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DLC coatings deposited by magnetron sputtering on **insulating substrates** with high hardness and enhanced adhesion properties

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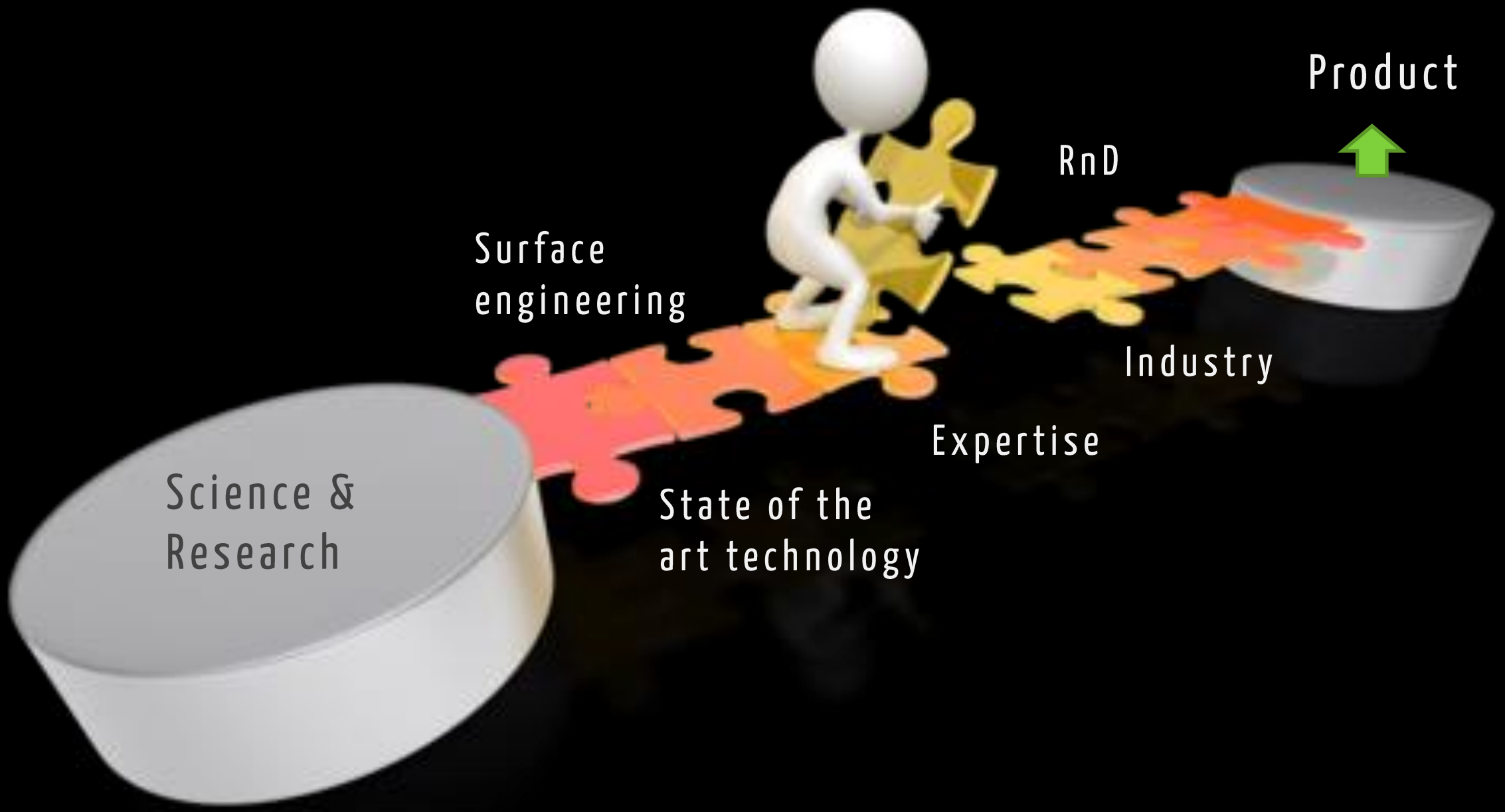
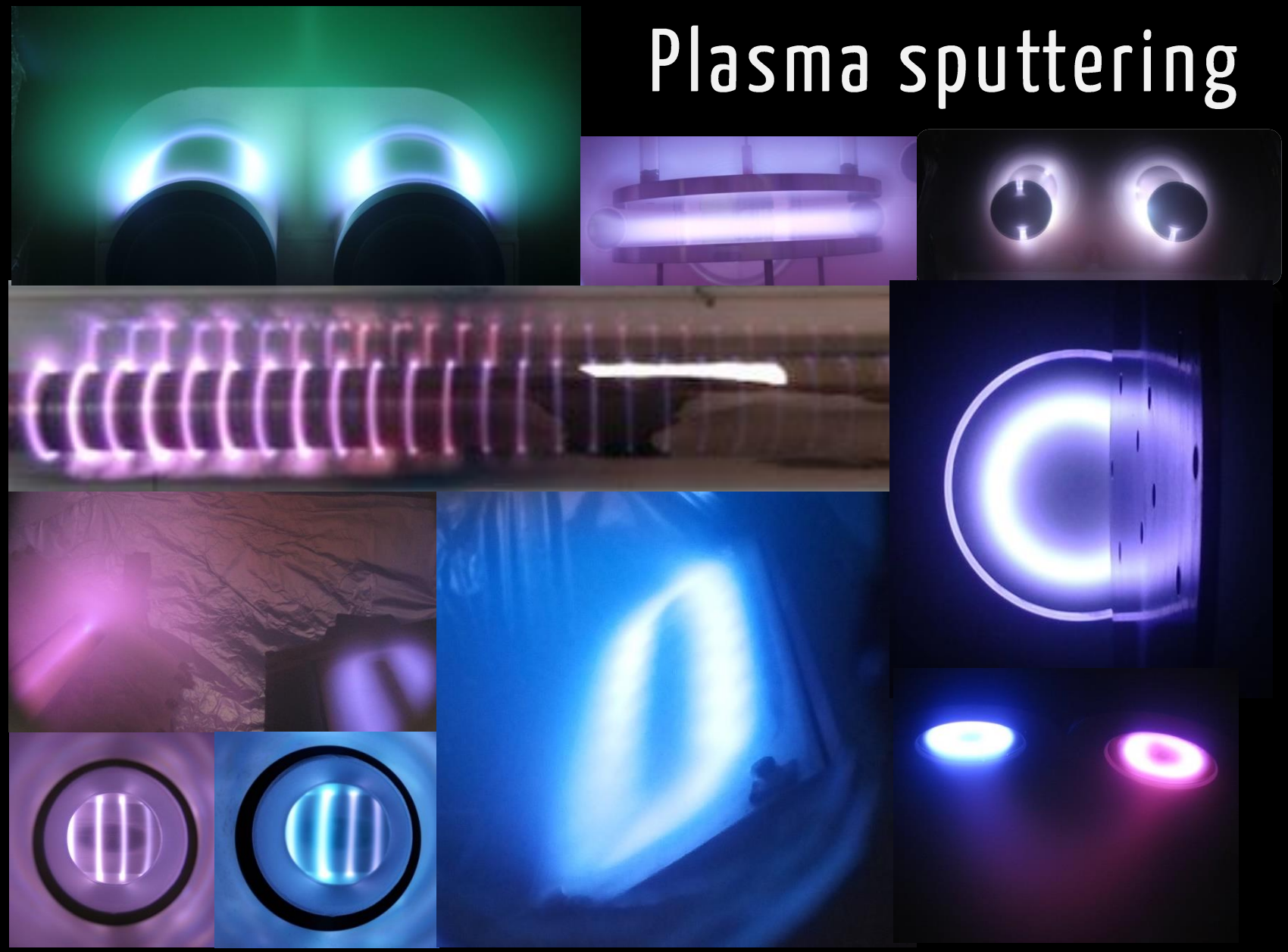
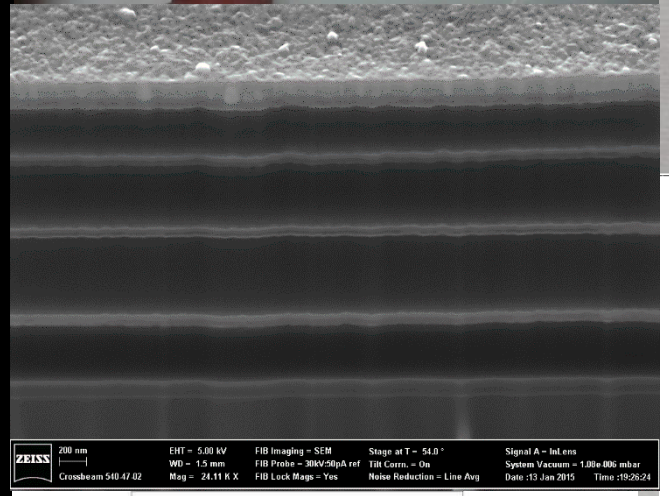
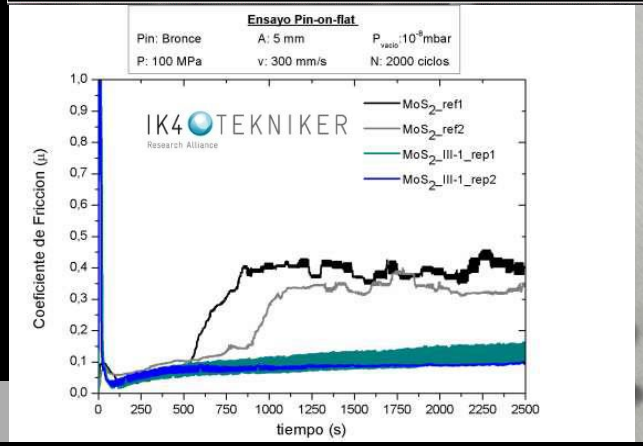

Product
RnD
Surface
engineering
Industry
Expertise
Science &
Research
State of the
art technology

