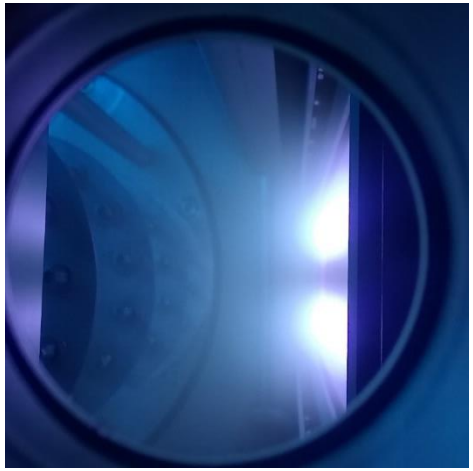
HiPIMS with positive voltage reversal : widening the process window

Dr. Iván Fernández Martínez

Garmisch-Partenkirchen, September 21st, 2018



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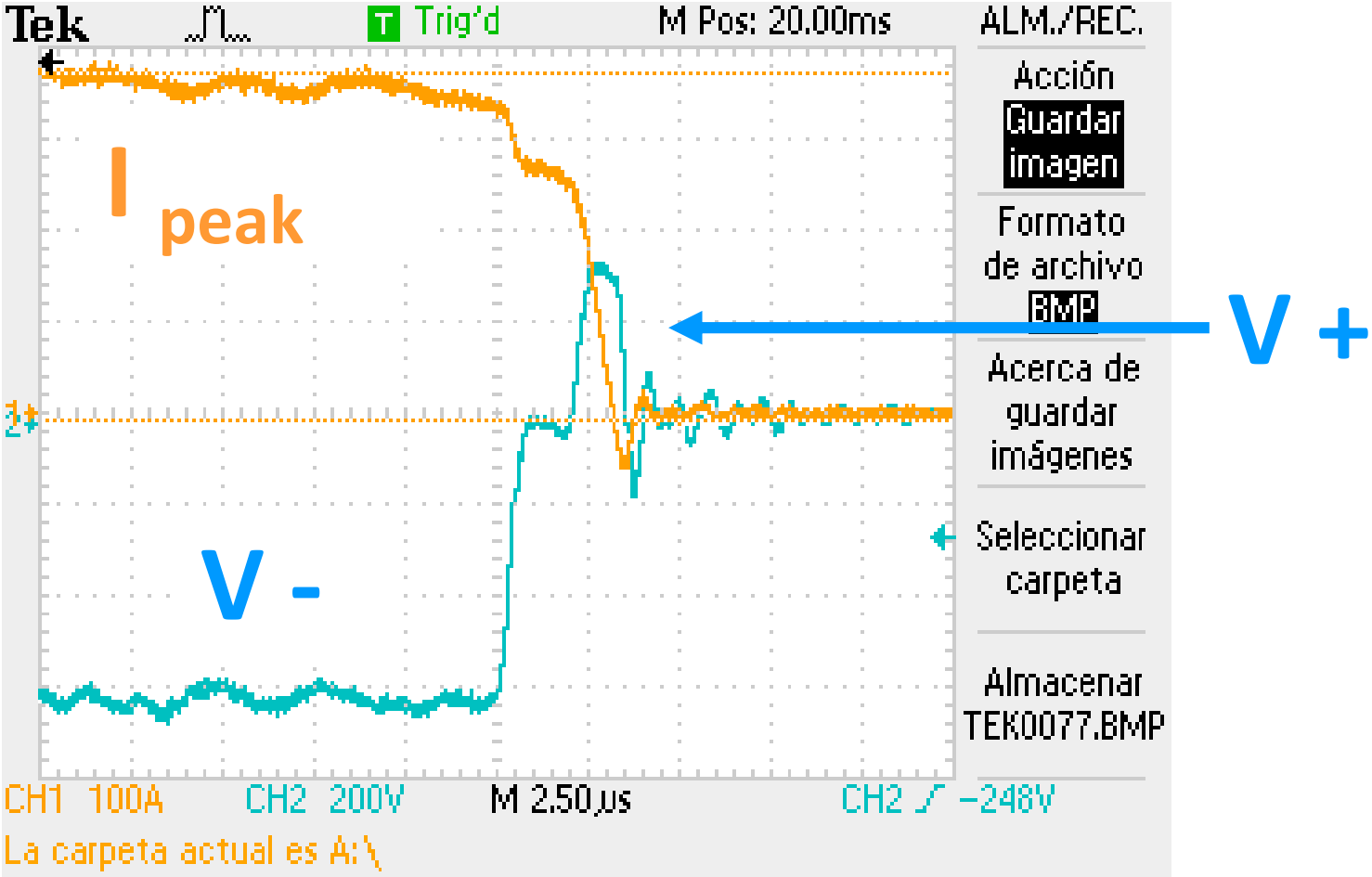
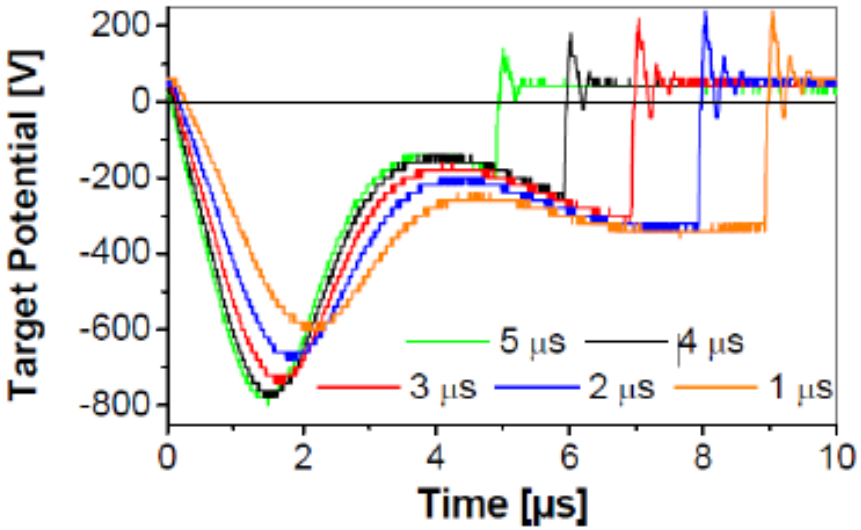
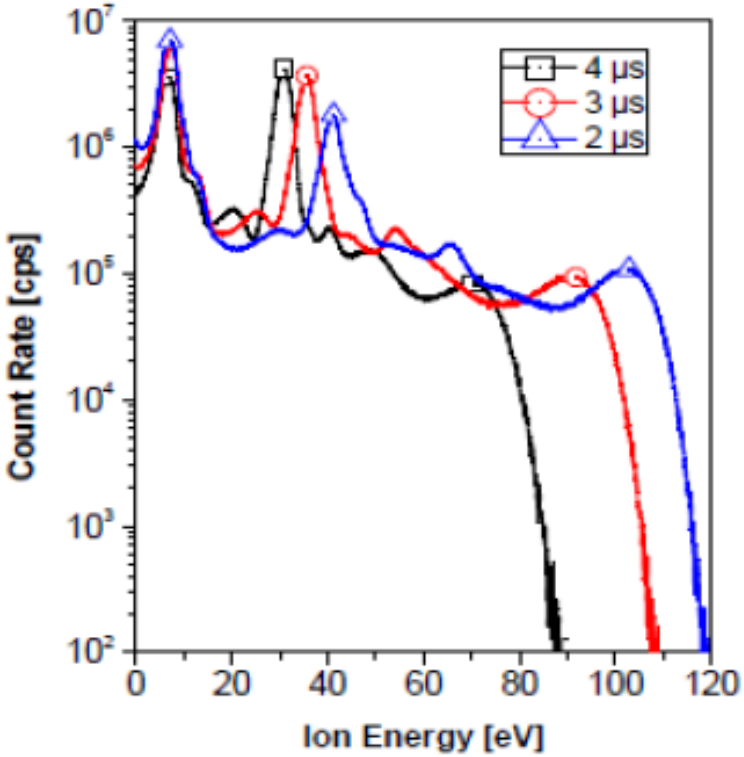
HiPIMS with positive V reversal



HiPIMS with positive V reversal





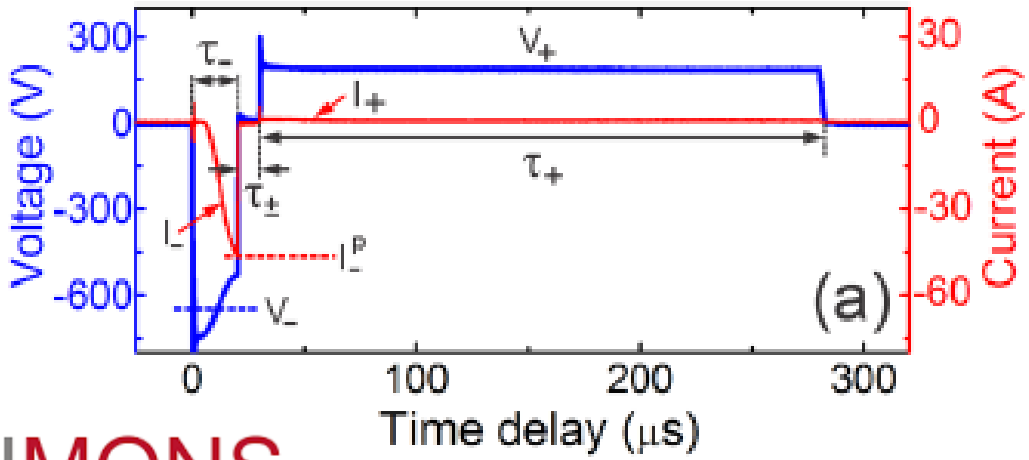
Serial switching in Asymmetric Bipolar Pulsed-DC!

