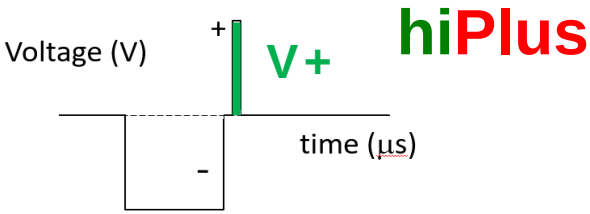
The role of HiPIMS and Discharges with a Positive Voltage Reversal on Coating Properties in Industrial Applications such as Hard Coatings and DLC

Frank Papa[1,2], Dr. Iván Fernández Martínez[2], Ambiorn Wennberg[2], Gerhard Eichenhofer[3]

[1]Gencoa USA, Medina, Ohio USA
[2]Nano4energy , Madrid Spain
[3]Hip-V, Stocksund, Sweden
[4]4A-Plasma, Holzgerlingen, Germany



nano4ENERGY

Jose Antonio Santiago
Jon Molina
Miguel Monclus

Iván Fernández Martínez
Ambiorn Wennberg

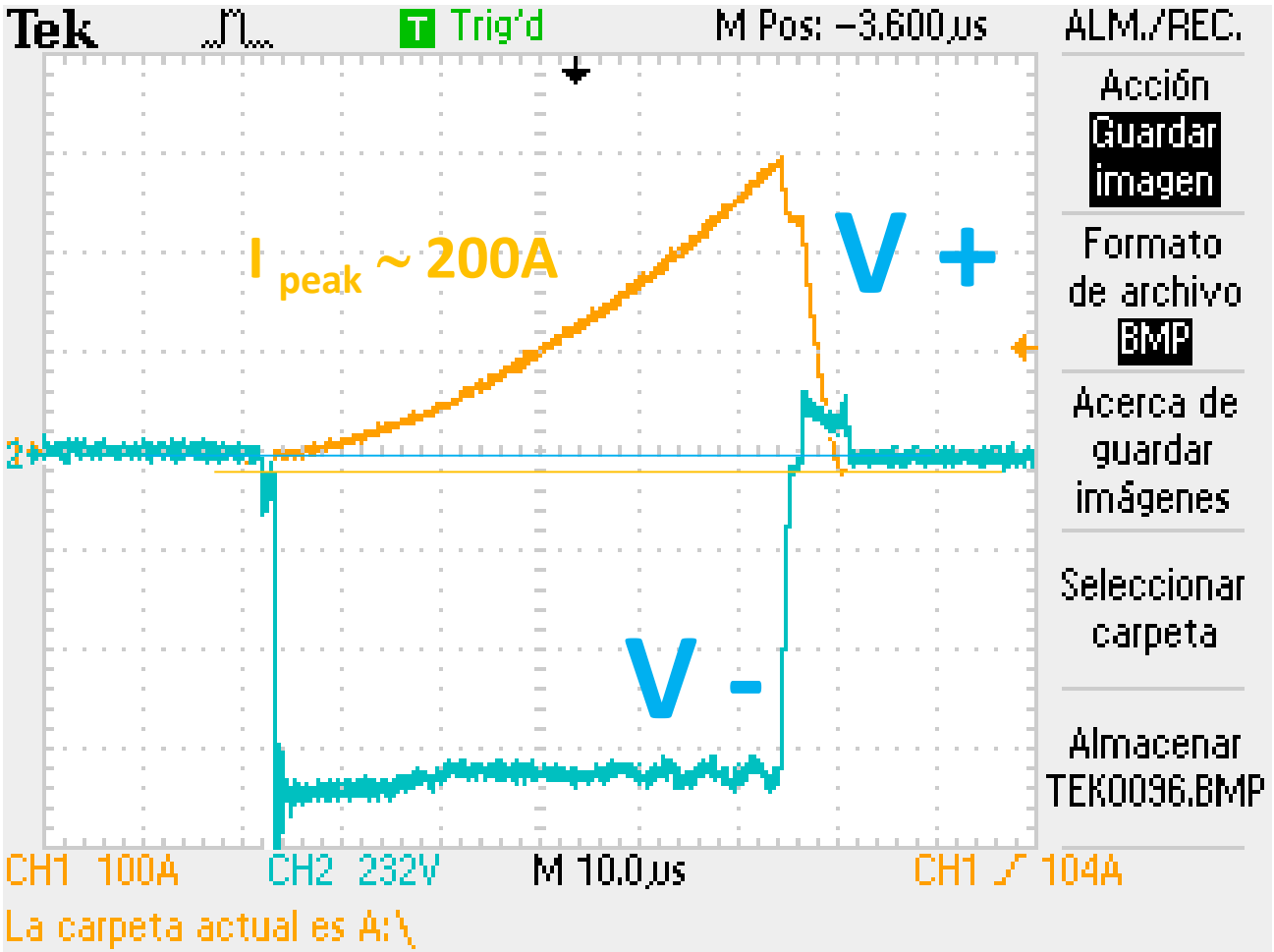
Raquel González-Arrabal

Juan C. Sanchez-Lopez