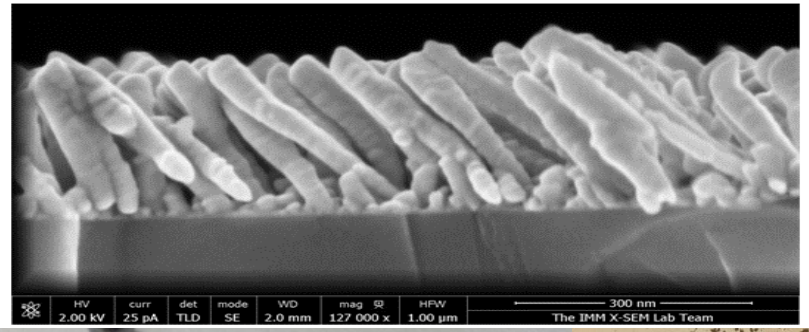
Plasma sputtering

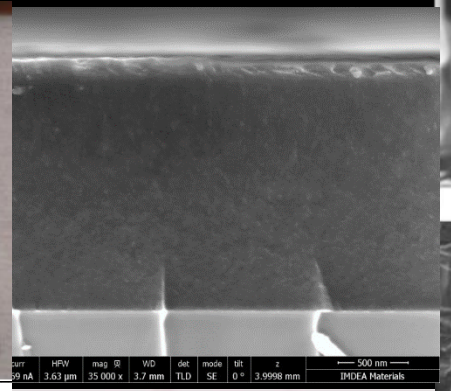


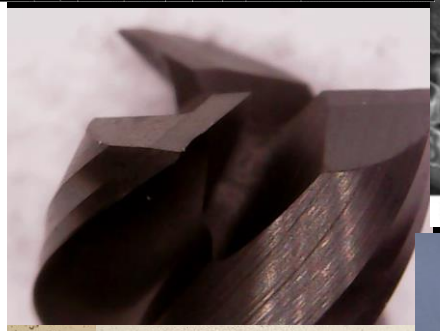
Coating solutions

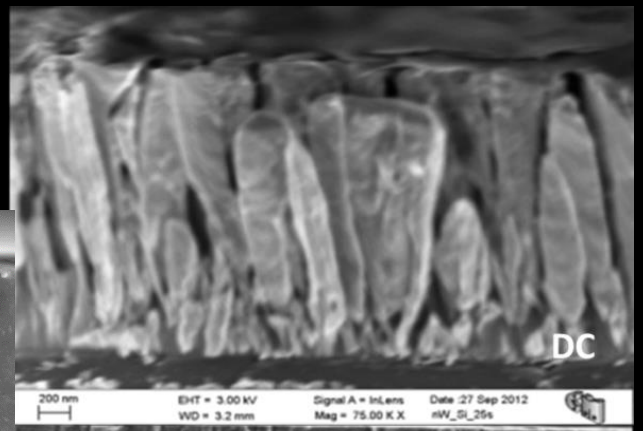


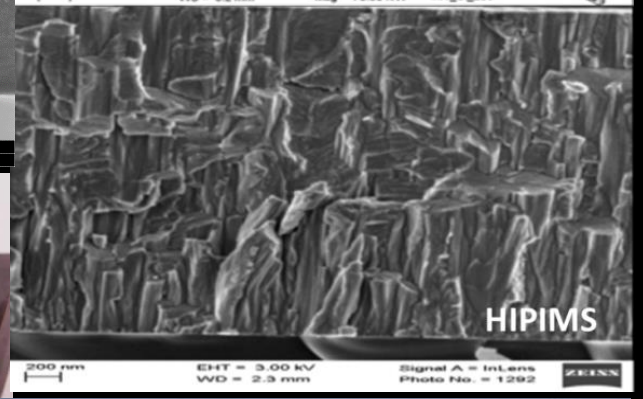


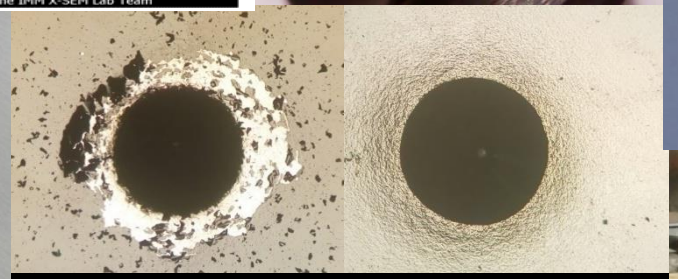












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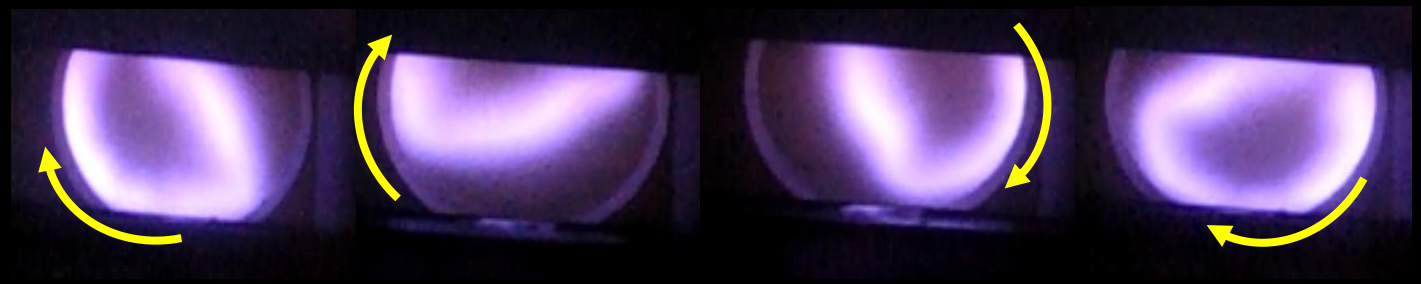
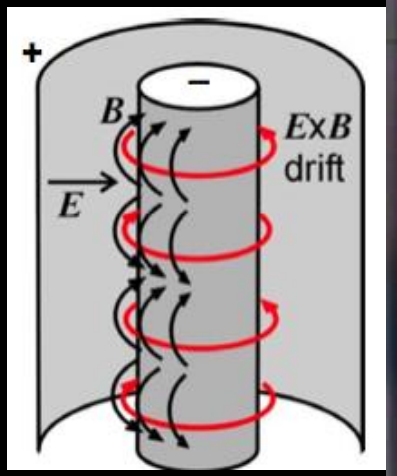
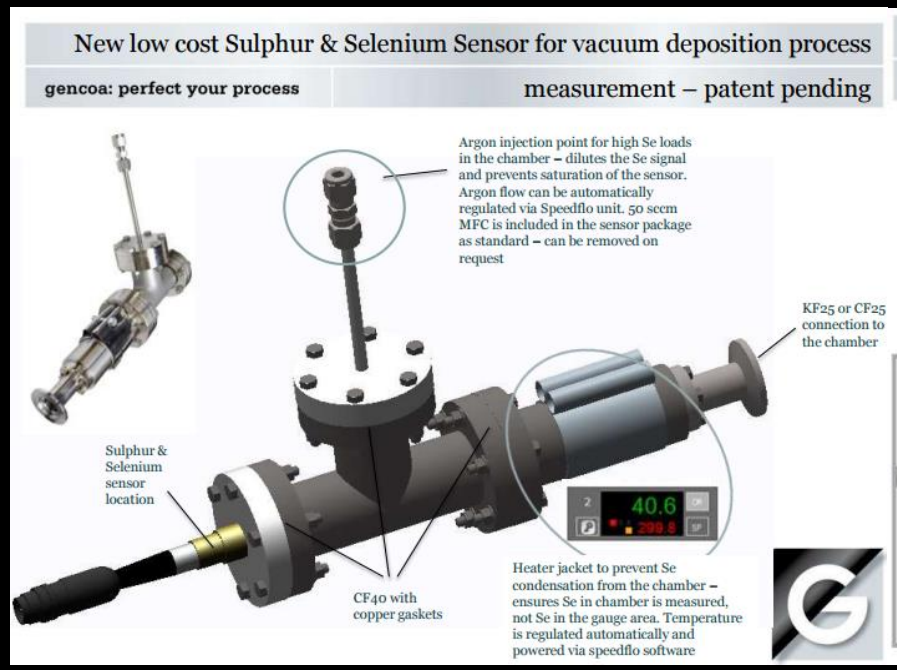
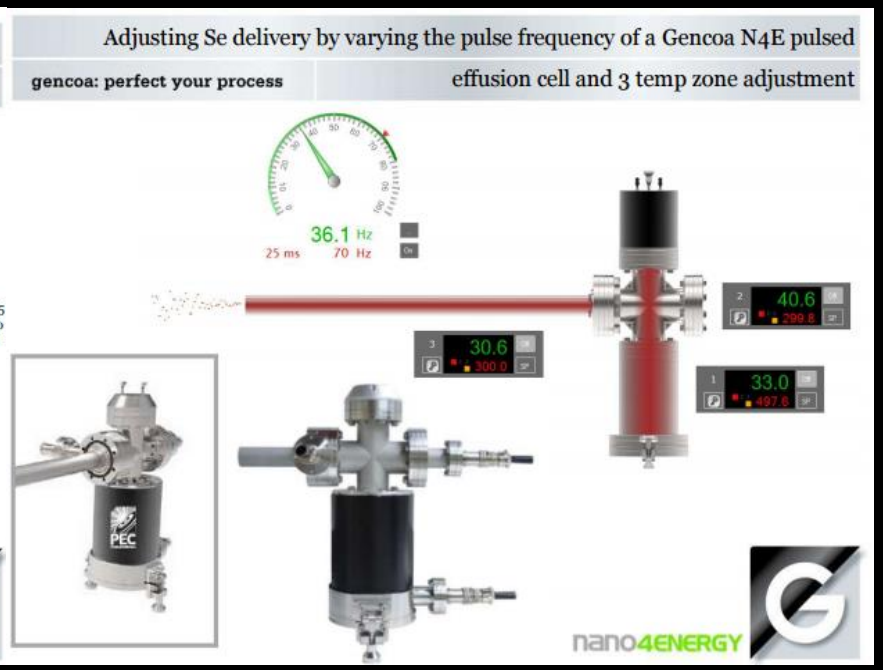
Instrumentation