Changkang Pan and Fred L. King. J Am Sot Mass Spectrom 1993, 4, 727-732.

Thomas Welzel, PhD thesis. *"Time resolved characterization of pulsed magnetron discharges for the deposition of thin films with plasma diagnostic methods"*

J W Bradley, et al," Plasma Sources Sci. Techno 11 (2001) 174.

Bipolar Pulsed HiPIMS (BHP)



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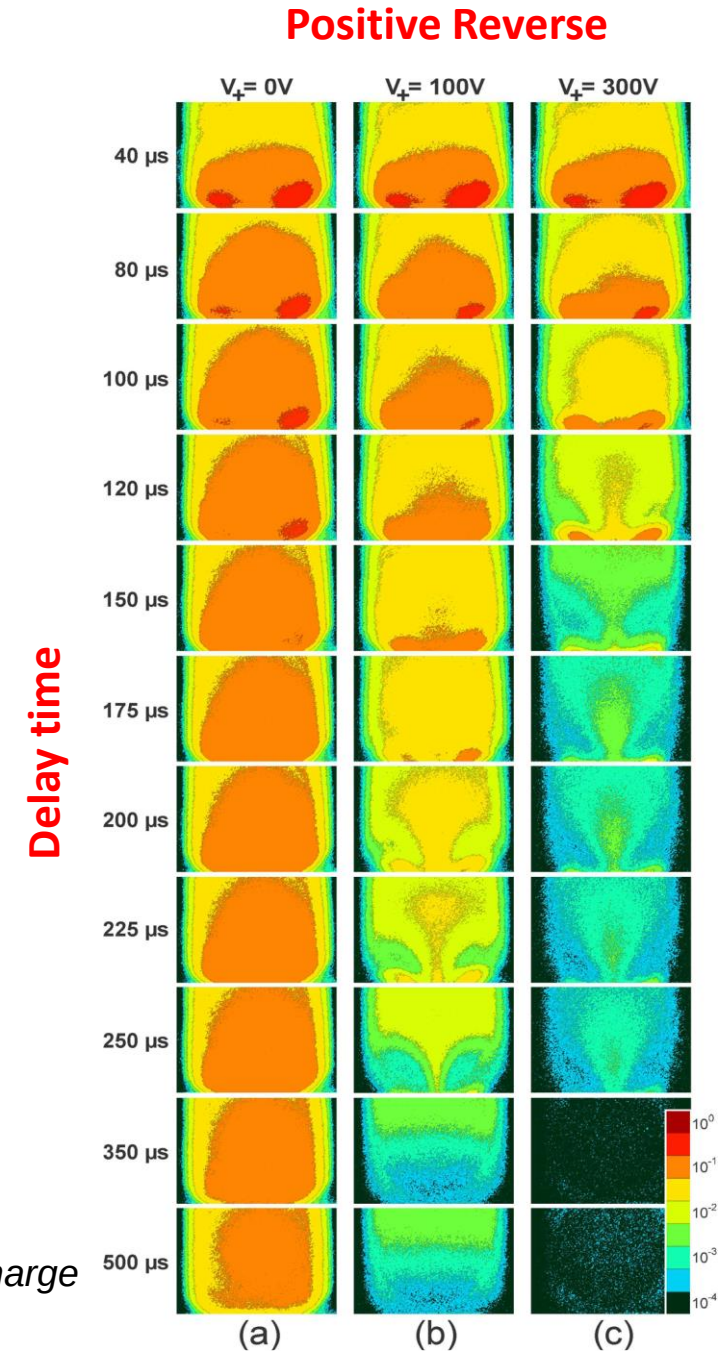
Université de Mons

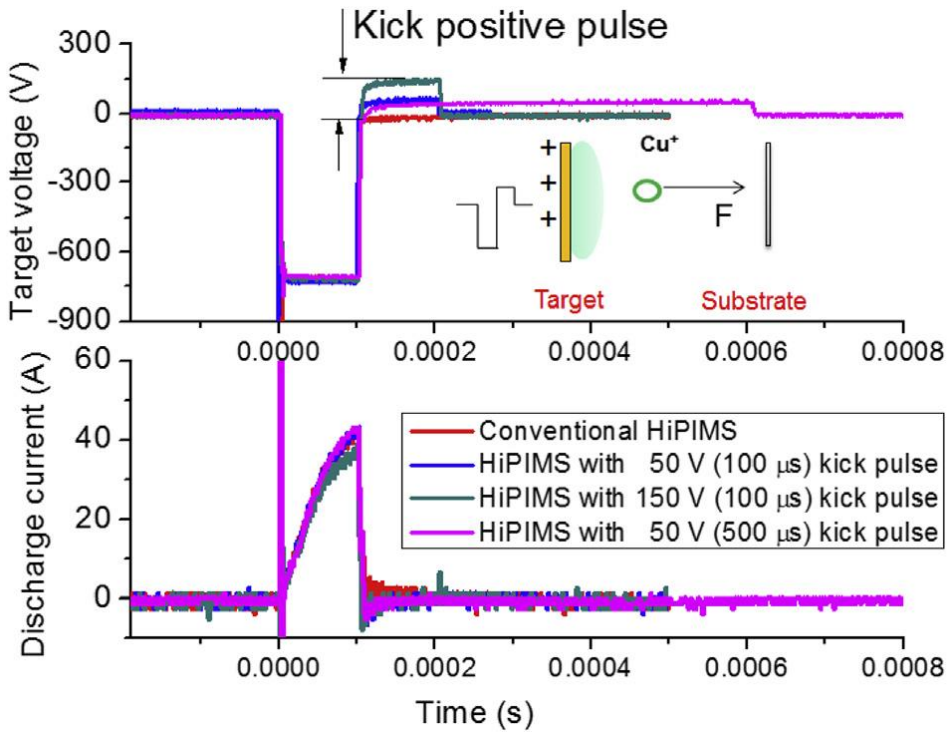
Time resolved Ti+ ground state density above the cathode.

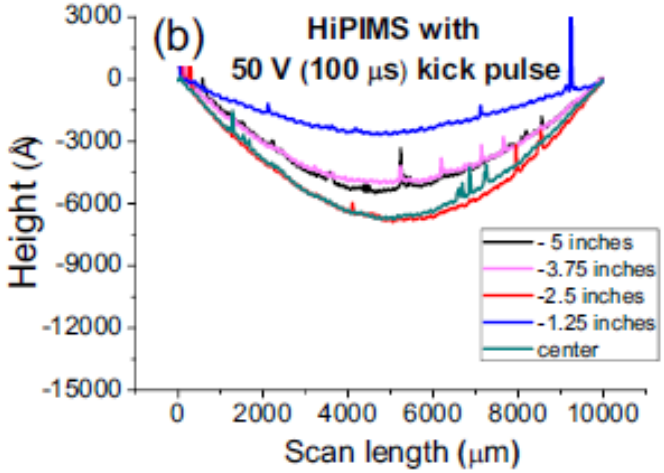
Laser induced Fluorescence (LIF) imaging.

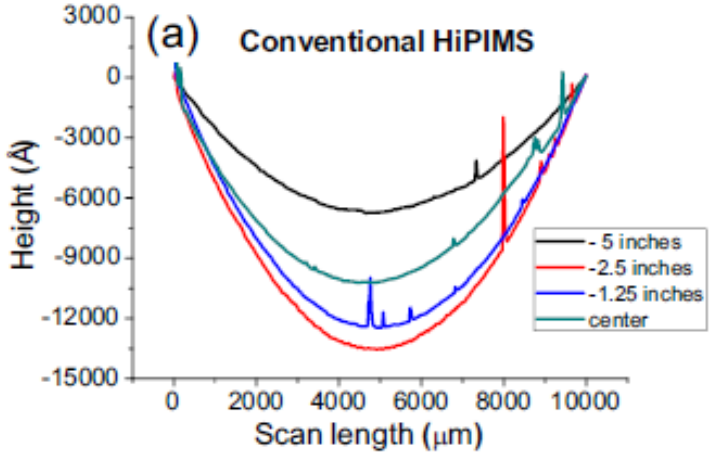
N. Britun et al., *"Ion density evolution in a high-power sputtering discharge with bipolar pulsing"* Applied Physics Letters 112 (2018) 234103



"Positive kick"