Cristina T. Rojas
J.Miguel García

Victor Bellido-González

Tomás Kozác
Jiri Capek
Petr Zeman

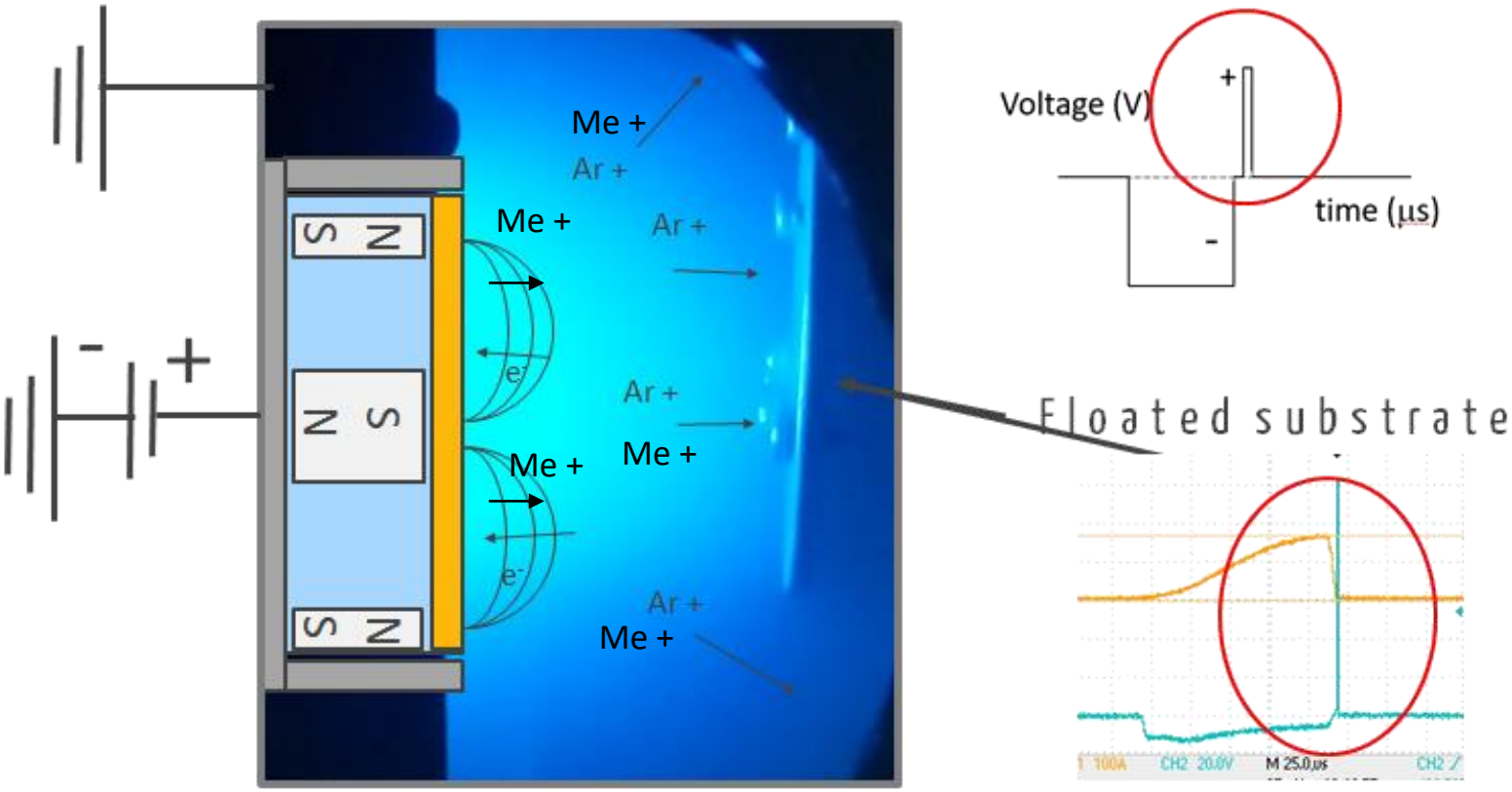
HiPIMS with V+



High density of ions in HiPIMS, so…..

……any effect on plasma and coating properties?

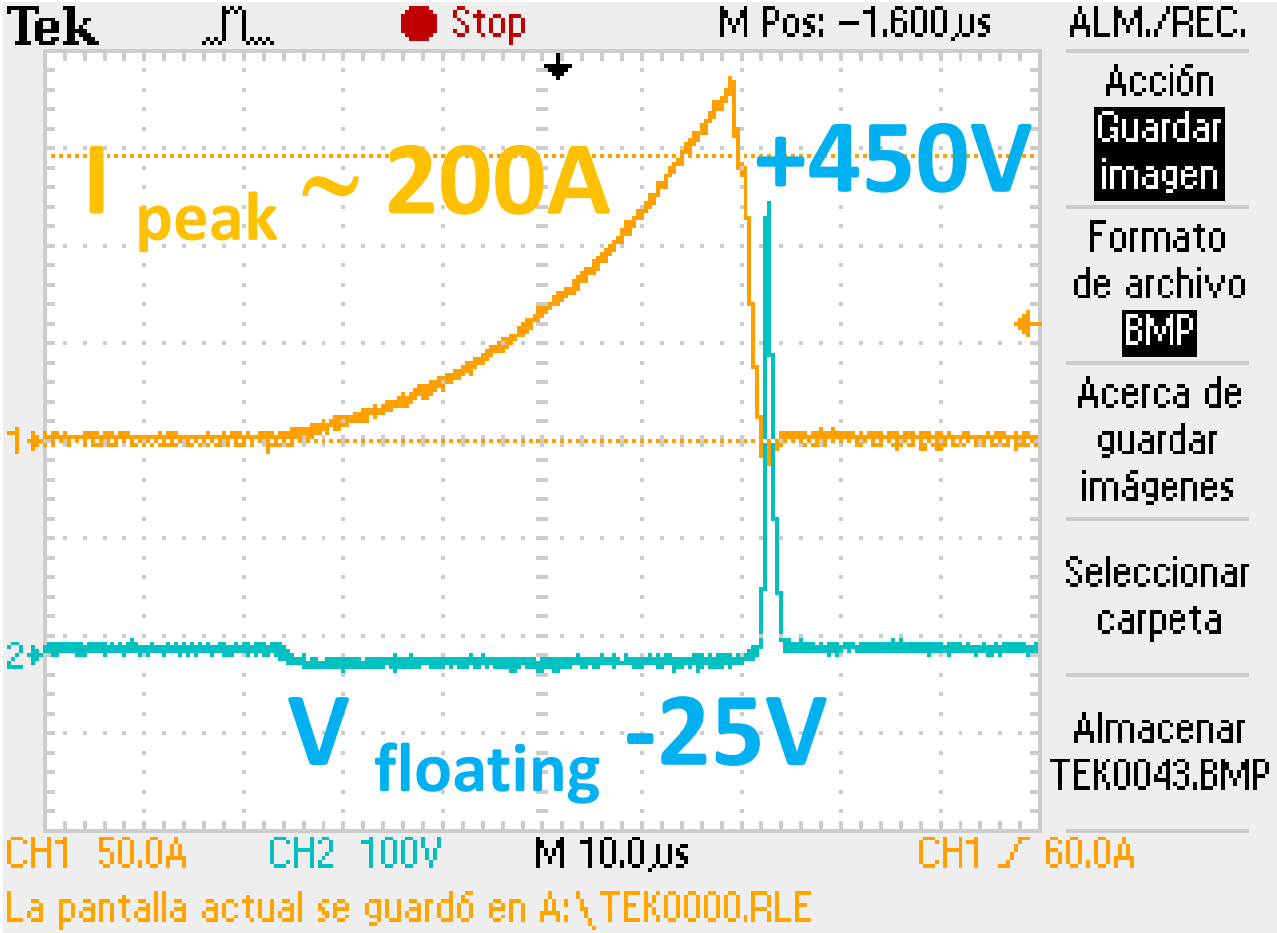
HiPIMS with V+



A new ion extraction mechanism : acceleration from target surface.

Raise of plasma potential (bombardment of low V surfaces)

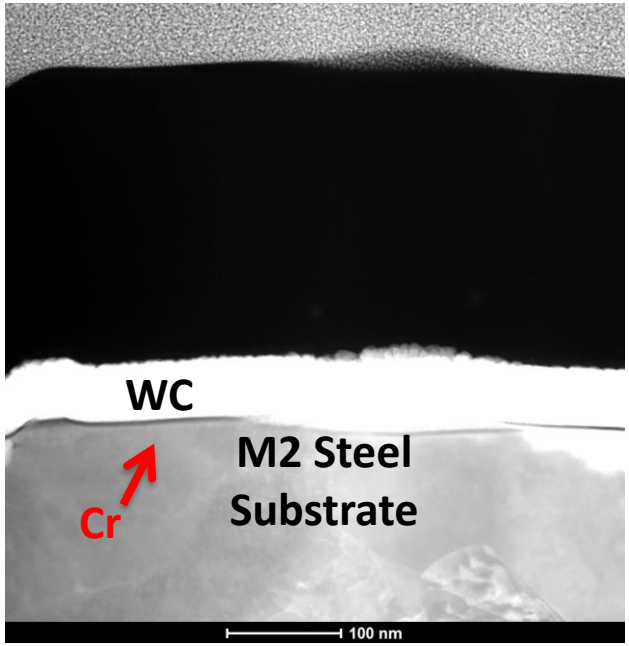
HiPIMS V+
Floating Potential



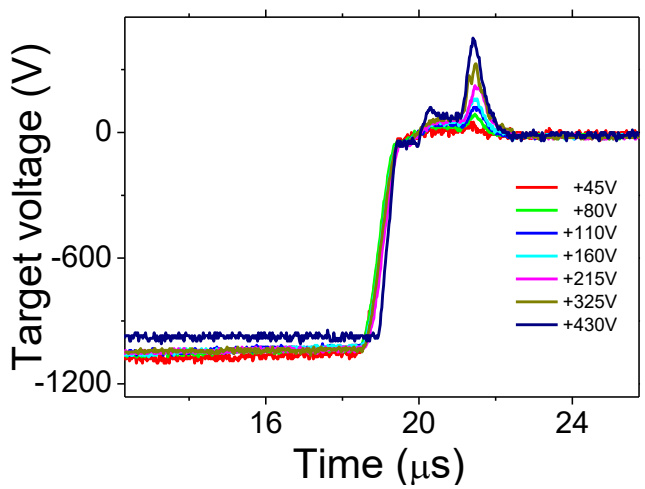
$$E_i = E_0 + Qe\,(V_{plasma} - V_{surface})$$