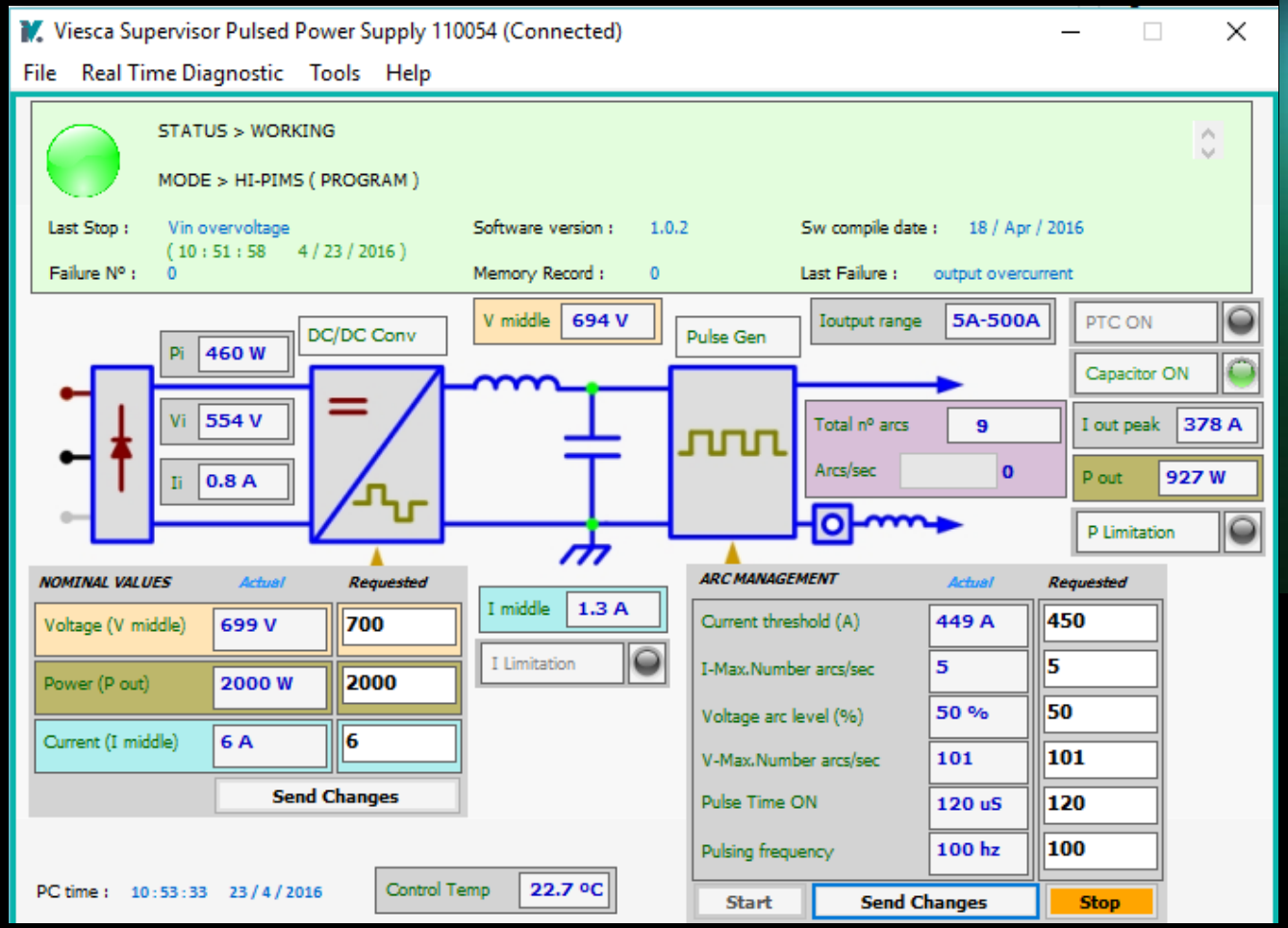








Power supplies



hipV

Diamond Like Carbon (DLC)

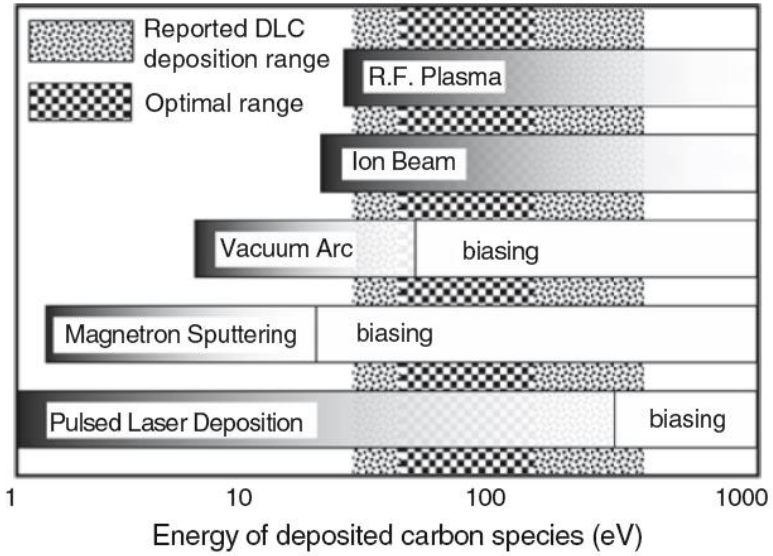
Diamond-like Carbon (DLC) is a metastable form of amorphous carbon with significant sp3 bonding. DLC coatings are of interest in a wide variety of applications to provide low friction and high hardness and wear resistance.

Applications

- **Glass: anti-scratch.**
- **Molds: prevent plastic transfer**
- **Engine parts: low friction (a-C).**
- **Space parts: low friction (a-C:H).**
- **Cutting tools: lubricated and dry conditions.**
- **Oil & gas: super lubricity in pipes.**
- **….**

DLC: State of the art

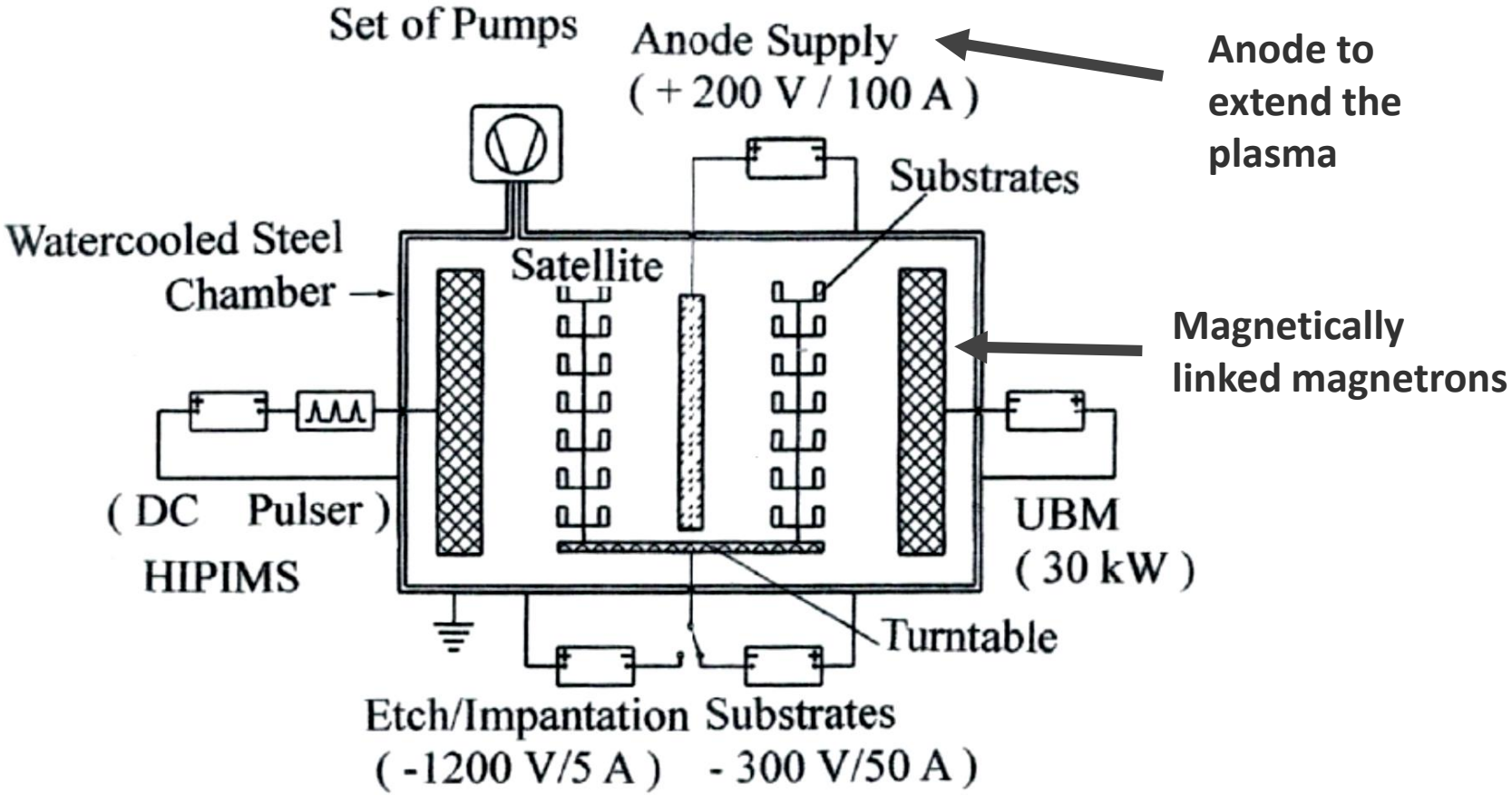
Material	Preparation technique	Density, (gm/cm^{-3})	% sp^3	Hardness, (GPa)	Young's modulus, (GPa)	Friction coefficient against metals*
Diamond	Naturally occuring	3.52	100	100	1,050	0.02–0.10
DLC	Sputtering	1.9–2.4	2–5	11–24	140	0.20–1.20
Me doped H:DLC	Reactive sputtering	–	–	10–20	100–200	0.10–0.20
H:DLC	r.f plasma	1.57–1.69	–	16–40	145	0.02–0.47
H:DLC, DLC	Ion beam	1.8–3.5	–	32–75	–	0.06–0.19
ta-DLC	Vacuum arc	2.8–3.0	85–95	40–100	500	0.04–0.14
ta-DLC	PLD	2.4	70–95	30–60	200–500	0.03–0.12