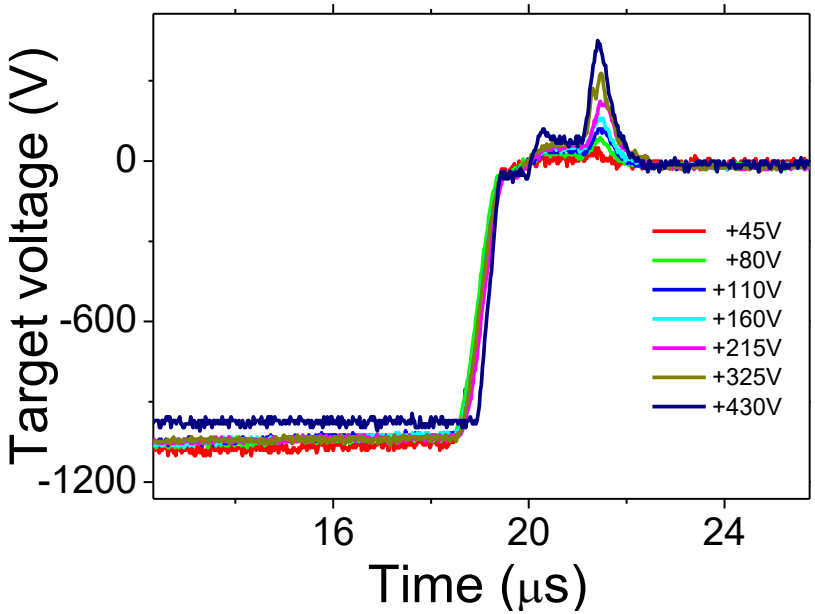


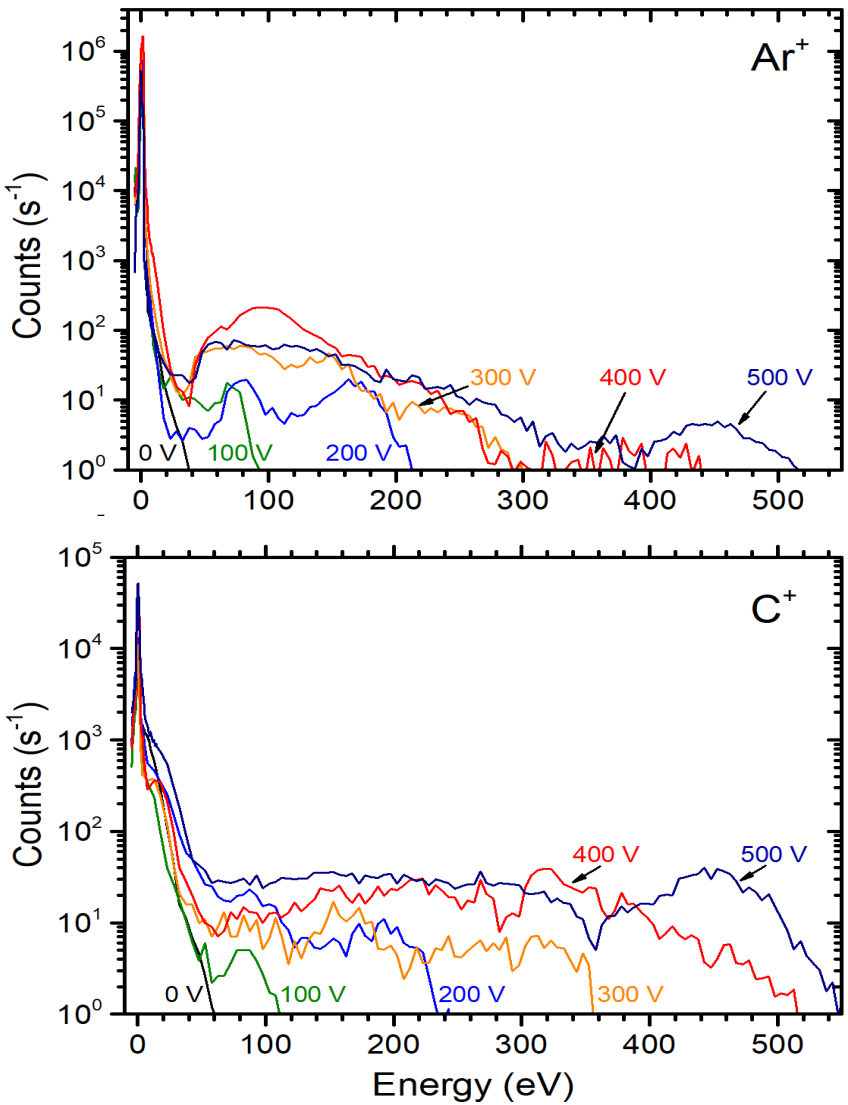


Baohua Wu et al., *"Cu films prepared by bipolar pulsed high power impulse magnetron sputtering"* Vacuum 150 (2018) 216-221

HiPlus for ta-C

UNIVERSITY OF WEST BOHEMIA

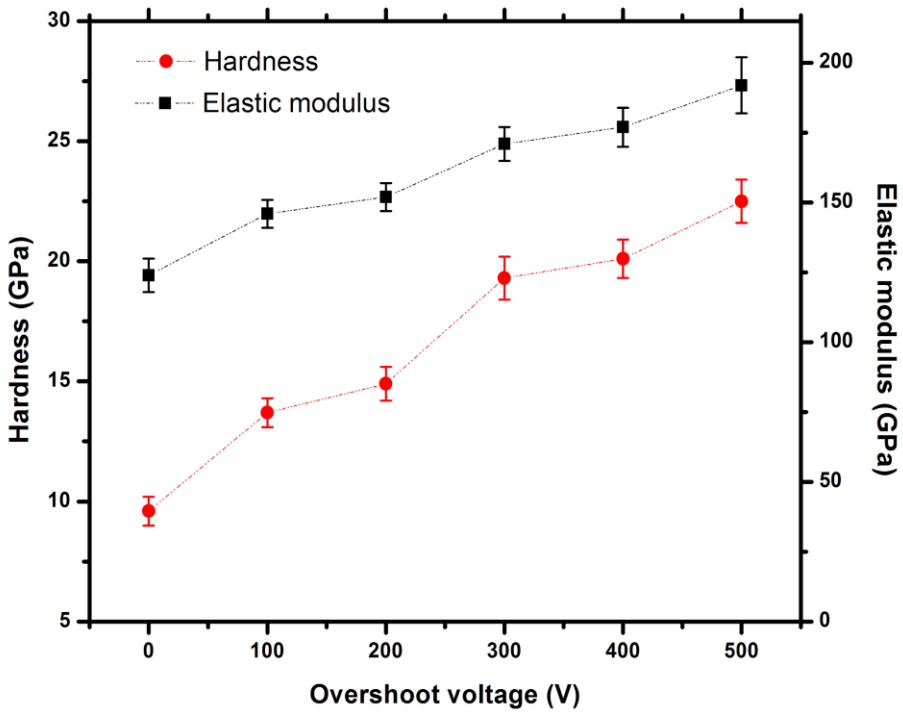




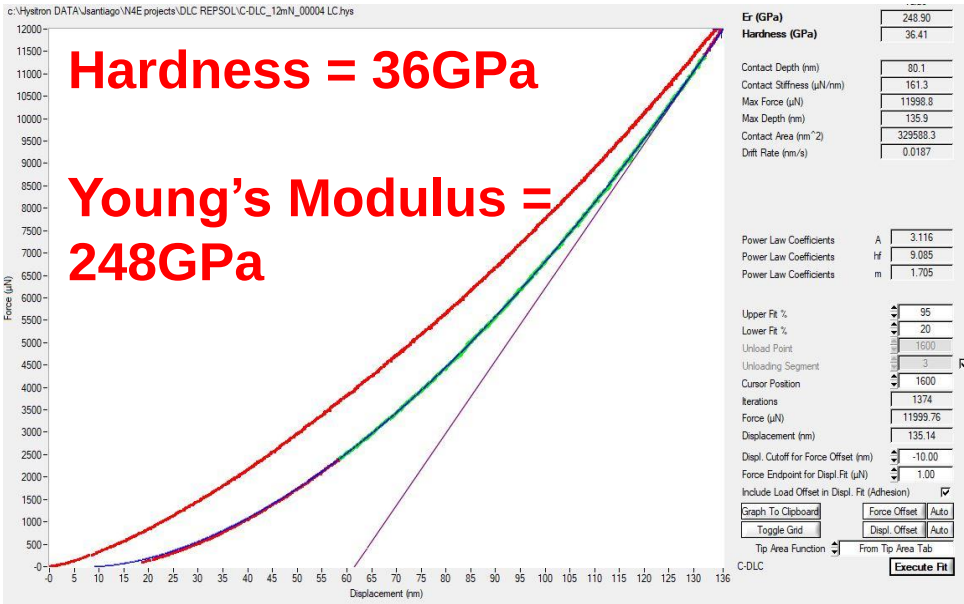
J.A.Santiago et al, *"The influence of positive pulses on HiPIMS deposition of hard DLC coatings"* Submitted to SCT

HiPlus for ta-C : 35GPa Hardness

Floated substrates



Biased substrates

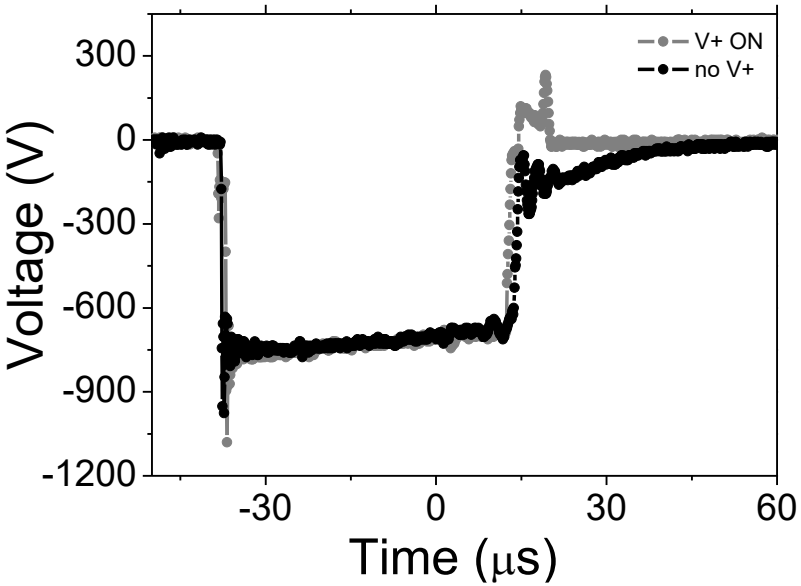


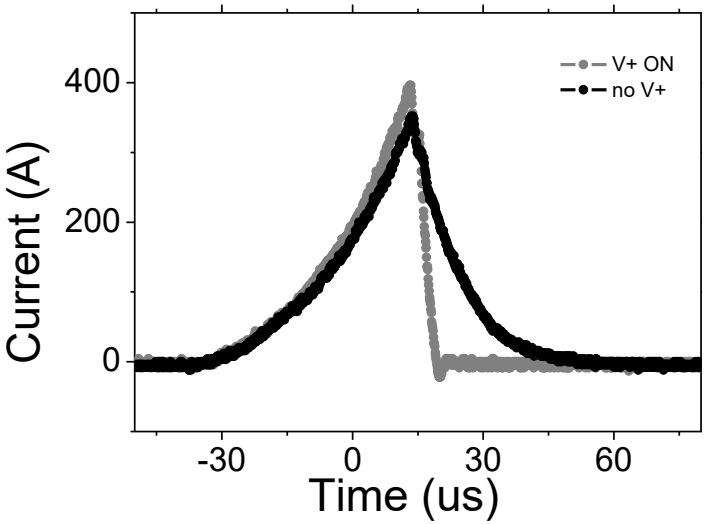
More energetic ions → higher sp^3 hybridization

Triboindenter TI950 from Hysitron equipped with a diamond Berkovich indenter.

