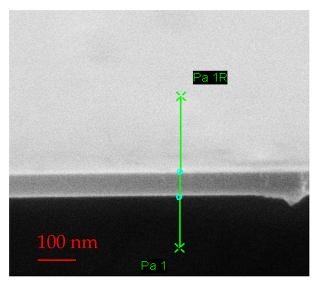


V2 = **50 V** (bias)

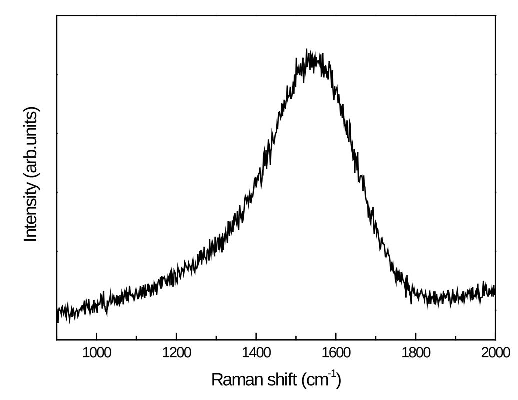
Raman Analysis







Raman Analysis



Preliminar Analysis
- Amorphous compact morphology
- Bias greatly influences thickness 30 nm vs 60 nm
- Similar morphology compared with Pulsed Laser Deposition
- From Raman analysis Carbon deposited at higher energy with PLD