Ion assistance required ~ 100eV

A. Voevodin, Surf. Coat. Technol. 82 (1996) 199–213.
J. Robertson, Surf. Coat. Technol. 50 (1992) 185–203.

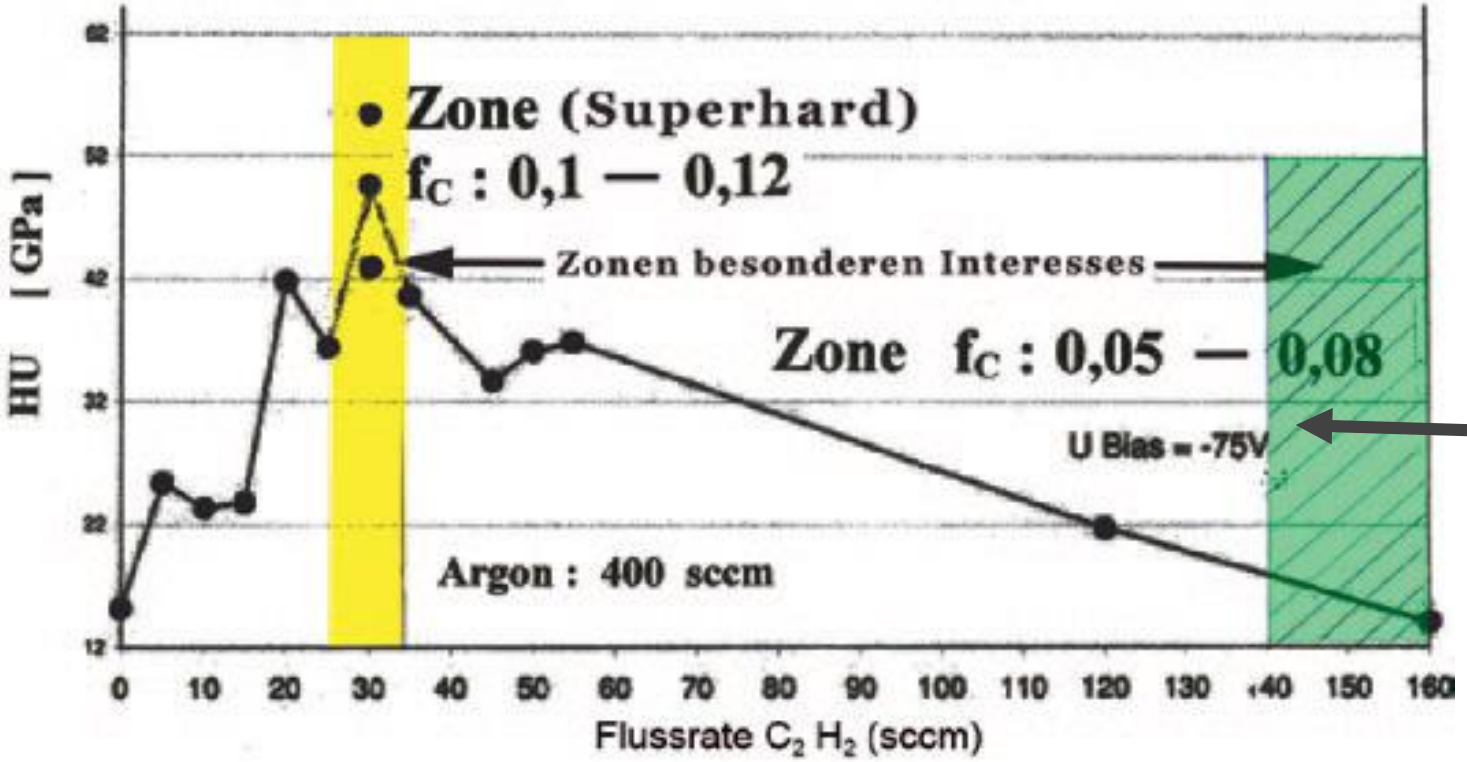
DLC hard coating magnetron deposition



Anode to extend the plasma

Magnetically linked magnetrons

DLC hard coating magnetron deposition



55GPa Micro hardess, comparable to filtered arc

Bias required

Glass?
Plastics?

Drawbacks with current technologies

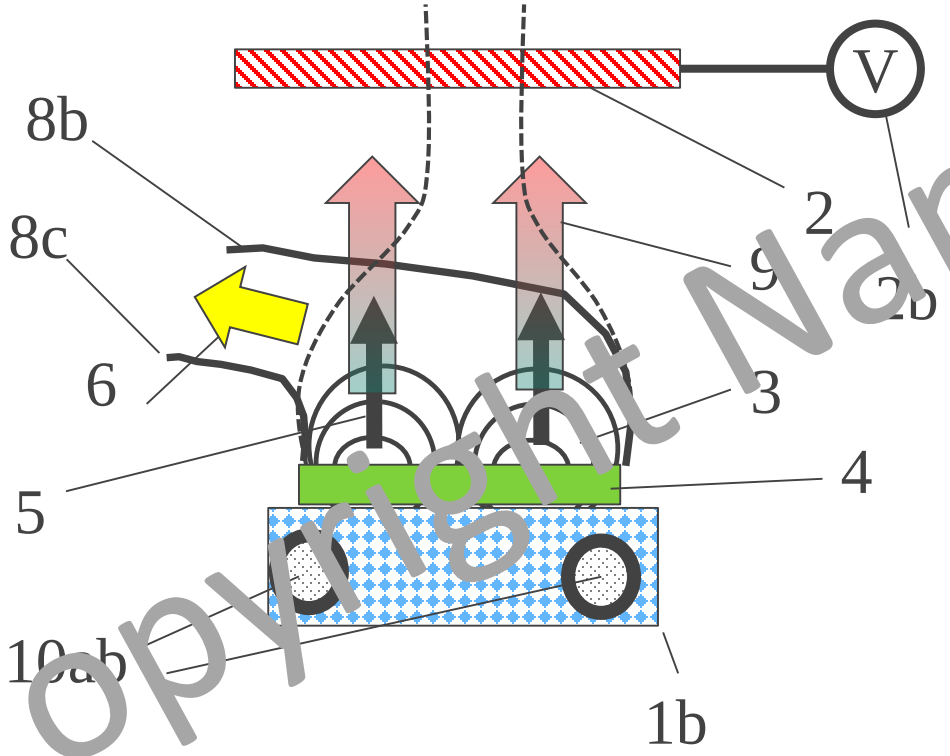
- High level of electron bombardment
- Bias requirements
- Low deposition rates
- Very narrow process window

SOLUTION?

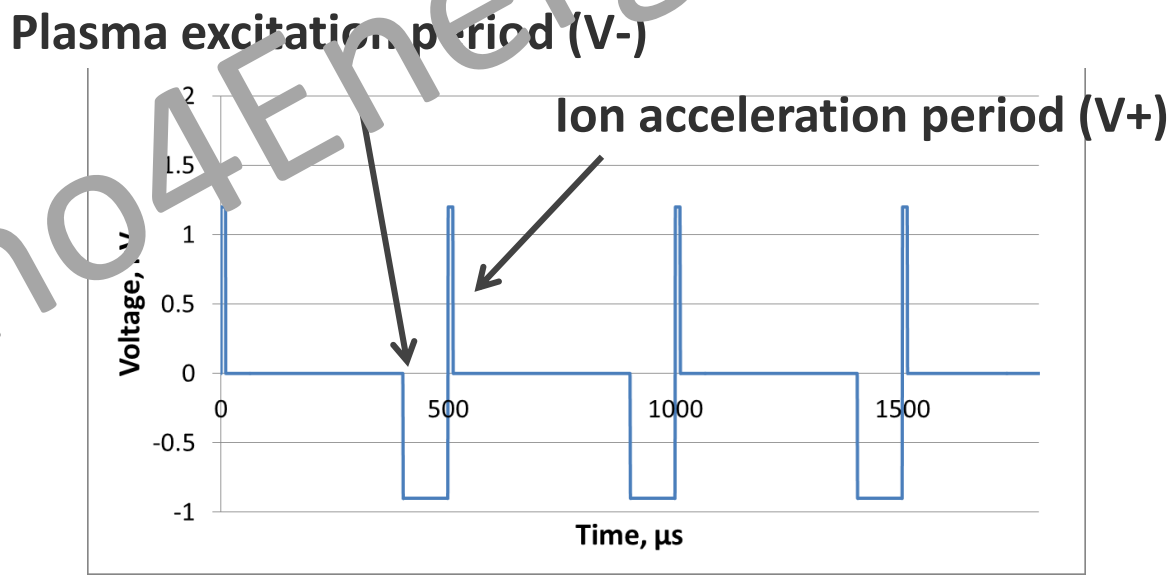
Ion assisted deposition on insulators

GENCOA

Magnetron magnetic design (electron filter)