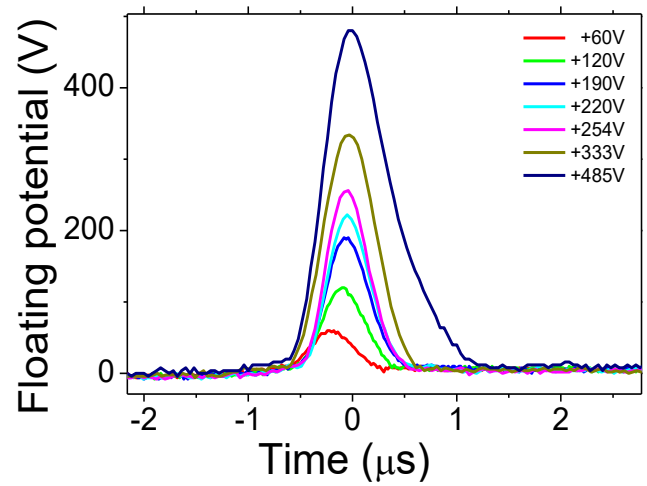
HiPIMS with V+ H-free DLC

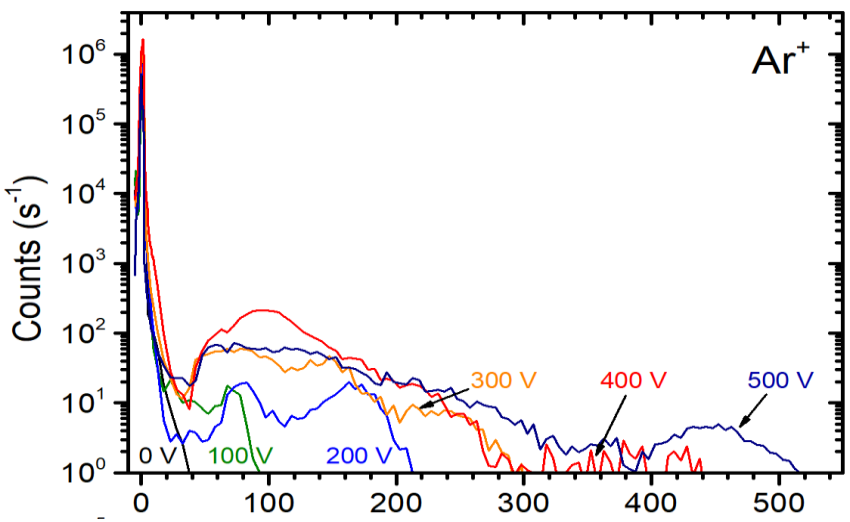
6kW Hip-V 1200V – 500A.
Cr, WC and Graphite targets
40x10 cm^2 rectangular magnetrons.
Pure Ar atmosphere.
Deposition on Silicon + HSS coupons