HiPlus V+ for Me:N(back to 2016)

‘Passive’ voltage reversal : shorter pulses (<5us) and delay time (<1us)

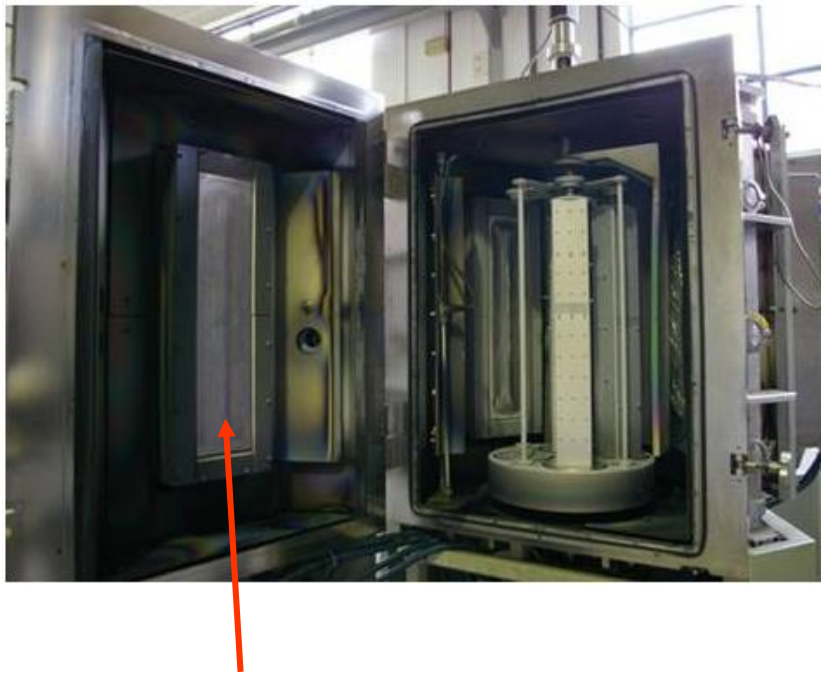


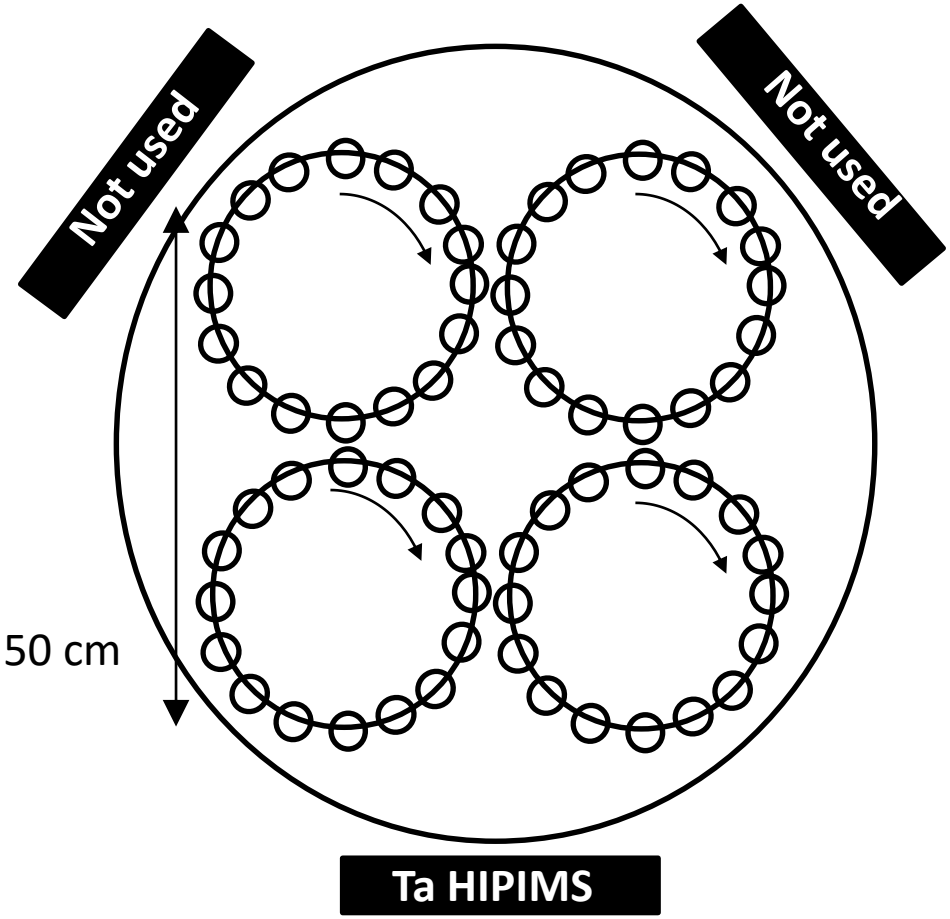


Tests performed in different batch coaters

Presented at SVC 2016

TaN coatings in a CFUBM



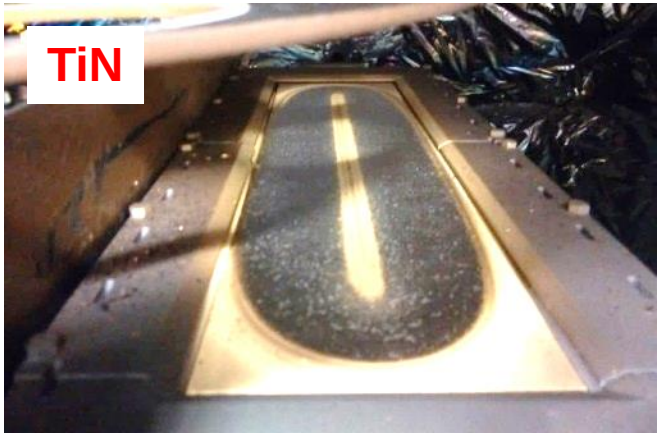


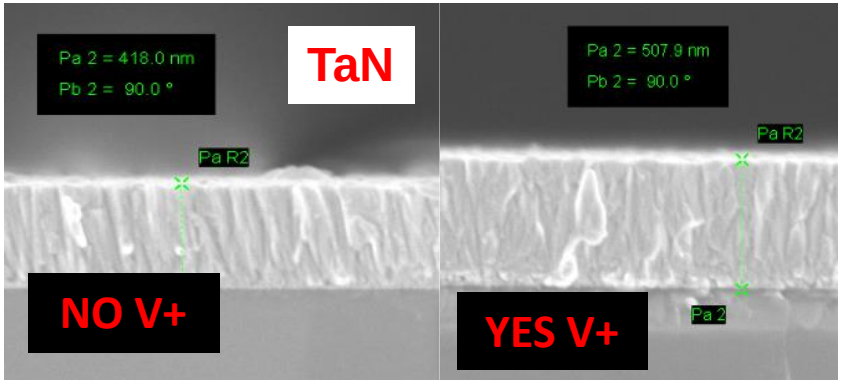
Rectangular magnetron 550x125 mm2
Ar + N2 atmosphere
RT deposition

HiPlus V+ for Me:N

1 .- New technology launched at 2016.
2.- Demonstrated >25% increase in deposition rate for Me-N and ta-C in different industrial machines (for example in PVT and Tekniker batch coaters).
3.- Generate enhanced coating ion assistance → denser coating structure.
4.- Reduced arc appearance in reactive sputtering.