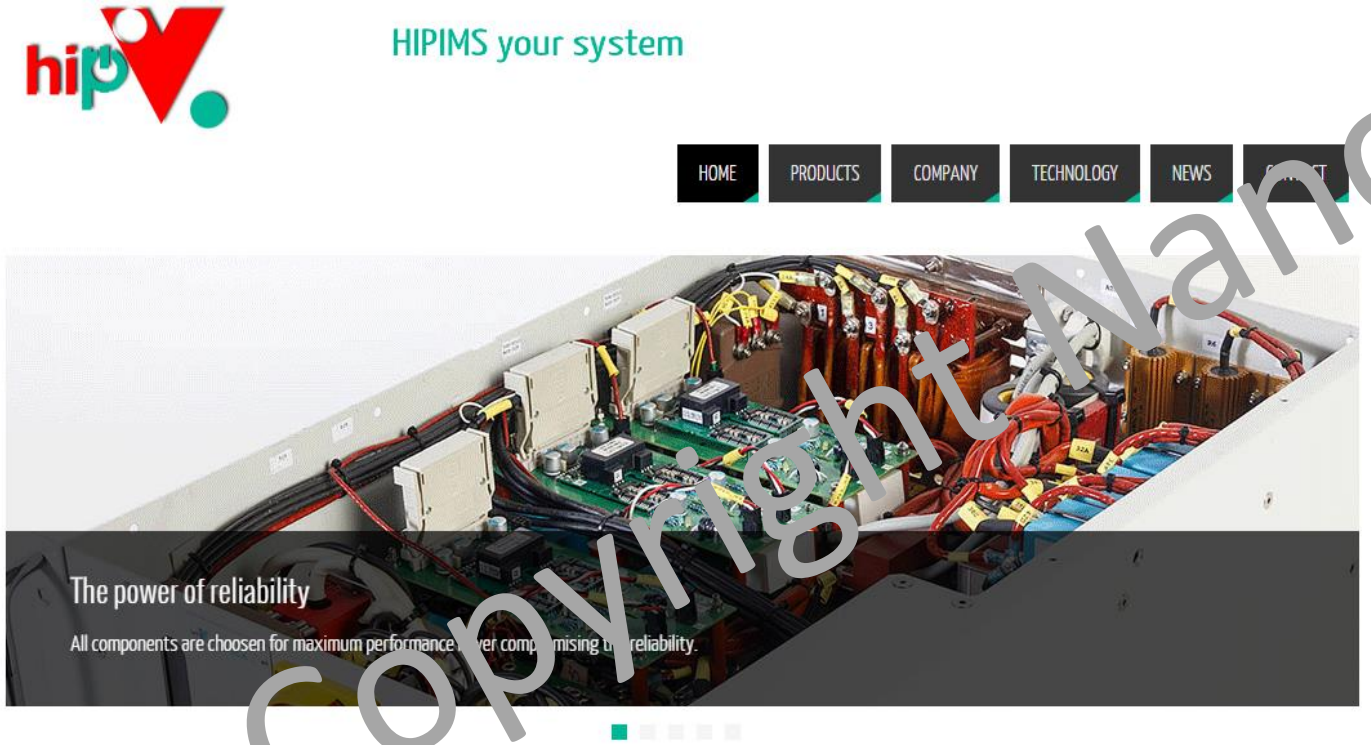
Modified asymmetric bipolar pulsed PS

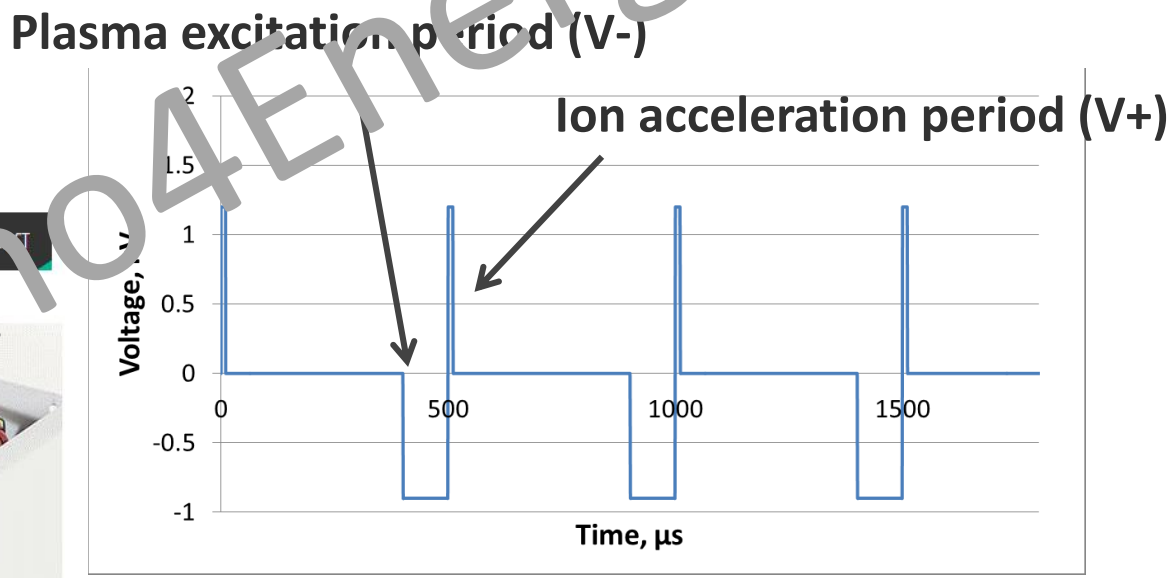


Ion assisted deposition on insulators

GENCOA

Modified asymmetric bipolar pulsed PS





- Positive ion bombardment
- No electron bombardment
- Reduced thermal load?

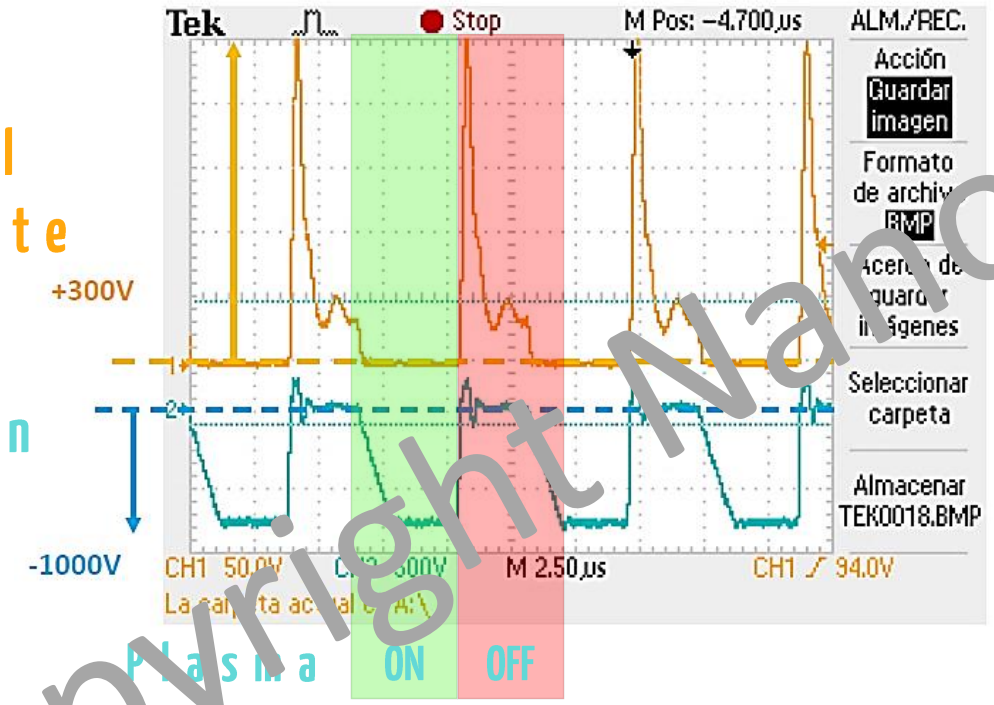
Ion assisted deposition on insulators

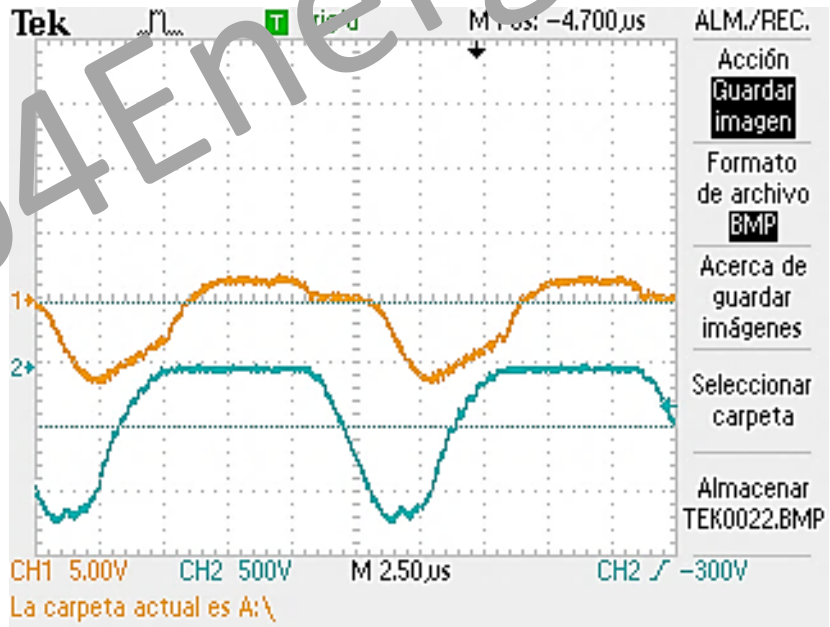
GENCOA

Modified asymmetric bipolar pulsed PS

Floating Potential in substrate

Magnetron Voltage





Hardness > 30GPa
Modified DC-Pulsed PS

Hardness < 12GPa
Commercial DC-Pulsed PS

Ion assisted deposition on insulators

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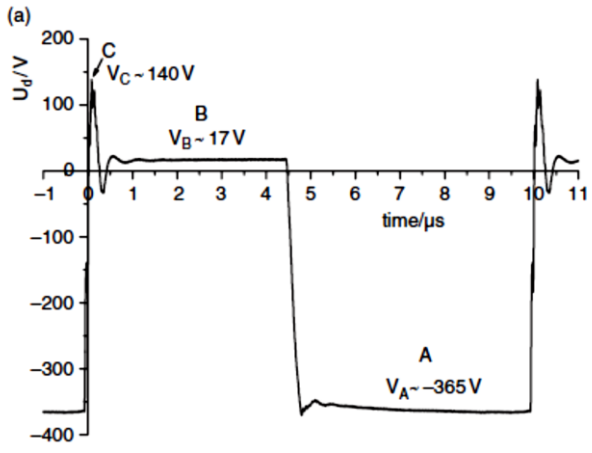
Evidence of high energetic ions



INSTITUTE OF PHYSICS PUBLISHING
PLASMA SOURCES SCIENCE AND TECHNOLOGY
Plasma Sources Sci. Technol. 11 (2002) 165–174
PII: S0963-0252(02)34675-9

The distribution of ion energies at the substrate in an asymmetric bi-polar pulsed DC magnetron discharge

J W Bradley[1], H Bäcker[1], Y Aranda-Gonzalvo[1], P J Kelly[2] and R D Arnell[2]

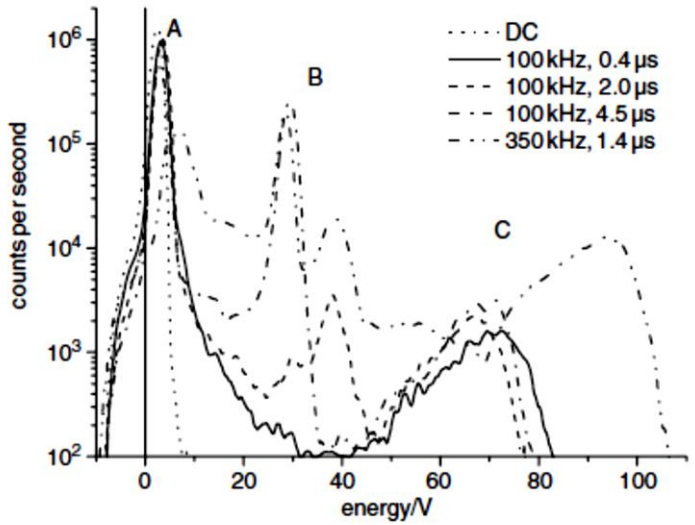


Figure 4. Ar^+ energy spectra (IEDF) for the cases: 100 kHz at 0.4, 2.0 and 4.5 μs reverse time and 350 kHz at 1.4 μs reverse time.