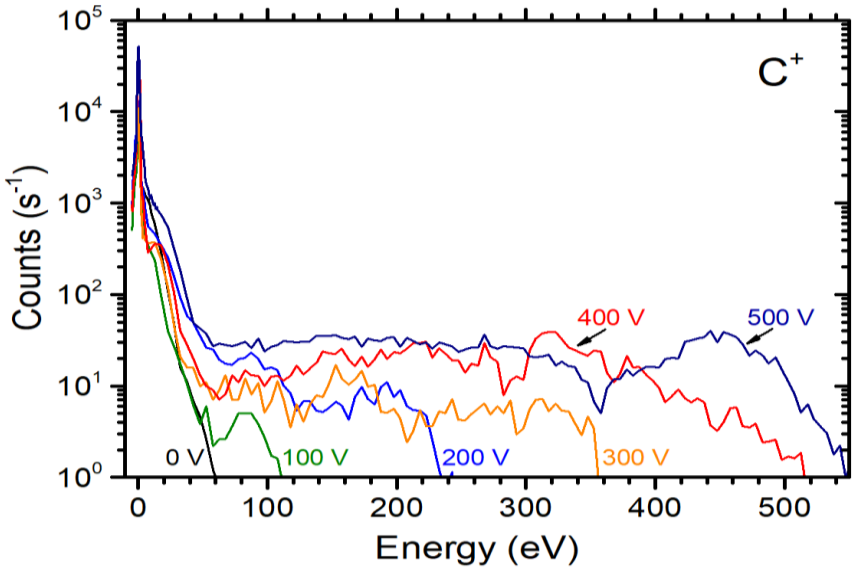


HiPIMS V+ on graphite : IEDF







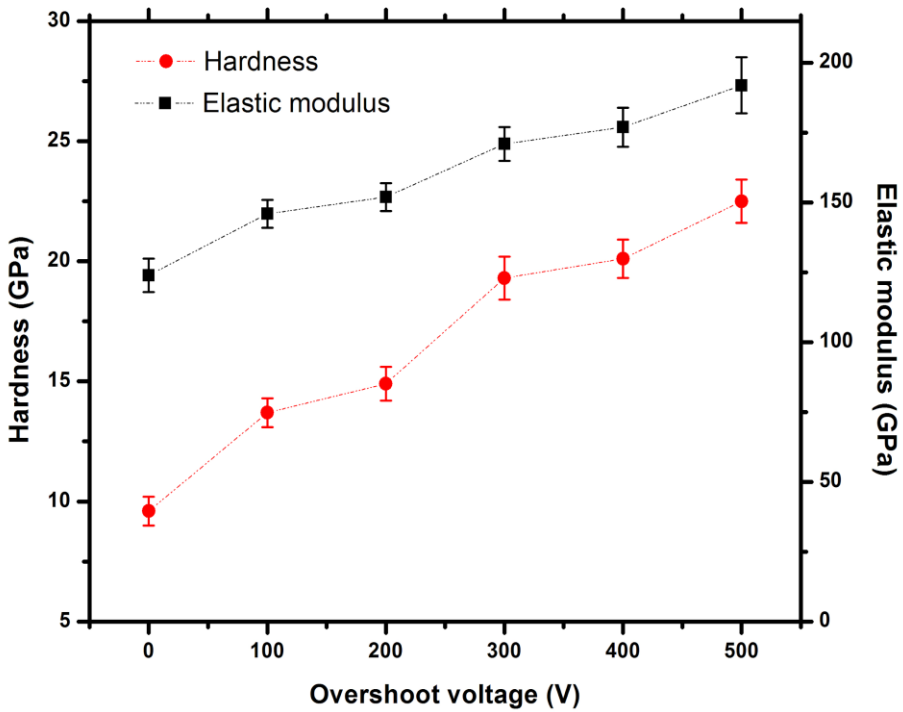


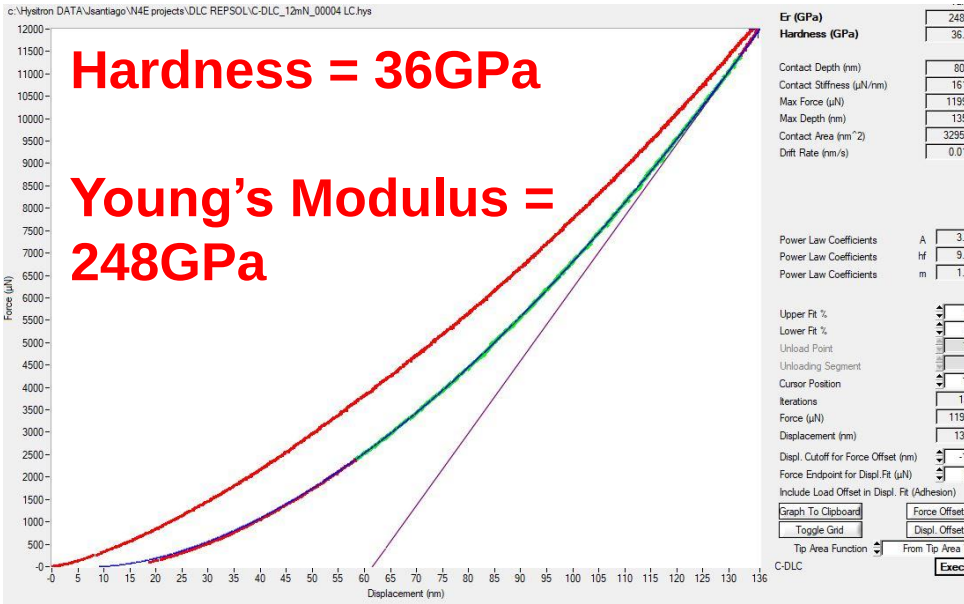
High energy ions are generated in the switching electric field.

UNIVERSITY OF WEST BOHEMIA

nano4ENERGY

Nanomechanical properties: H/E t-a:C

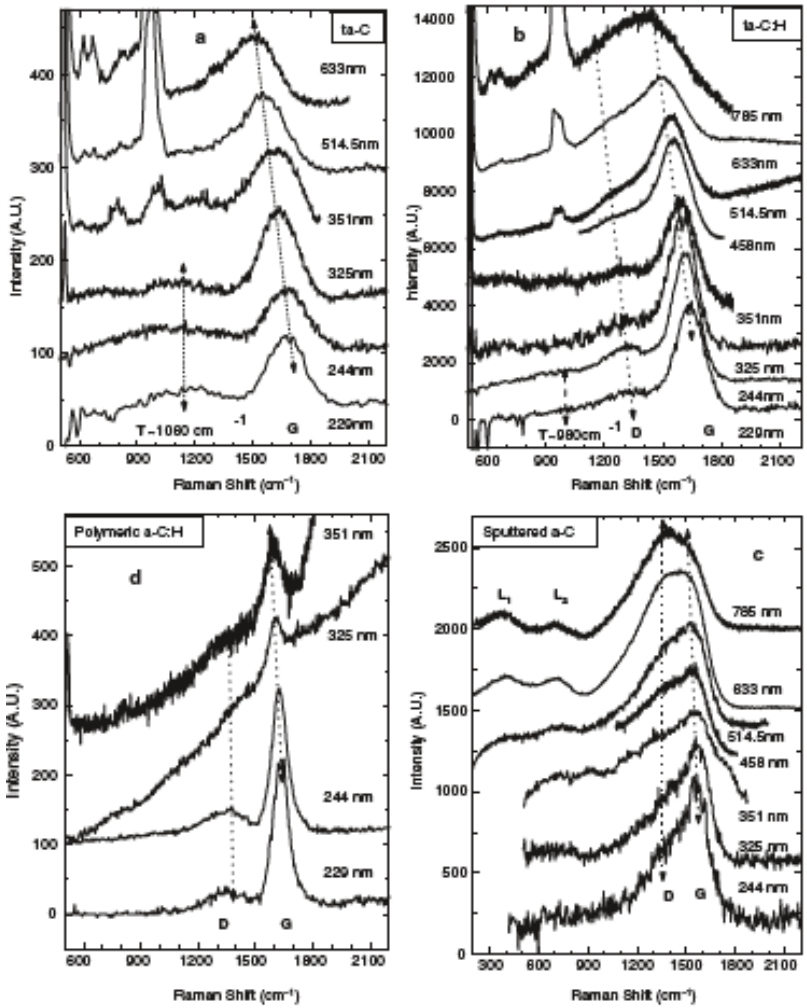




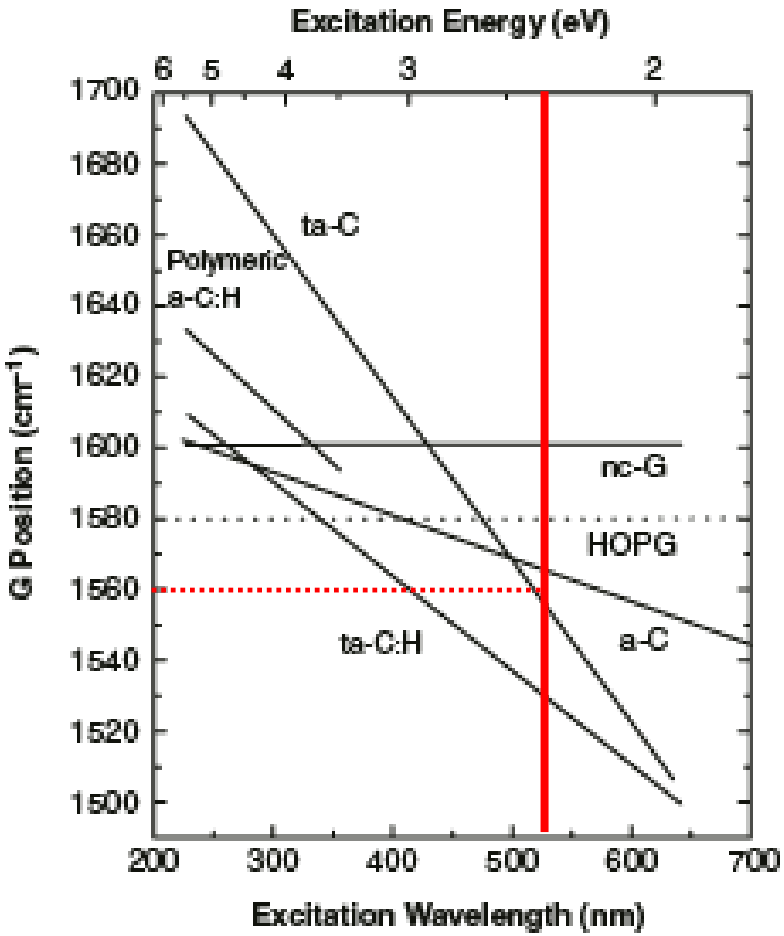
More energetic ions → higher sp^3 hybridization

Triboindenter TI950 from Hysitron equipped with a diamond Berkovich indenter.