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

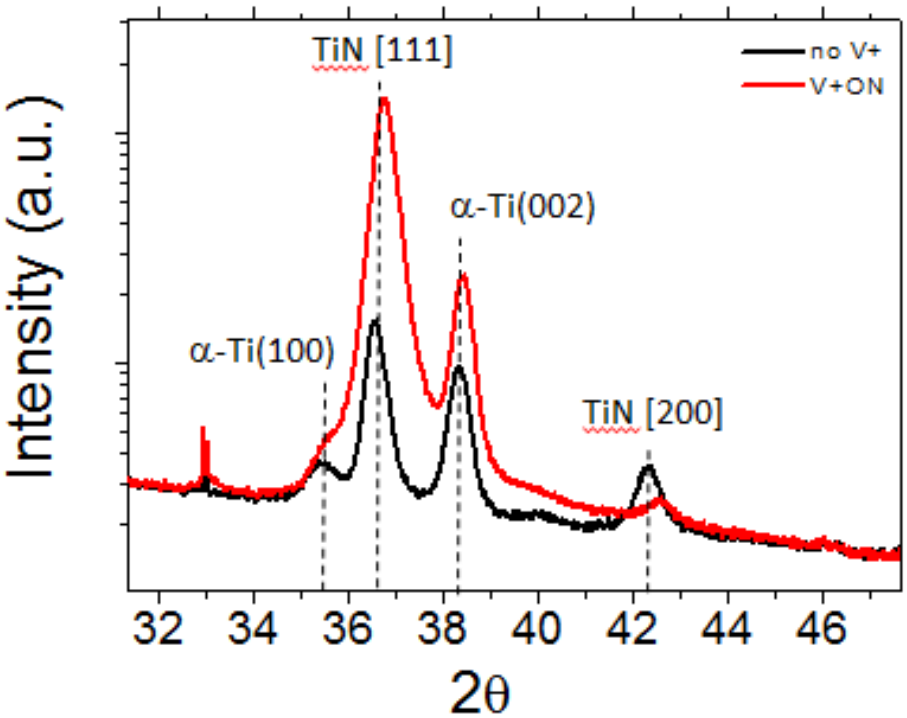


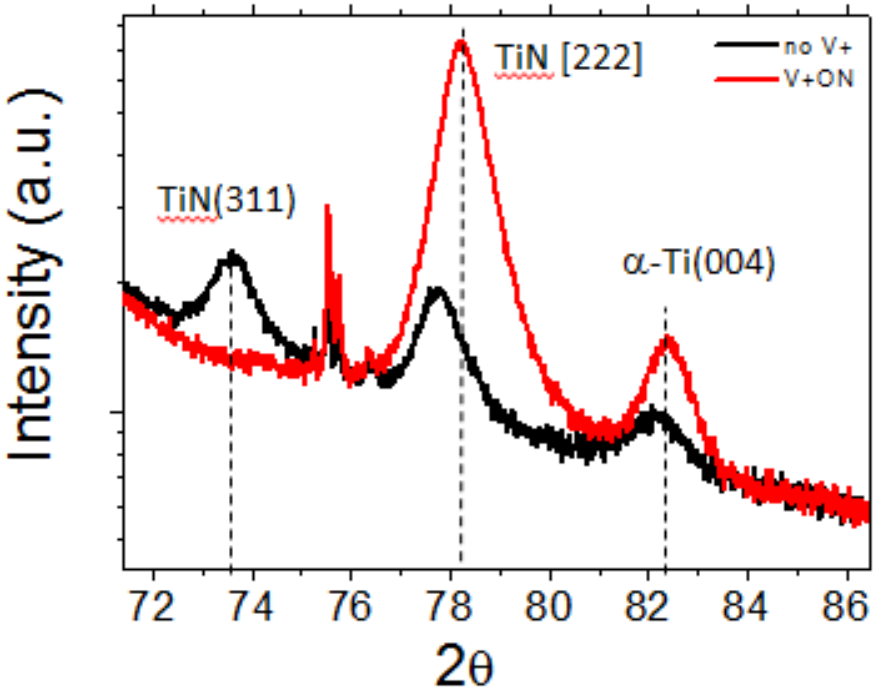


Setpoint [%]	45	45
Hardness [GPa]	22.0	13
POSITIVE	**YES**	**NO**

25% increase in ion incorporation!!
(deposition rate and hardness)

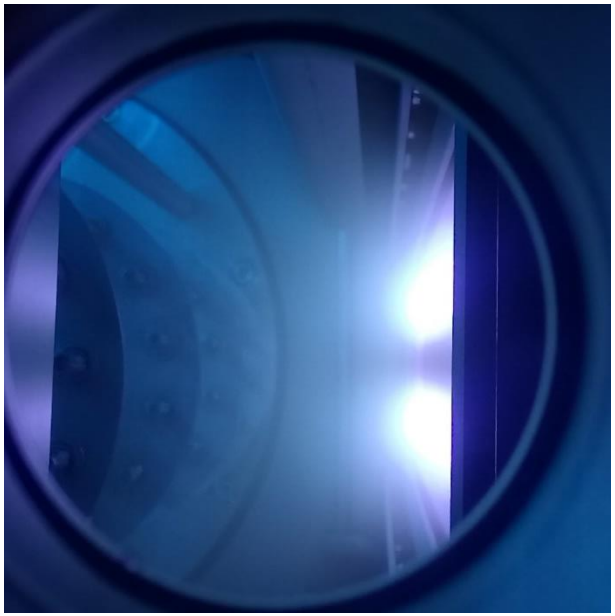
HiPlus V+ for Me:N





Change in morphology with HiPlus V+

Example of Implementation on Industrial Tool

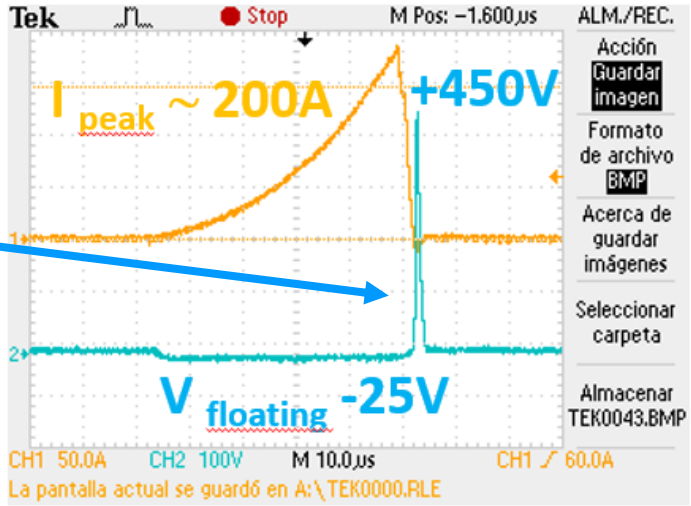


HiPlus for biased substrates

It seems to be very convenient in large batch coaters (where parts to be coated are not continuously exposed to ion flux):

- Enhanced deposition rate

- Enhanced ion assistance (raise of plasma potential)



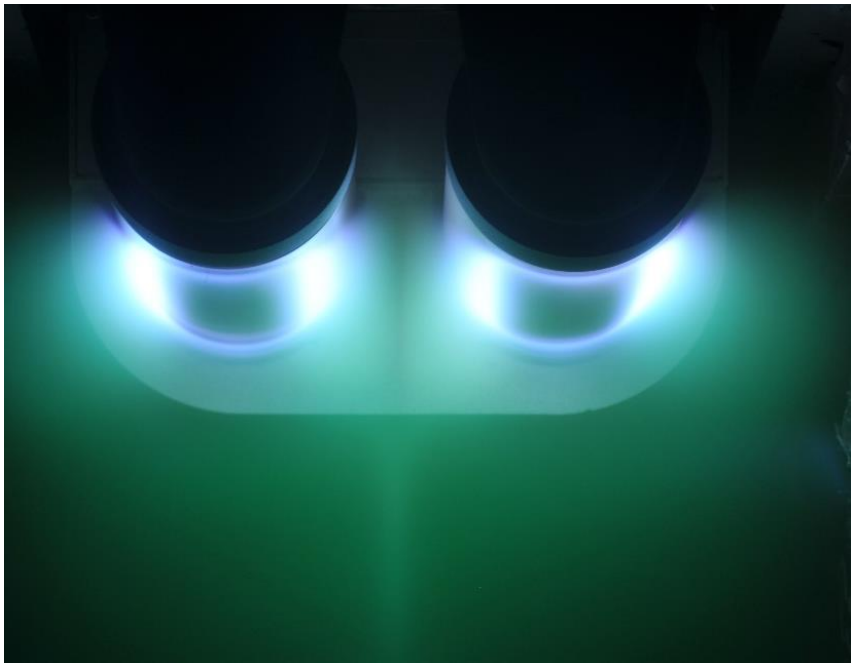
$$E_i = E_0 + Qe\,(V_{plasma} - V_{surface})$$