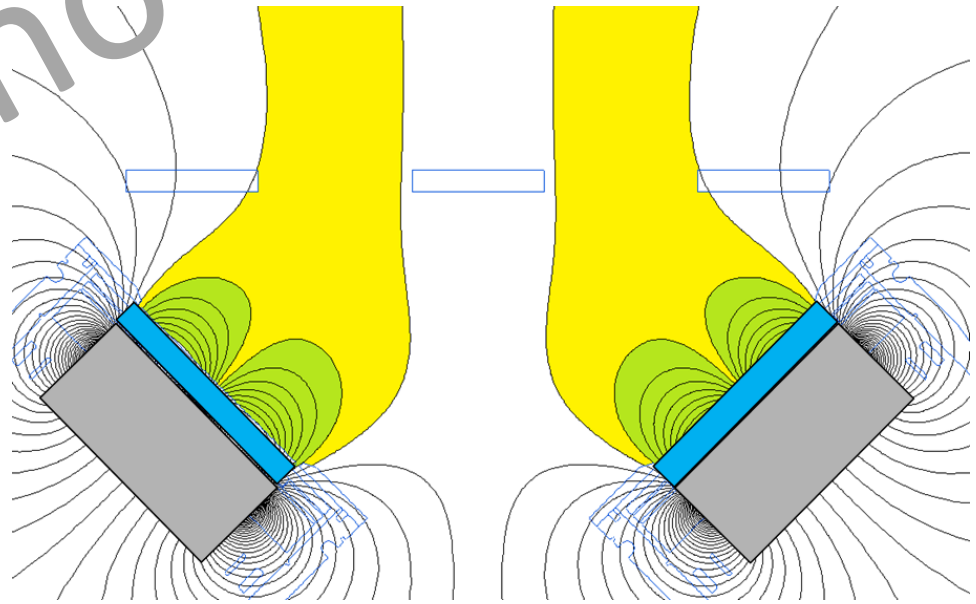
3 energy regimes are measured

Ion assisted deposition on insulators

GENCOA

Magnetron magnetic design (electron filter)

Magnetron size 400x100mm2 (industrially relevant) – WC, Graphite targets
Optimized magnetic field configuration to enhance positive ion assisted deposition



Ion assisted deposition on insulators

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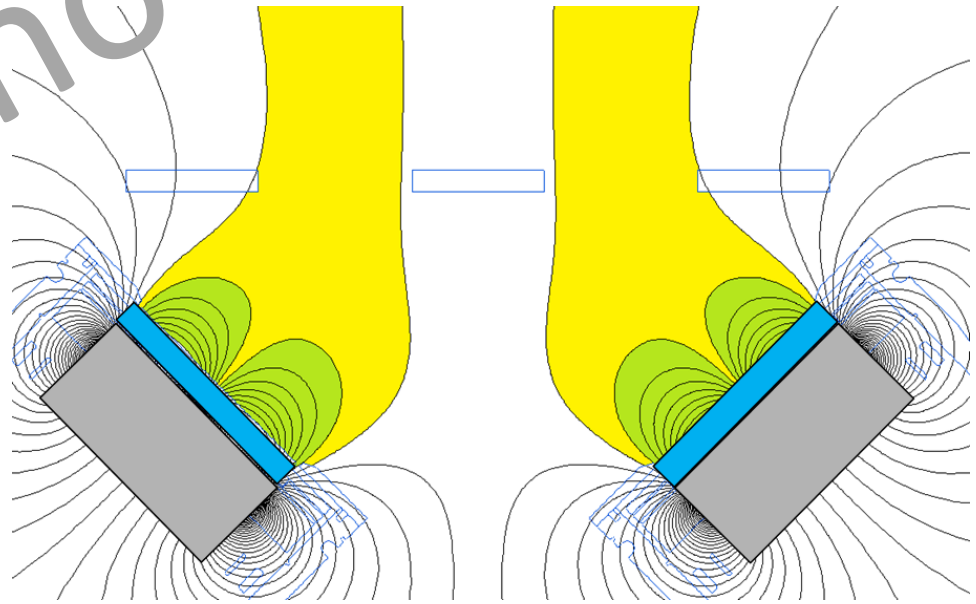
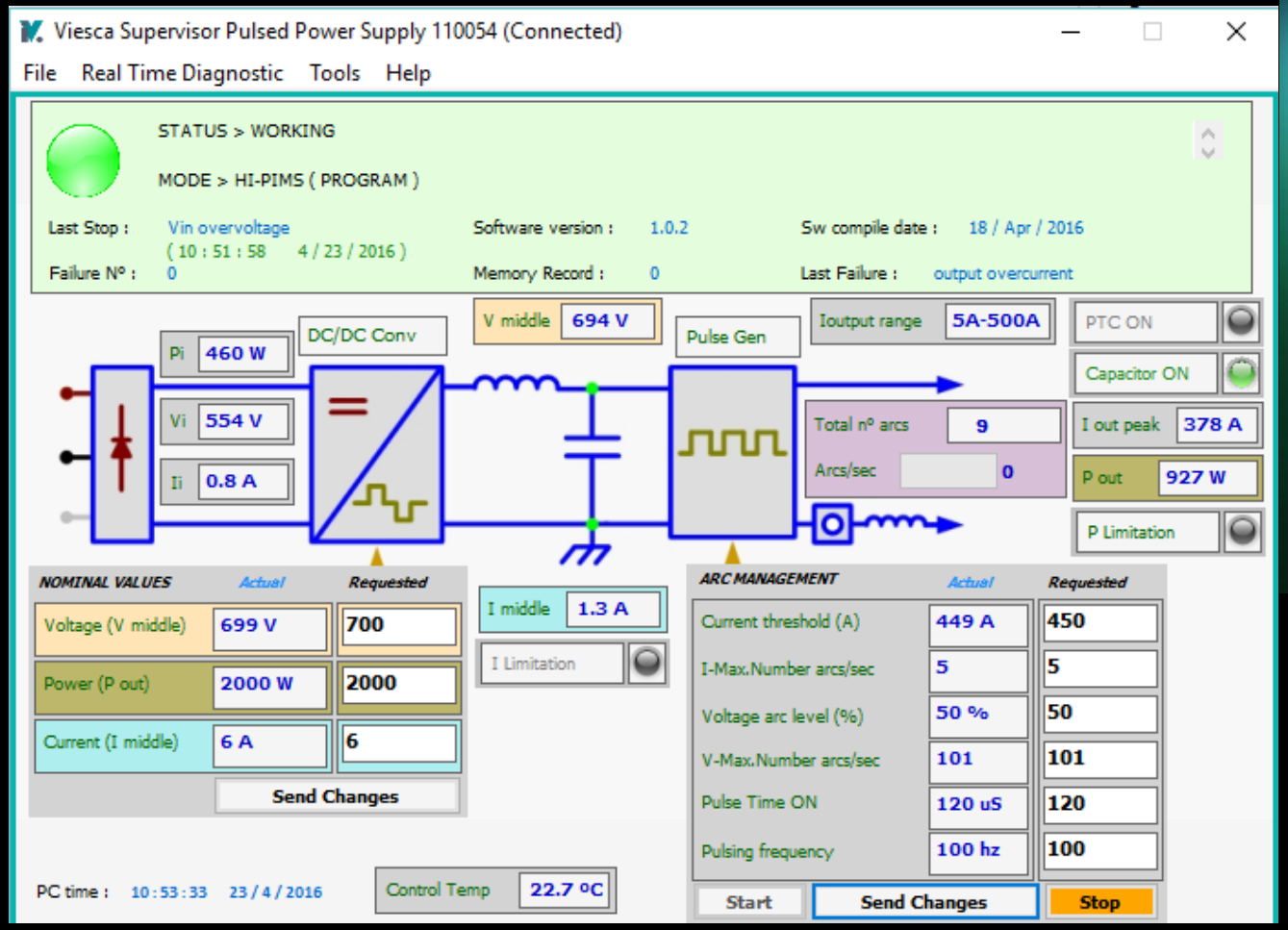