Raman shift – Carbon Coatings



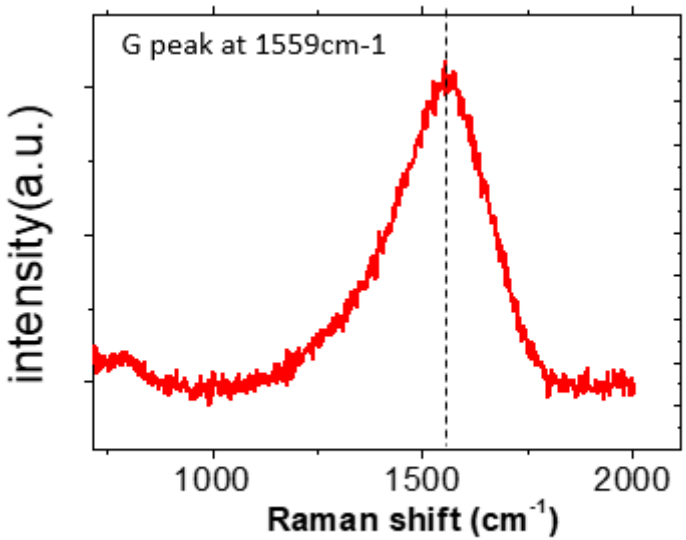
ig. 10 Multi-wavelength Raman spectra of (a) ta-C, (b) ta-C:H, (c) sputtered a-C and (d) poly-eric a-C:H. The peaks' trends and labels are indicated

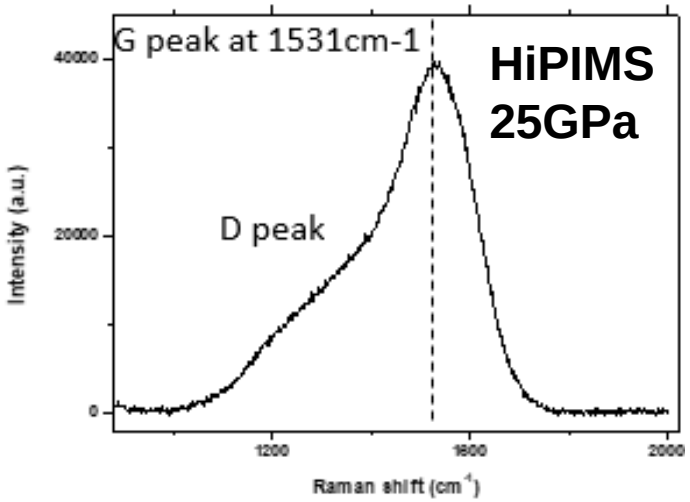


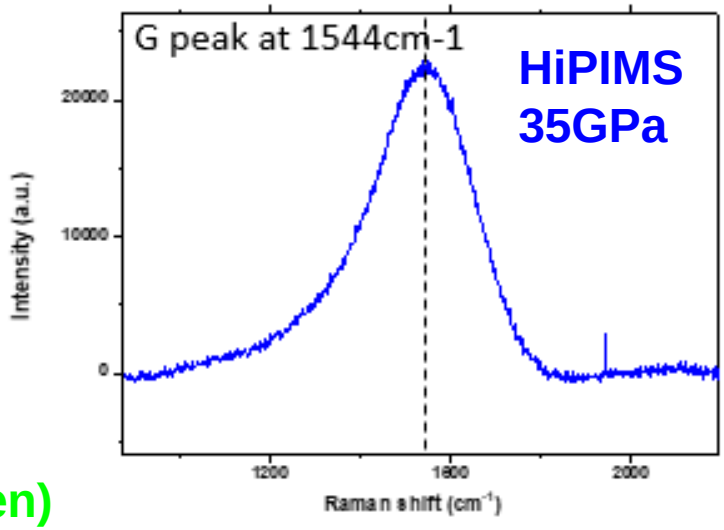
A.C. Ferrari, Chapter 2 in *"Tribology of Diamond-Like Carbon films"*

Getting close to t-a:C by filtered-arc

Reference commercial ta-C by Filtered Arc (60% sp3)





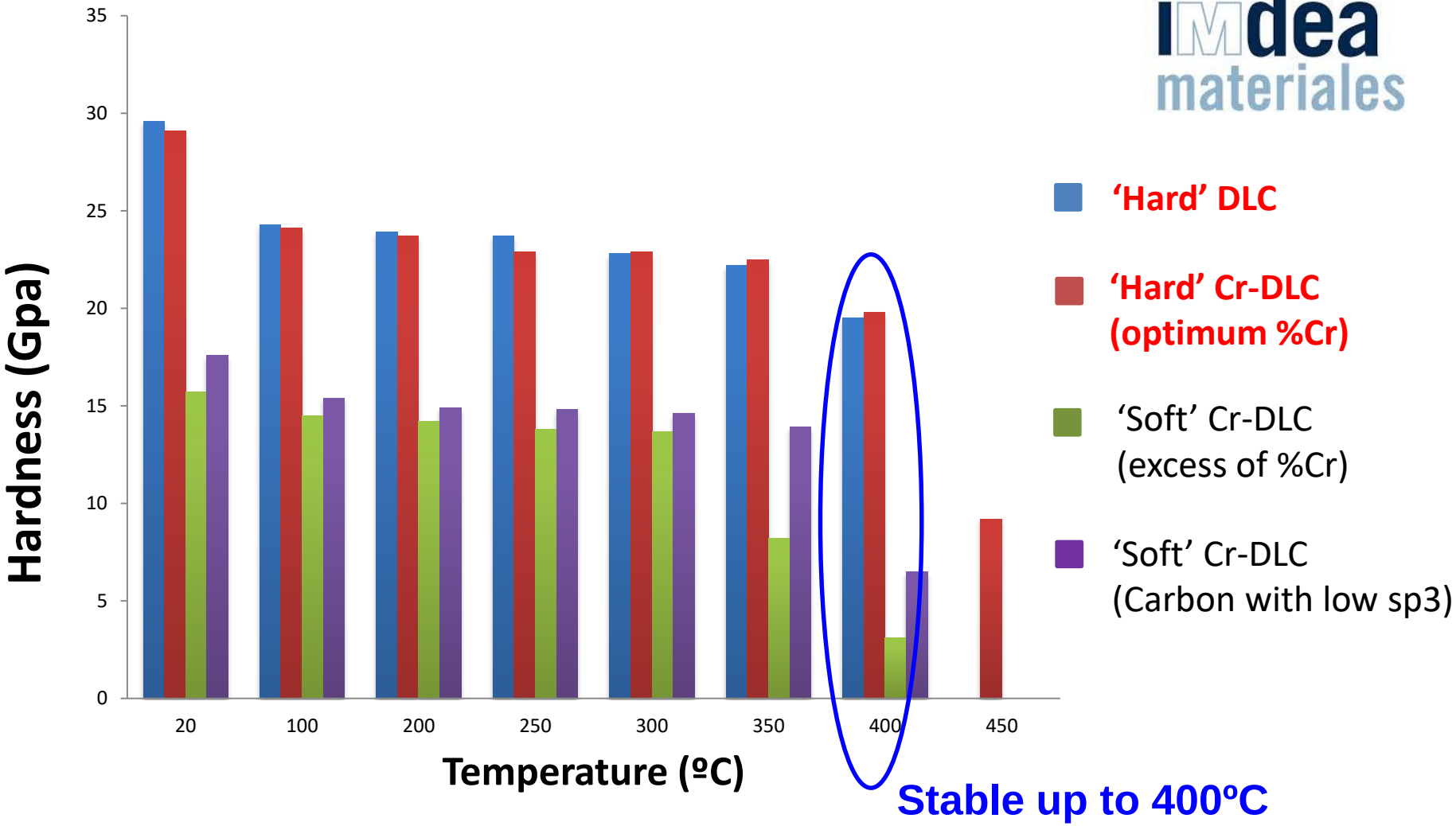


sp^3 ratio proportional to:

- G peak shift to higher wavenumbers
- D peak reduction

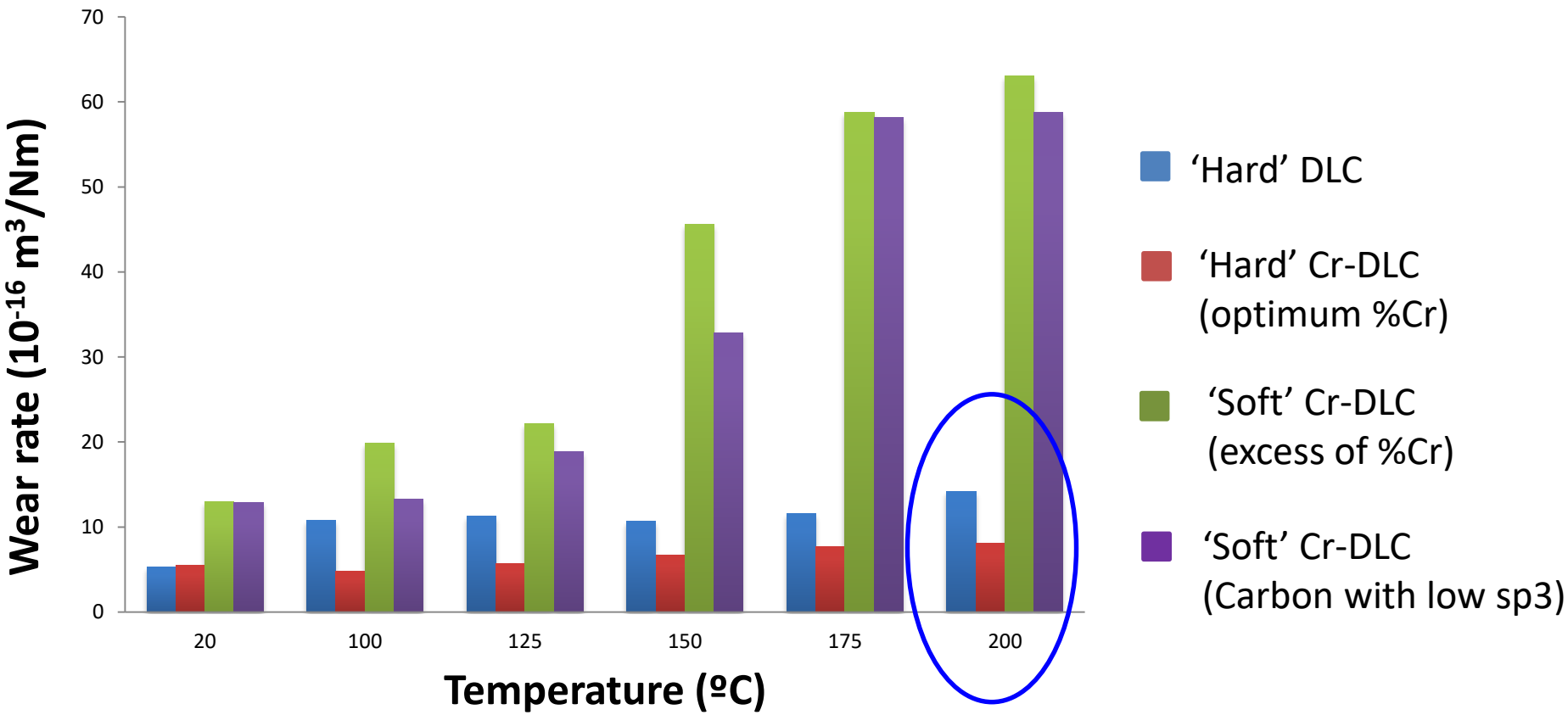
Raman excitation wavelength Argon 522nm **(Green)**

Double HiPIMS : Cr-doped DLC



Nanoindentation tests : Air, diamond Berkovich tip, Hysitron Xsol Stage and Tip

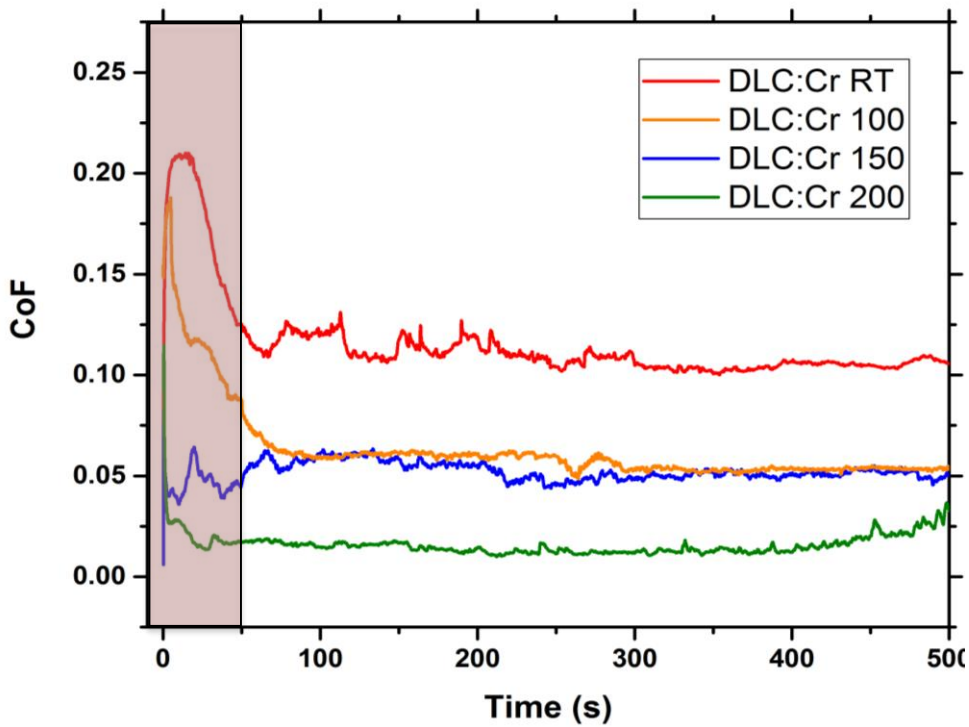
Cr-DLC : Wear vs T in air



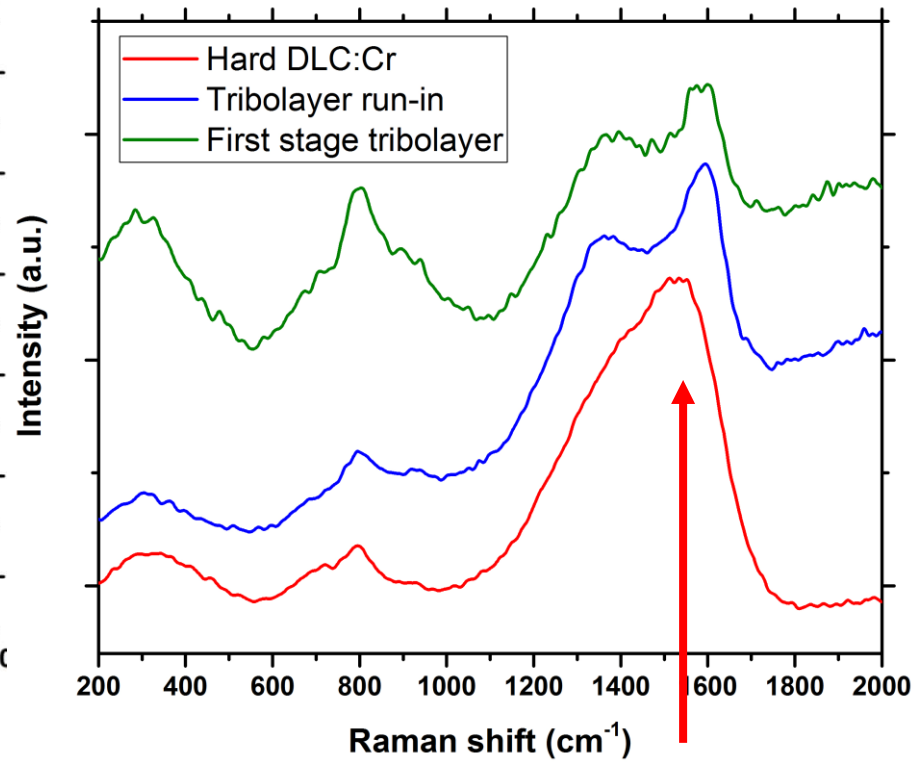
Lowest wear rate for Double HIPIMS Cr:DLC! < 0.5 x 10^{-15} m^3/Nm at 200ºC