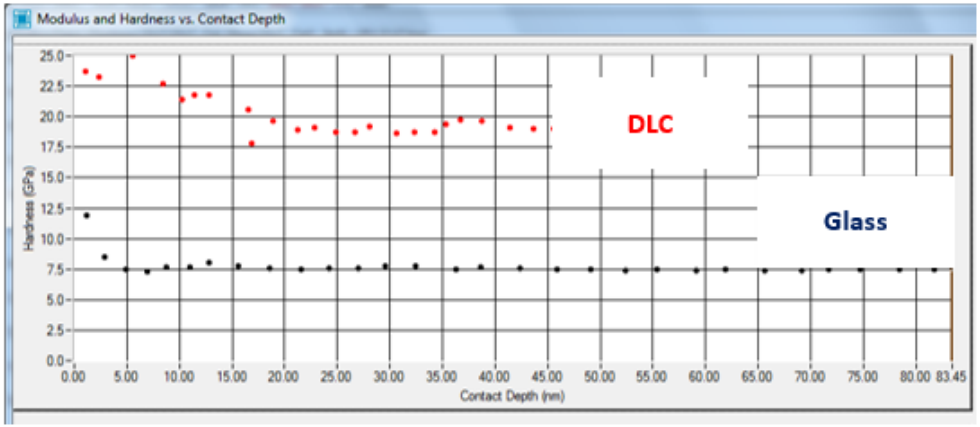
HiPlus for floated substrates

Nitch for positive pulsing

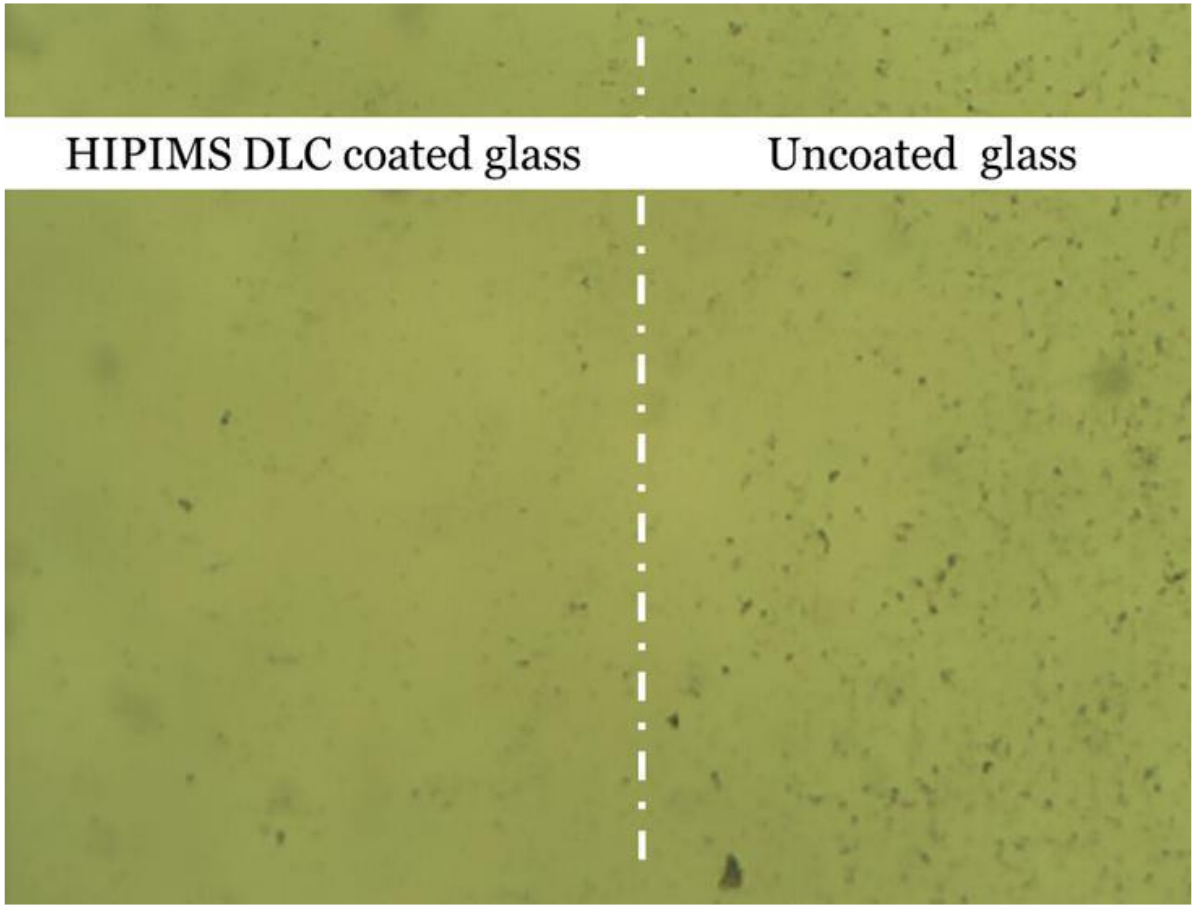
Carbon on glass : AC Dual

The implementation of magnetically guided anodes (or AC Dual) can boost <u>the film ion incorporation</u>.

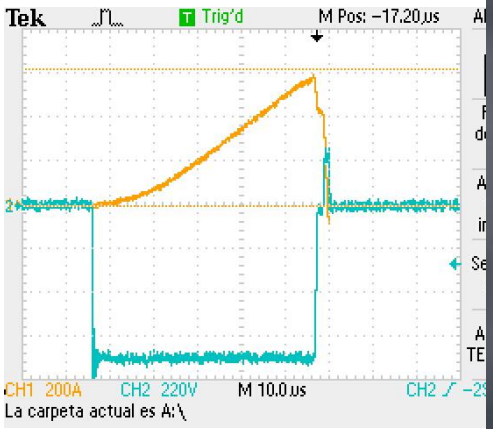


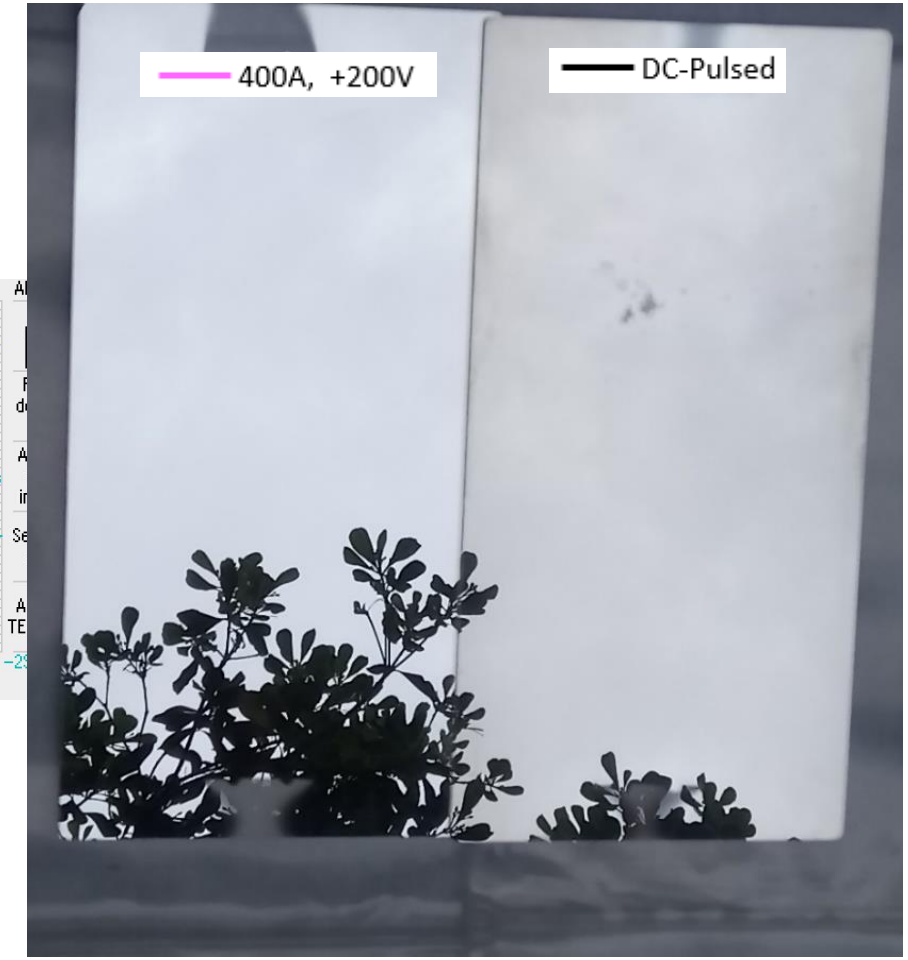


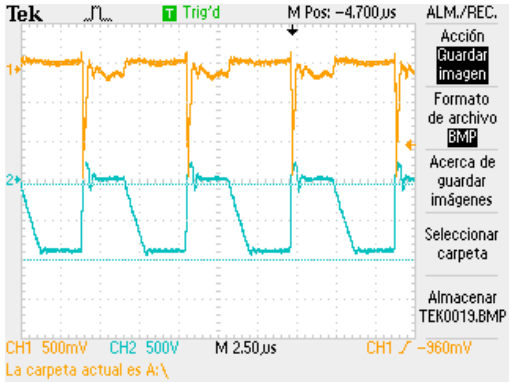
Carbon on glass : AC Dual + HiPlus



HiPlus V+ for glass metallizing





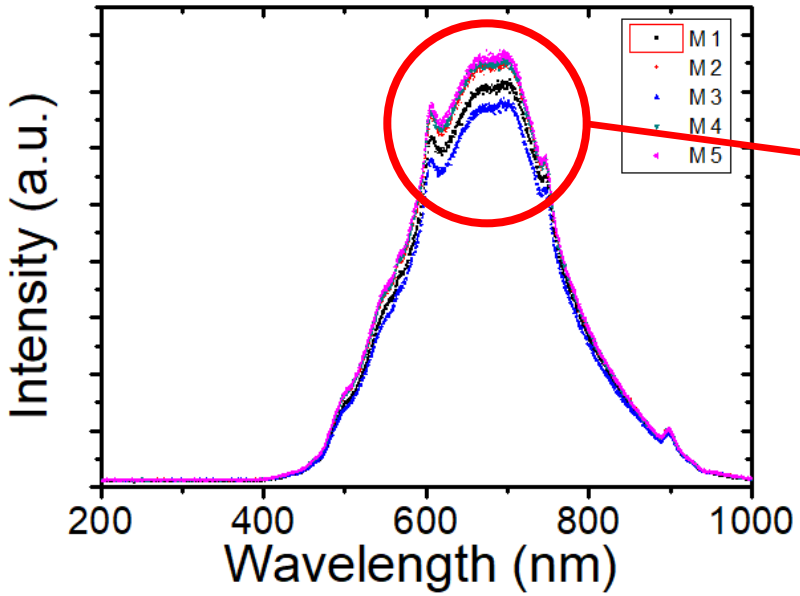


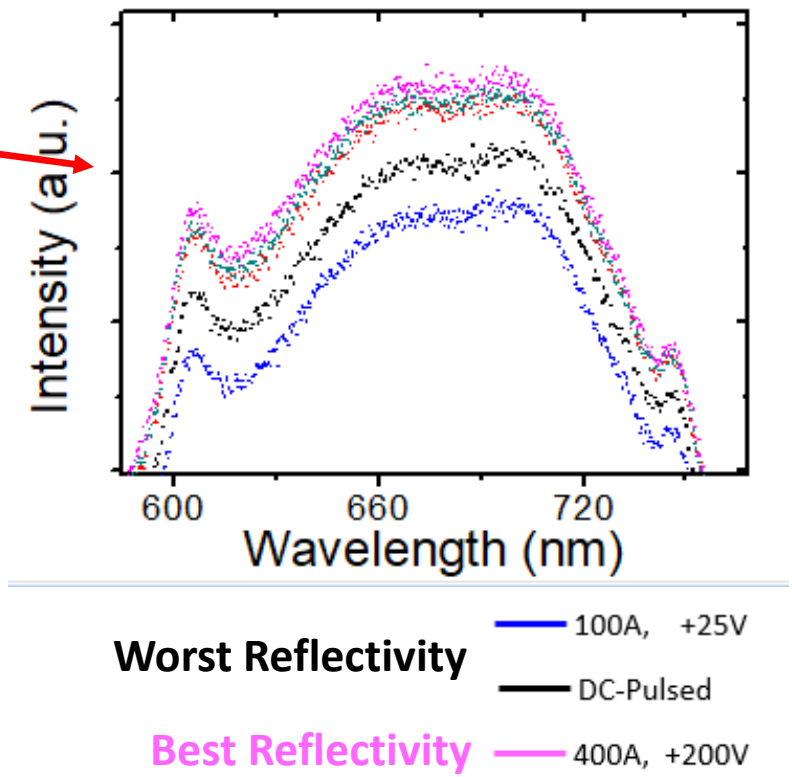
Reflectivity improvement with high I_{peak} & V+