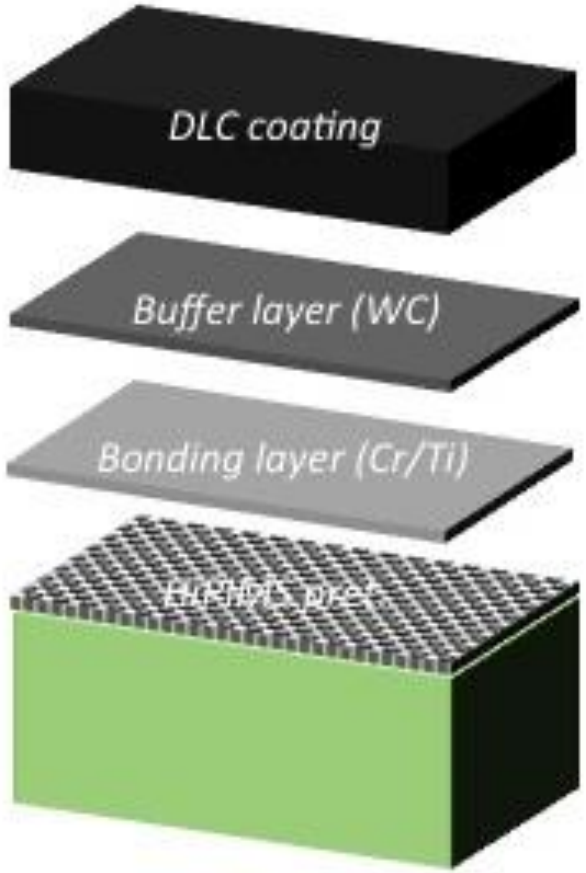
The hiP-V power supply

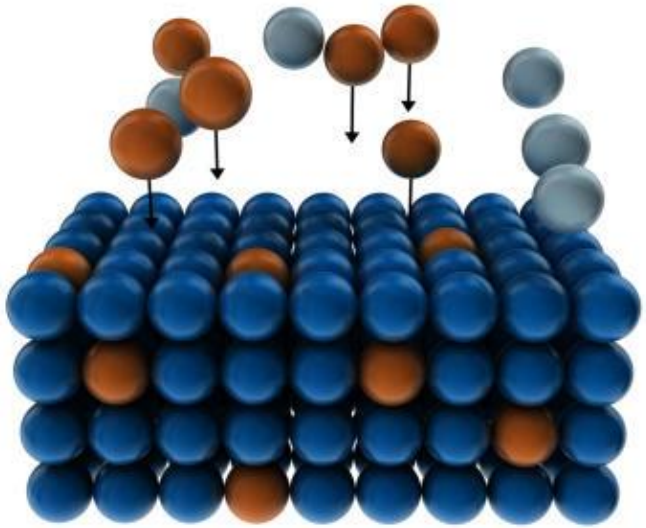


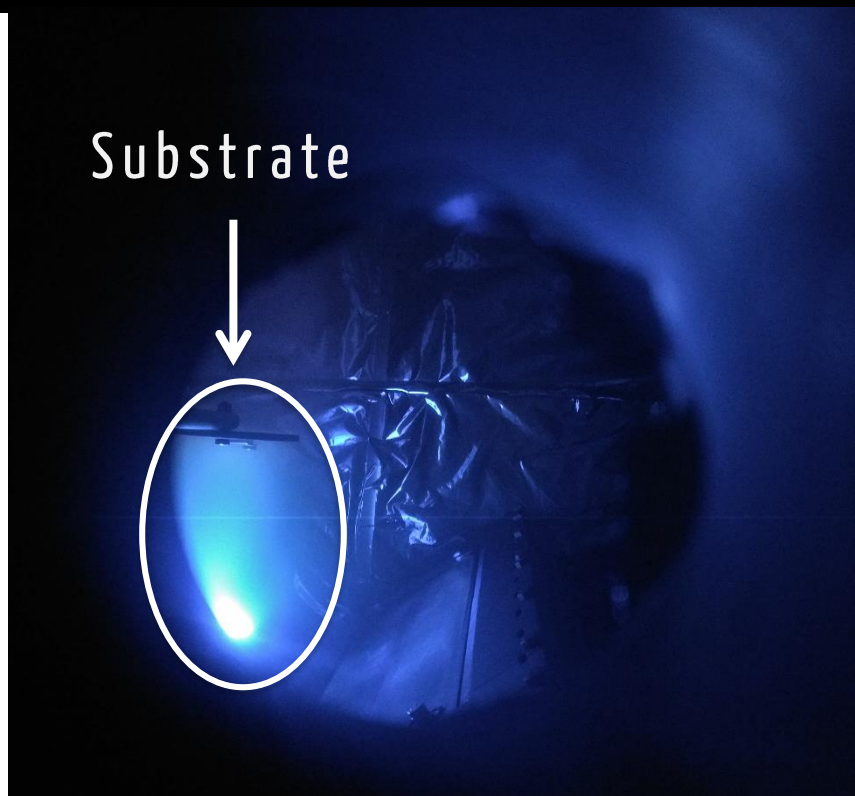
hiP-V

Adhesion

Surface preparation







Bias pre-treatment

Low accumulated stress @ high hardness

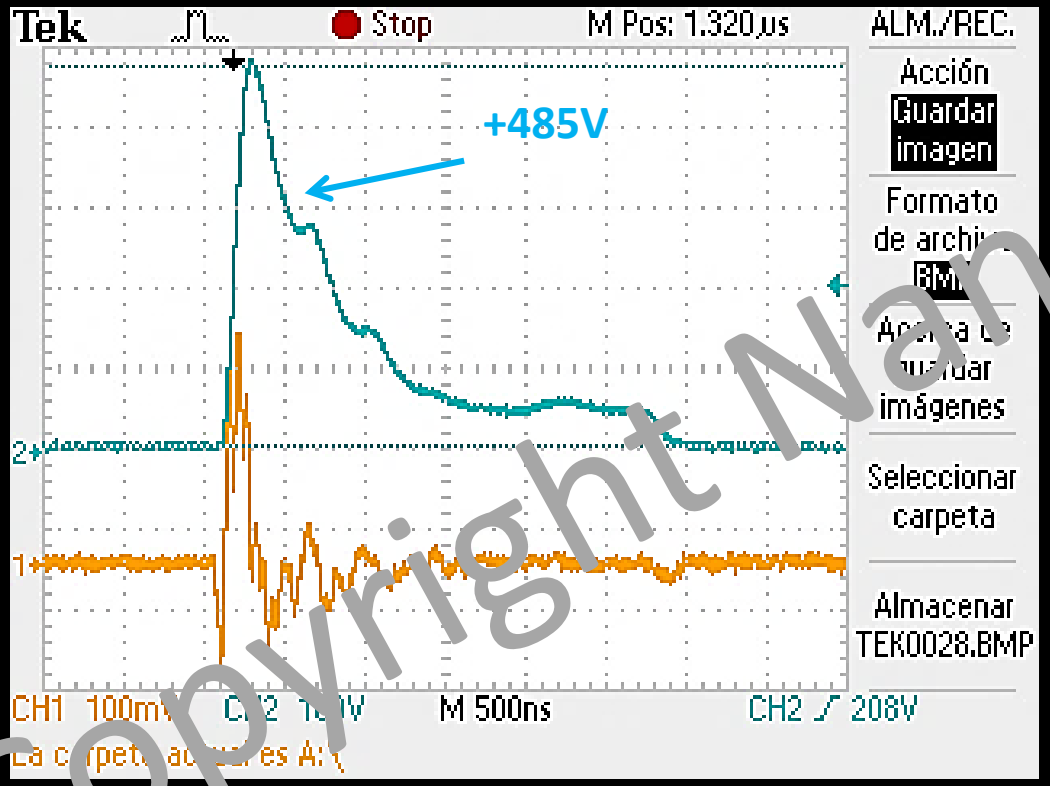
Biased process: high DLC coating stress

N4E process: low DLC coating stress

No charge build-up in sharped edges

DLC coating on Glass

Reactive Oxygen Ion Etching



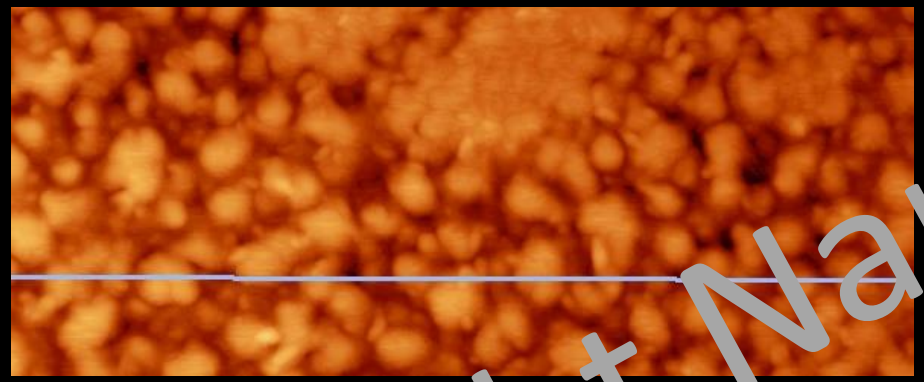
Current to floating potential (10mV/A)

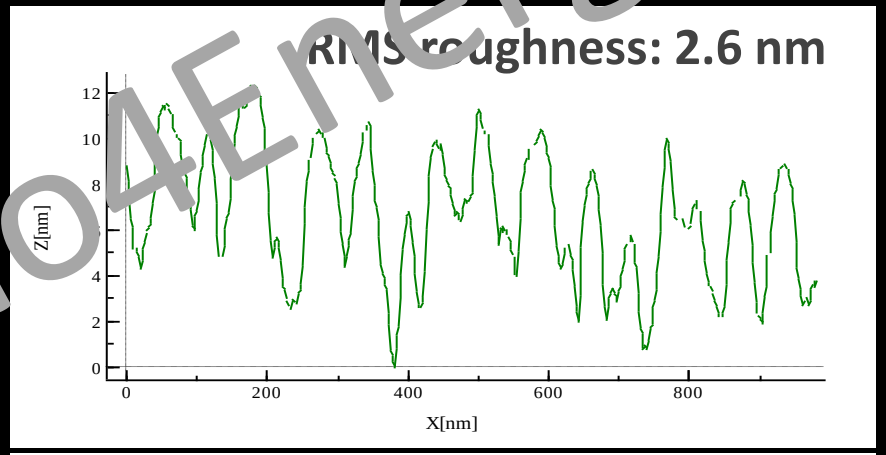
Substrate can be pre-treated by ion etching with reactive gases such as oxygen