Low amount of Cr is sufficent to delay graphitization.

COF for Cr-DLC



Formation of tribo-layer 200C



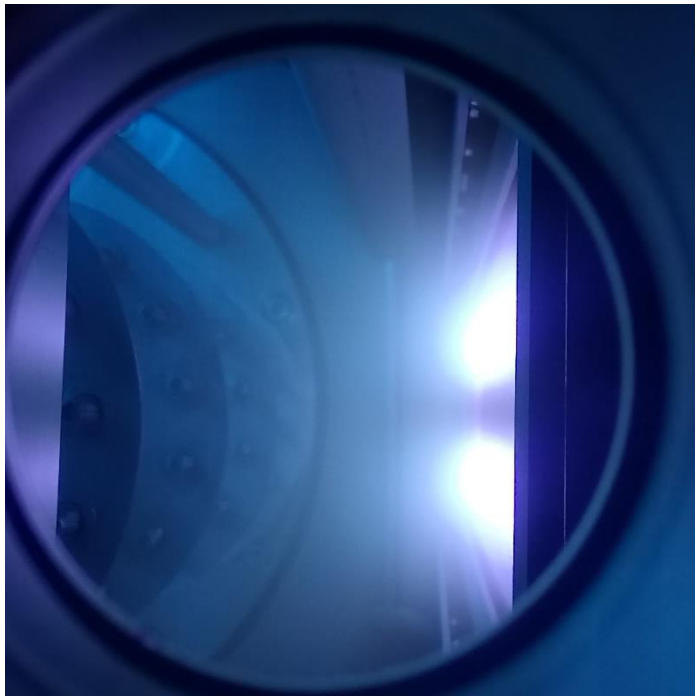
As deposited

COF for Cr-DLC as low as 0.02 at 200ºC
(as compared to 0.08 for standard 30GPa DLC)

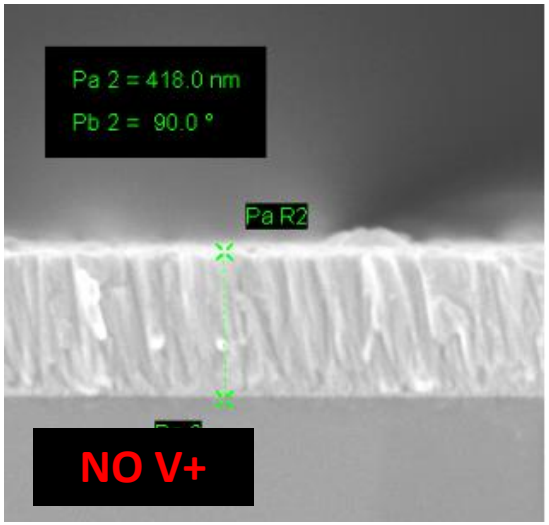
Pin-on-disk conditions : Air, Al2O3 ball, 5N, 10cm/s