HiPlus V+ for glass metallizing

Duralar® TECHNOLOGIES

VON ARDENNE



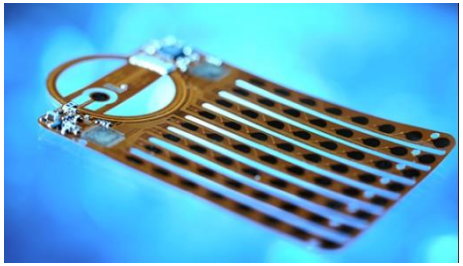


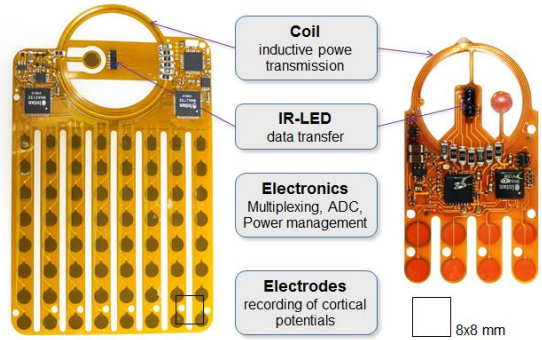
400A , +300V
100A, +25V
200A, +225V
400A, +200V
DC-Pulsed

Reflectivity Improvement with V+

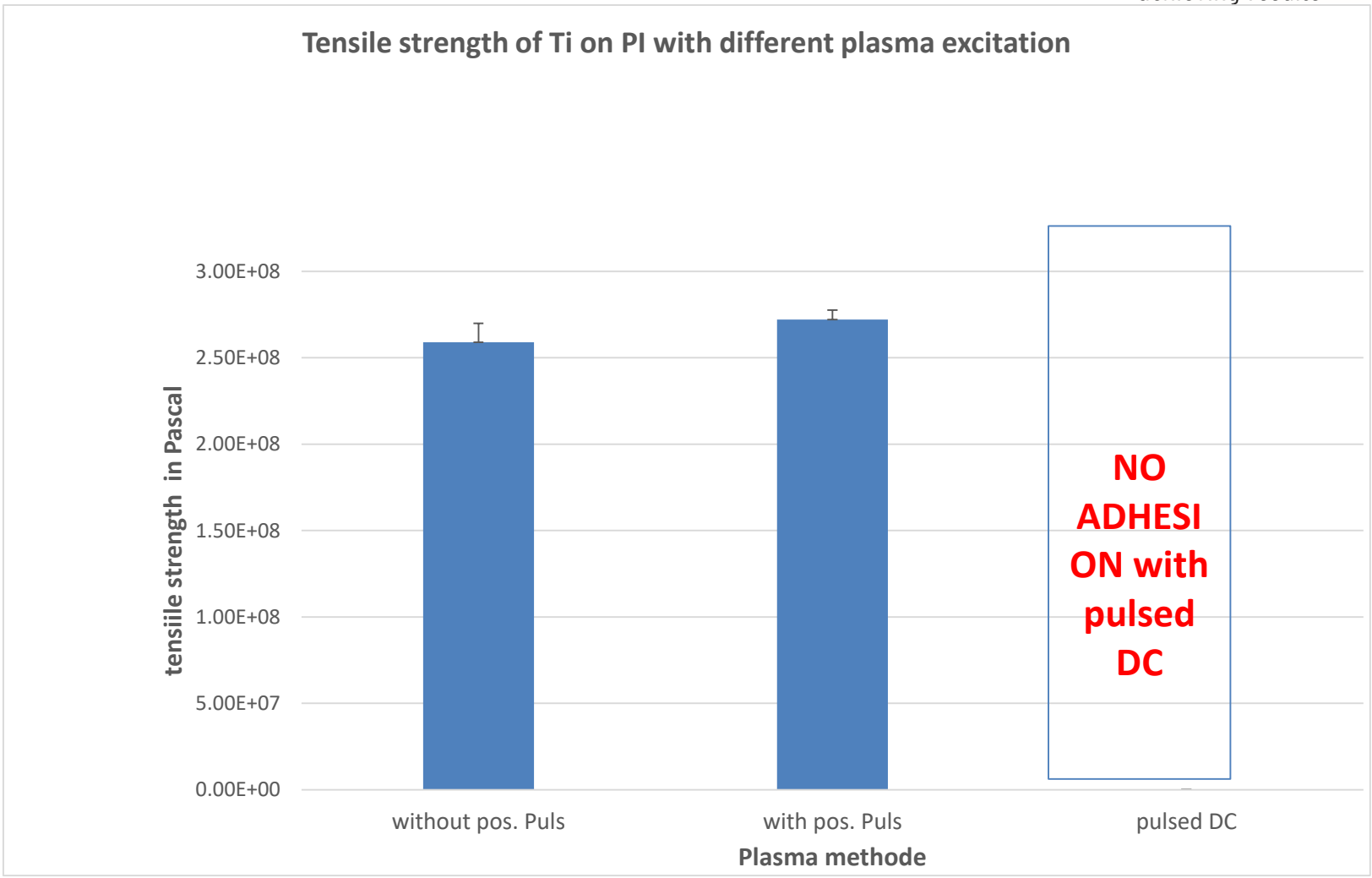
Ti on Polymid for active implants

HiPlus	HiPIMS [W]	Thickess [nm]	Dep. Rate [nm/W/min]	**Rel. Dep Rate**
ON	8000	239	0,0149375	**100,00%**
OFF	8000	208	0,013	**87,03%**
NA	DC-Pulsed [W]			
	5000	192	0,0192	**128,54%**





Ti on Polymid for active implants



With no plasma pre-treatment!

TiOx Roll-to-roll

HiPlus

INTELLIVATION ENGINEERED SOLUTIONS
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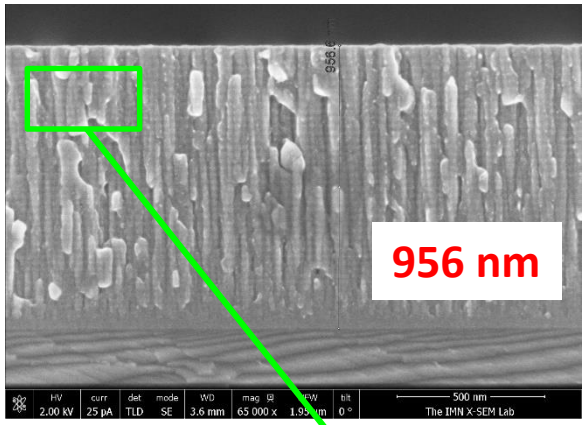
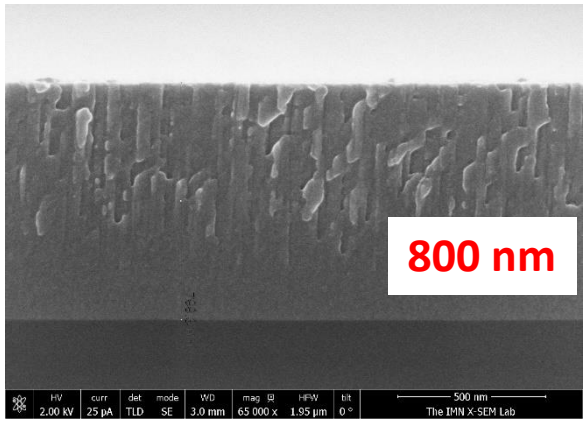
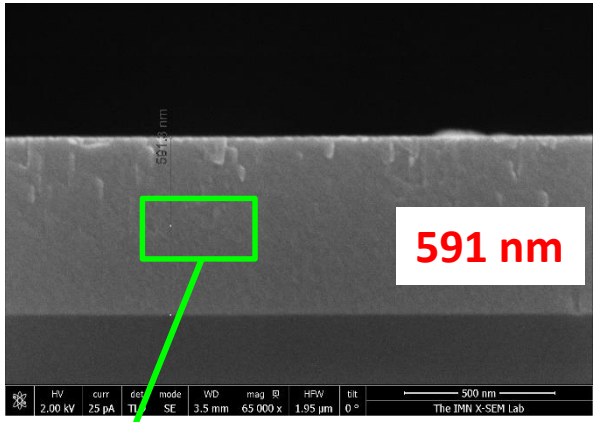
Pulsed DC

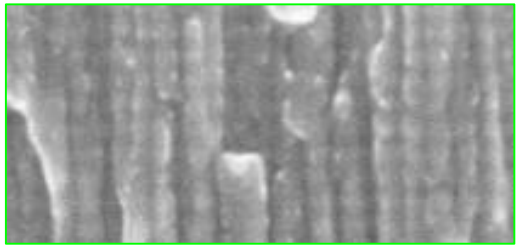


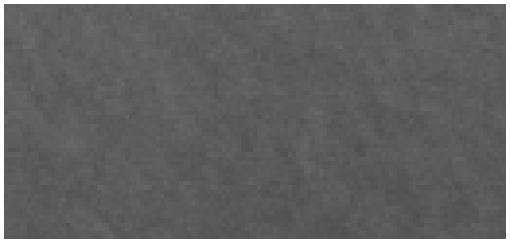
HiPIMS hiPlus : 200A, +350V



HiPIMS hiPlus : 400A, +400V





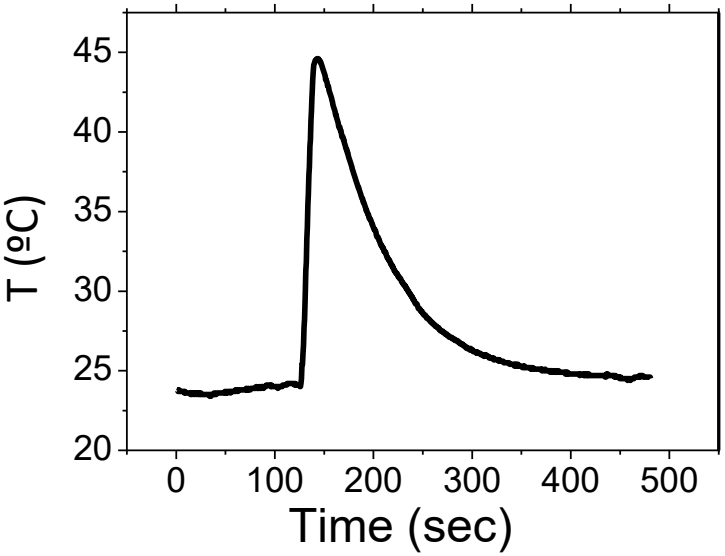


Denser films with no evidence of composition changes due when performing multiples passes.