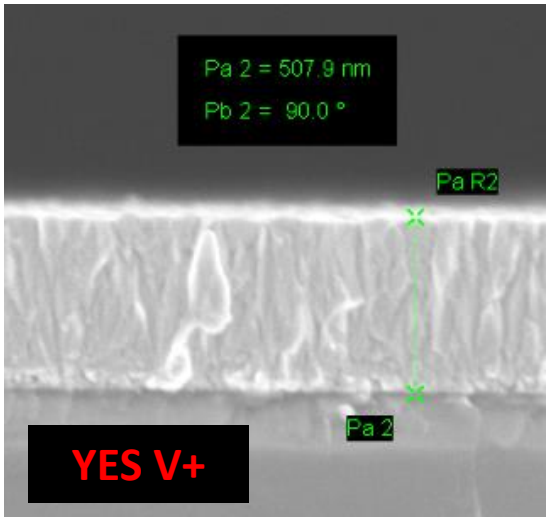
Examples of ‘Hard’ DLC Coated Parts

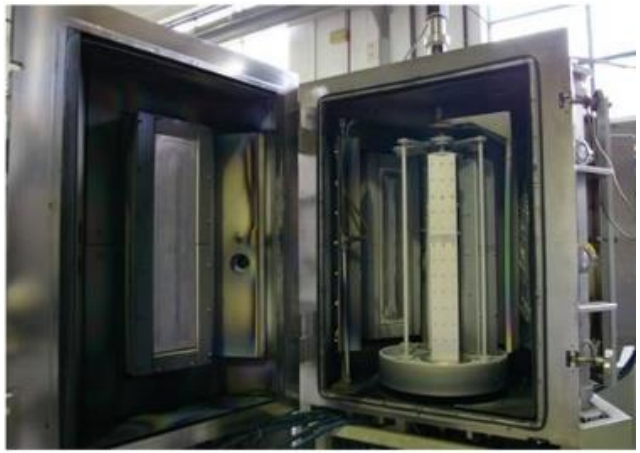
Implementation on Industrial Tool



HiPIMS with V^+ TaN CFUBM



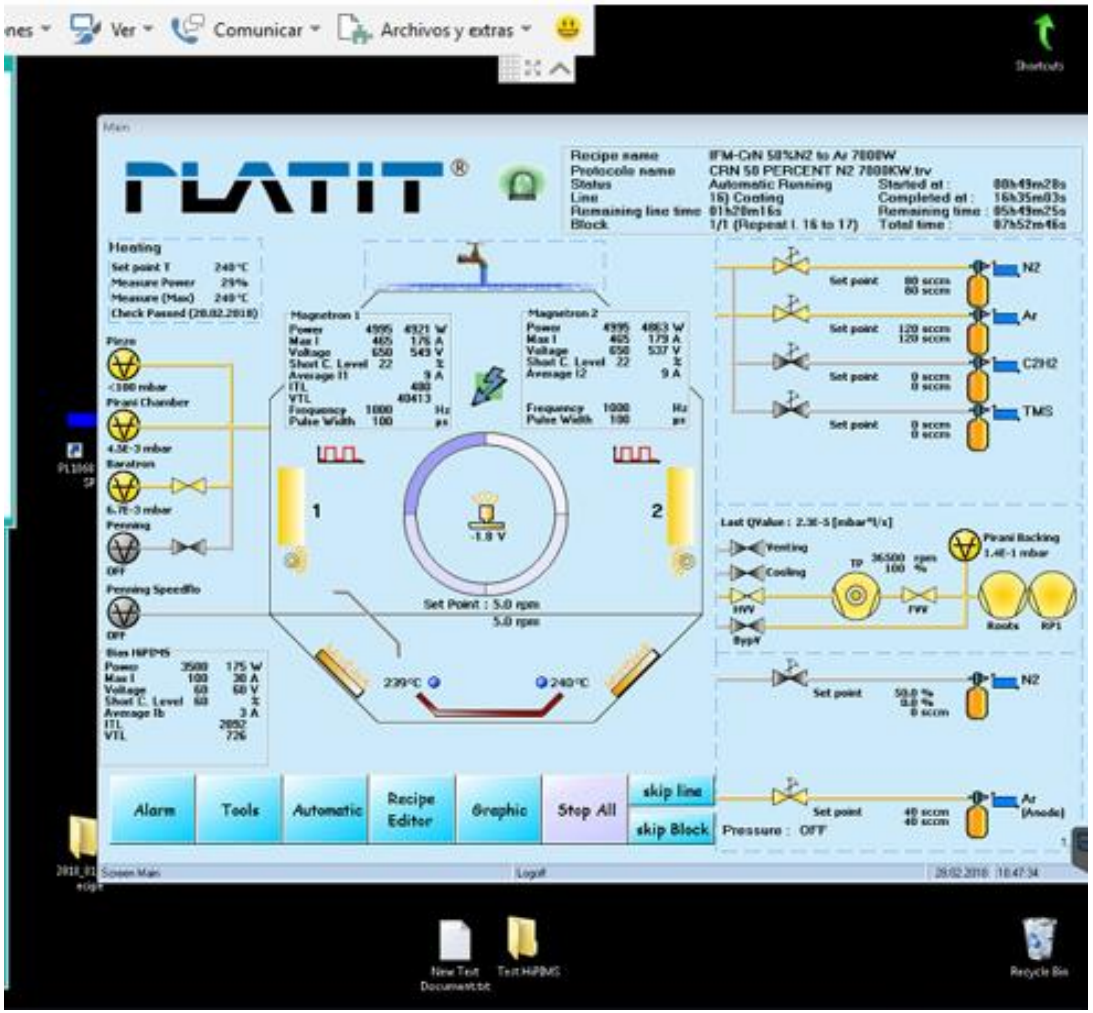




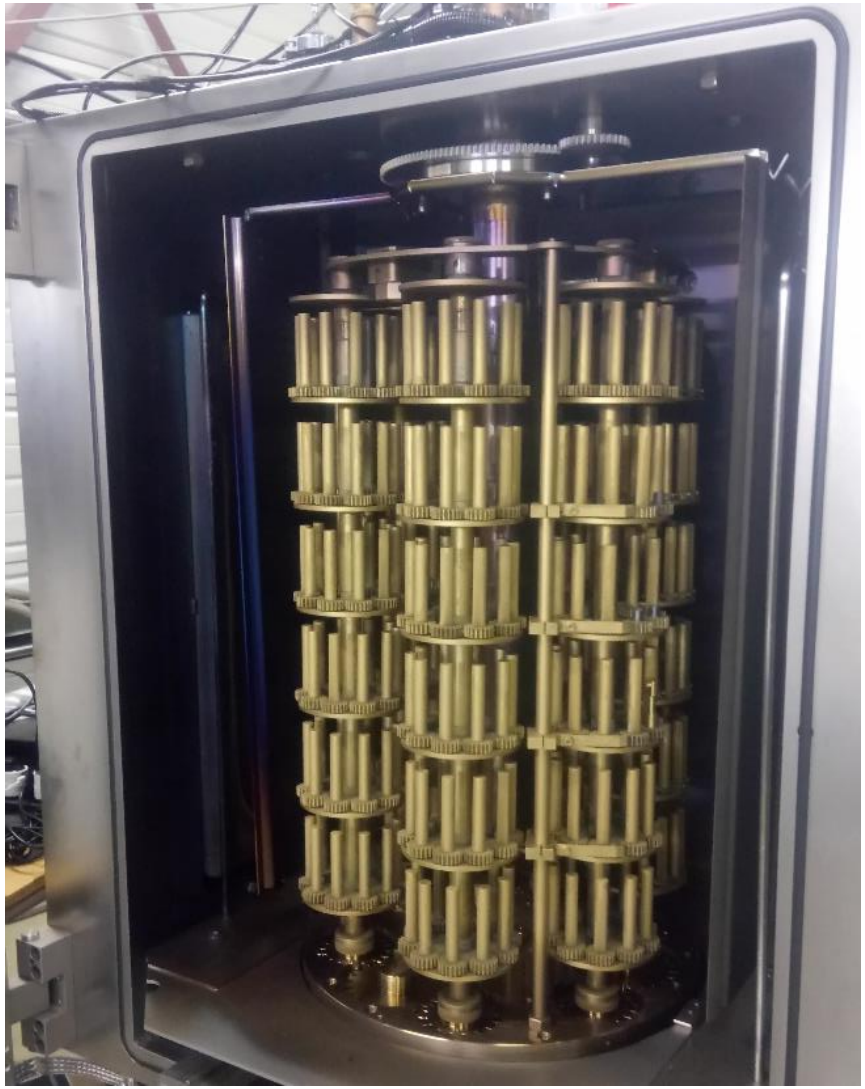
Dep .rate [µm/hr]	0.51	0.42
Hardness [GPa]	21	17
POSITIVE	**YES**	NO

25% increase of deposition rate (ion incorporation into the film)

CrN/ZrN in Industrial System

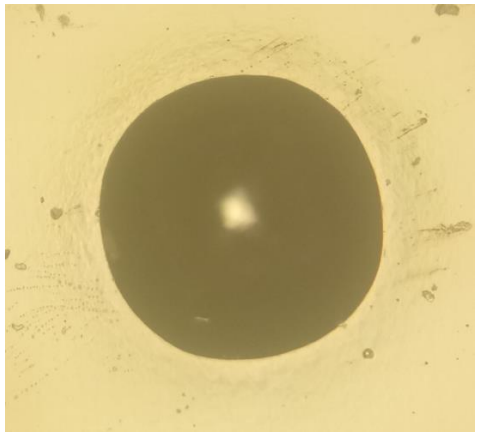


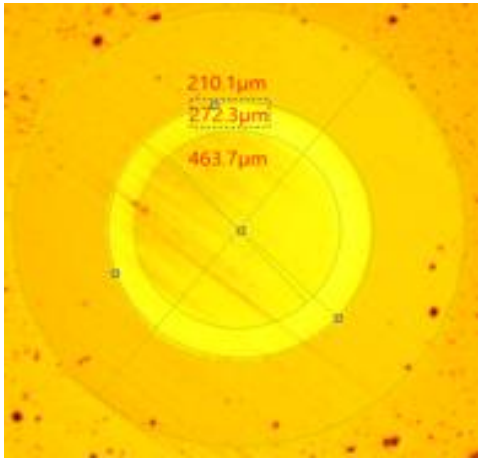
CrN/ZrN in Industrial System



3-fold rotation
2 x magnetrons
5kW average each
-60V bias
650 mm diameter x
650 mm height

CrN/ZrN in Industrial System





23-25GPa
250 C

1um/hr!! for CrN and ZrN

Summary

- HIPIMS with Positive Voltage Reversal can be used to control the degree of metal/gas ionization as well as ion energy
- 25% increase in deposition rate as compared to standard HIPIMS
- Self “Ion Assisted” deposition for coatings on insulating substrates
- Successfully implemented on several Industrial platforms

Thank you for your attention !!

Visit us in booth #310 Gencoa