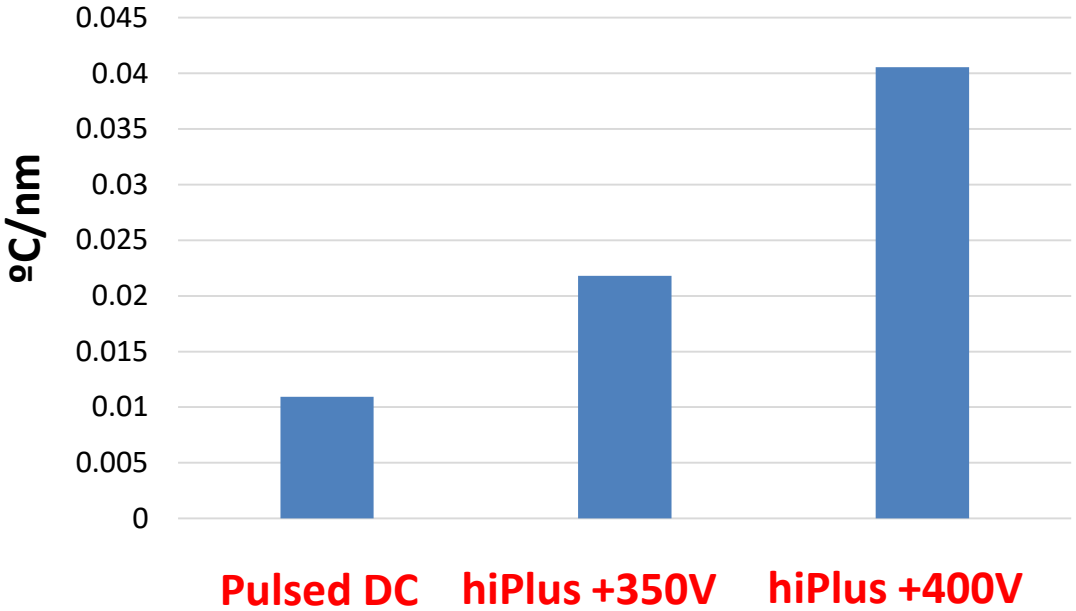
All coatings performed at equal average power and deposition time.

TiOx Roll-to-roll : thermal load

Thermocouple on PET web.



Temperature raise / Dep. Rate



Enhanced ion energy fluxes into insulating surfaces

Cada M, Bradley, J W Clarke G C B and Kelly P J 2007 *'Measurement of energy transfer at an isolated substrate in a pulsed dc magnetron discharge'* J. Appl. Phys. **102** 063301

ZnSnOx Roll-to-roll : WVTR

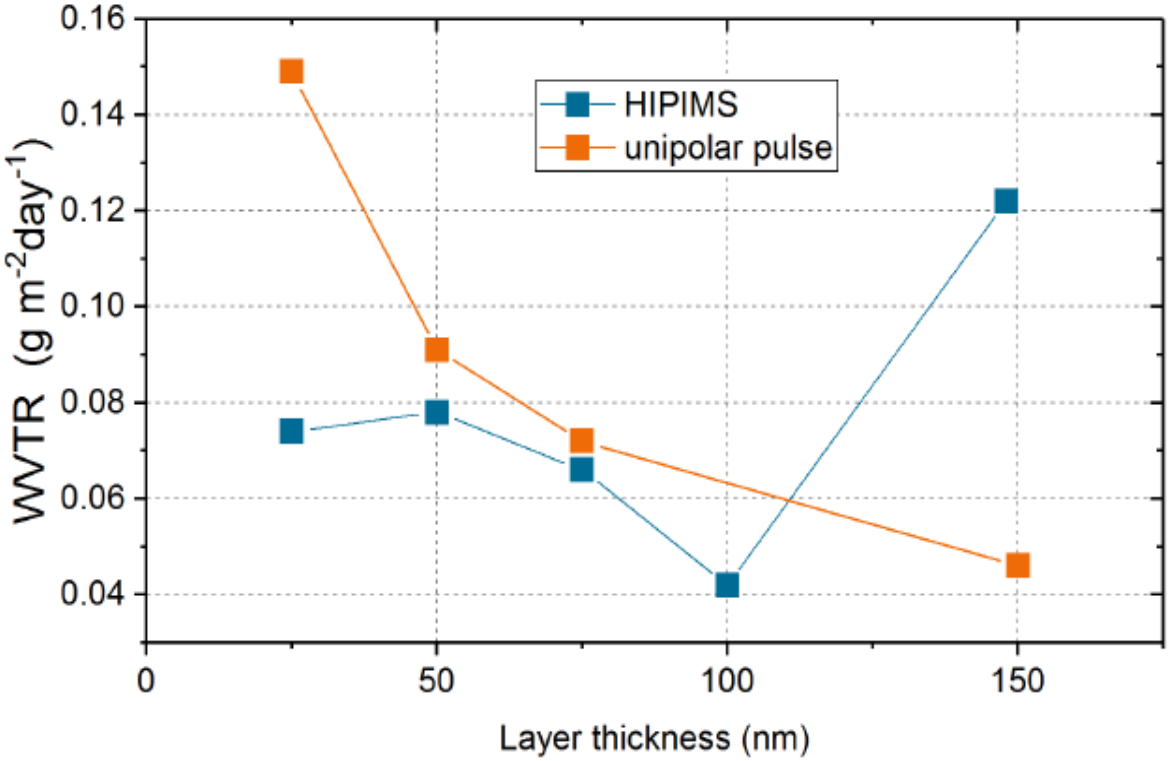
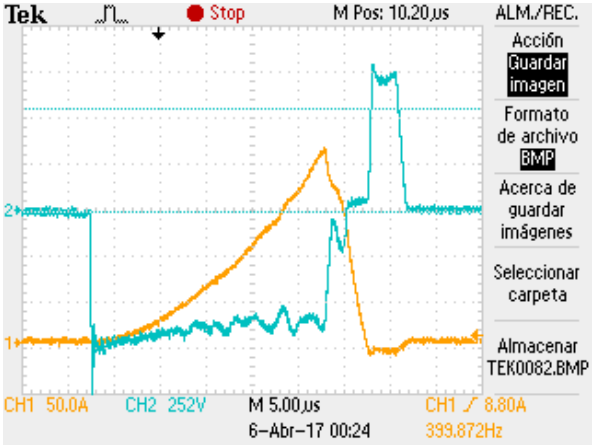


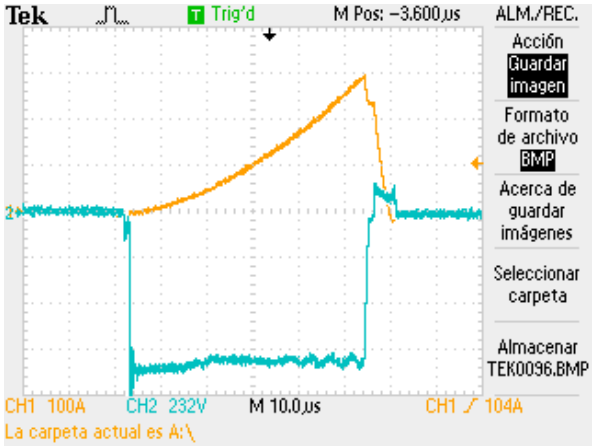
Figure 8: Water vapour transmission rate of ZnSnOx sputtered on conventional PET film (DuPont Melinex 400) at 9.5 kW, with additional 10 sccm oxygen

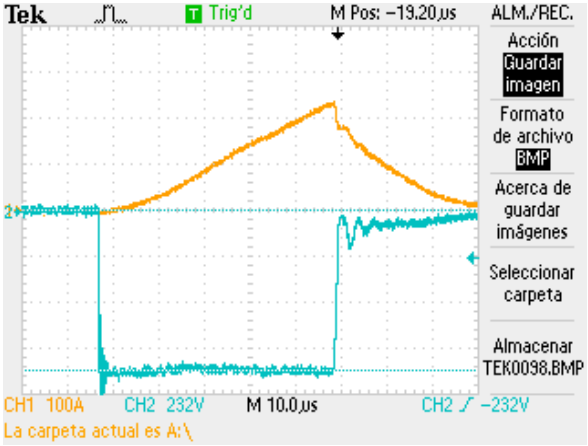
Evidence of lower permeation at lower film thickness

Goal for next year (2019)…

10 and 20kW industrial HiPIMS with fully controlled positive pulse….







Up to +1200V
Delay time <1us
Longer pulses

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Thank you for your attention!