DLC coating on Glass

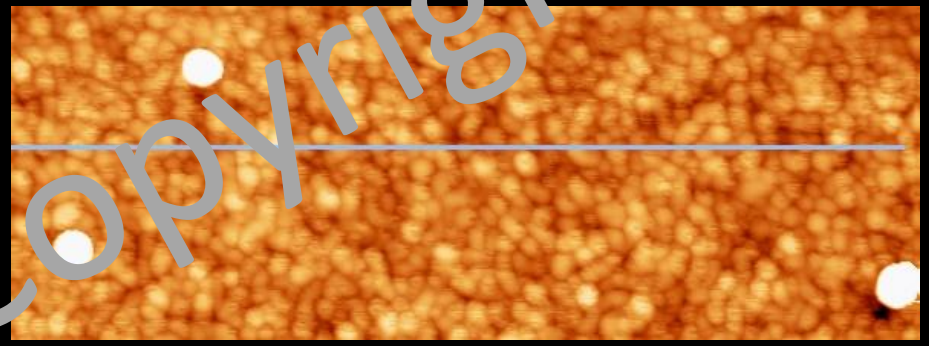
Reactive Oxygen Ion Etching

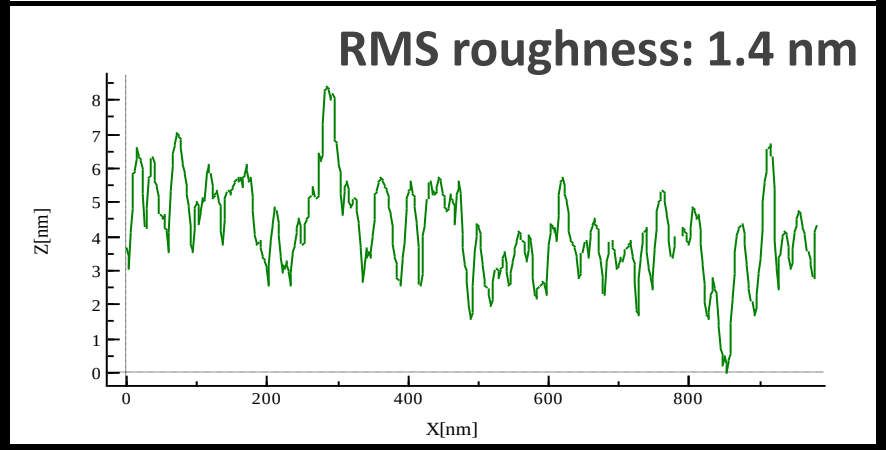
Untreated glass substrate





Oxygen treated glass substrate





DLC coating on Glass

Reactive Oxygen Ion Etching test results

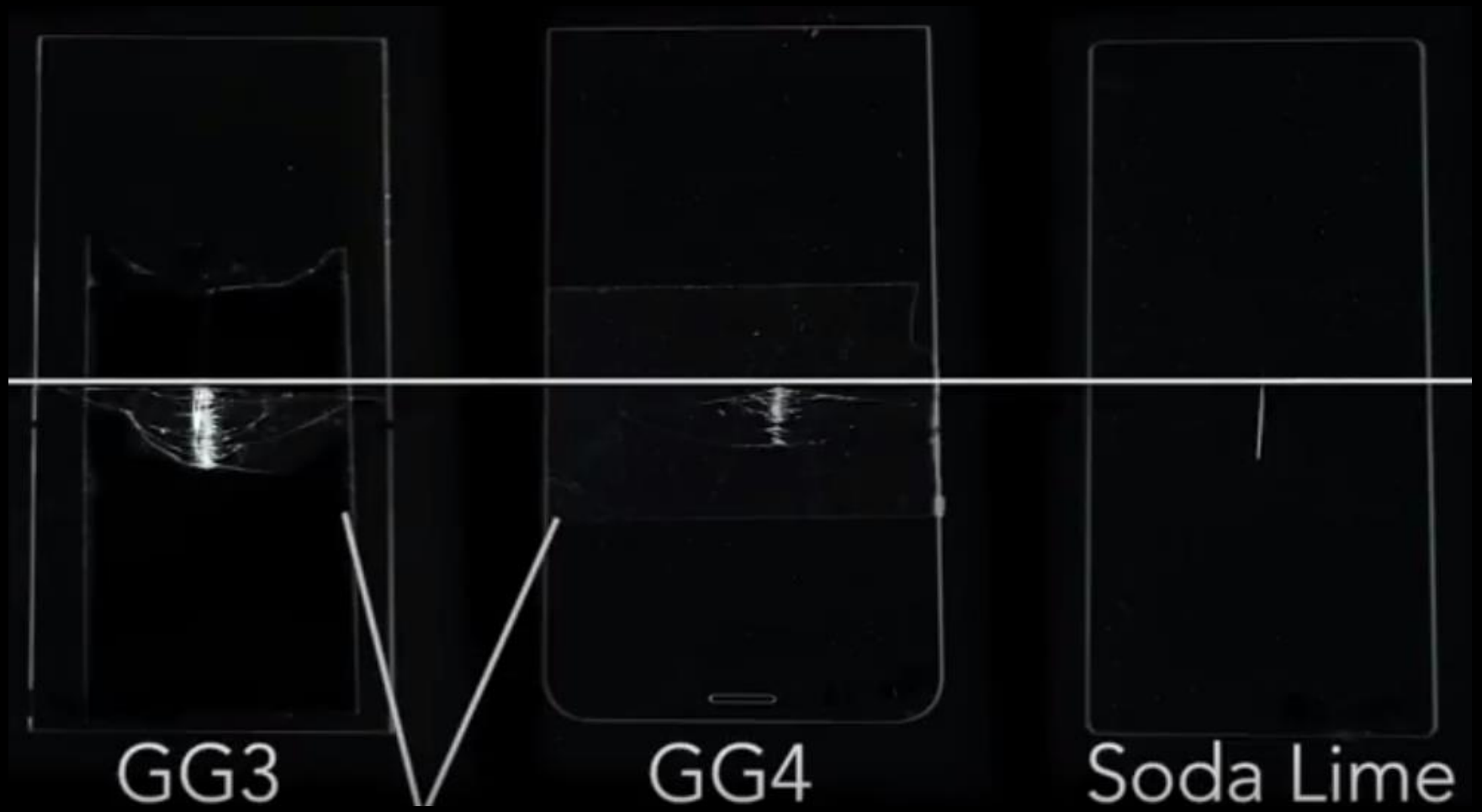
DLC Coating description	Total Light transmission	Taber test result
15 min O2 plasma cleaning + 60 sec DLC (aprox. 6nm)	89.2	≤20 times NG
30 min O2 plasma cleaning + 30 sec DLC (aprox. 3nm)	89	≤20 times NG
5 min O2 plasma cleaning + 30 sec DLC (aprox. 3nm)	91.2	≤10 times NG

DLC coating on Glass

24N scratch test

DLC coated

Uncoated



Tape to hold broken glass together

INTEVAC

nano4ENERGY

DLC coating on Glass

Haze test

DLC coated

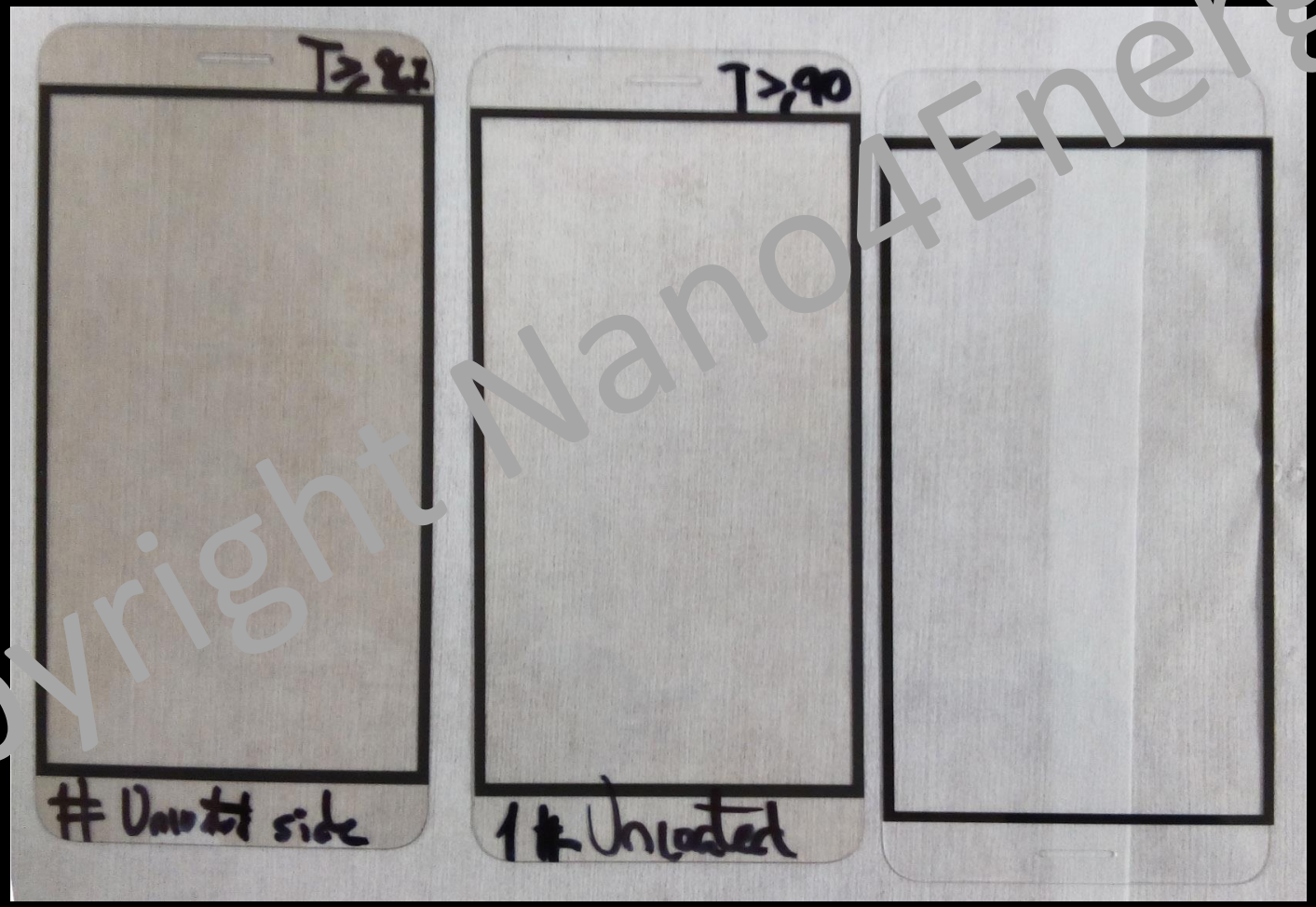
Uncoated

INTEVAC

nano4ENERGY

DLC coating on Glass

High level of light transmission

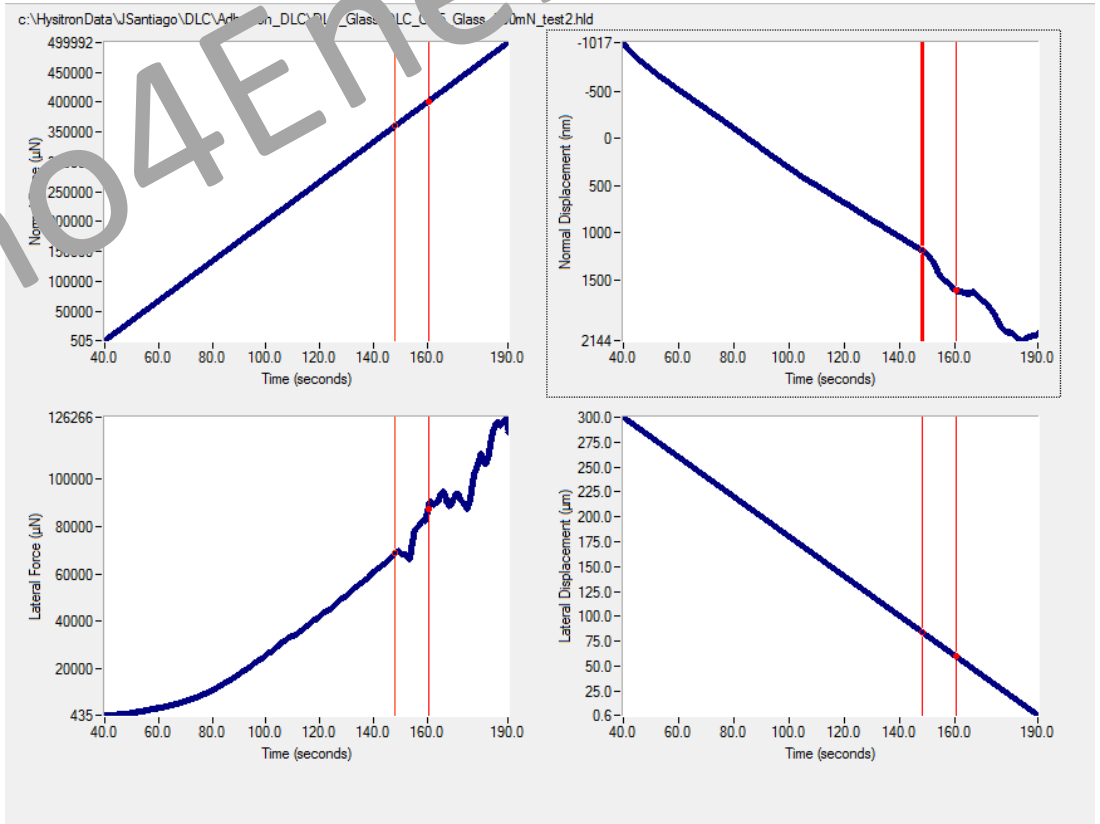


DLC coating on Glass

nano-scratch tests

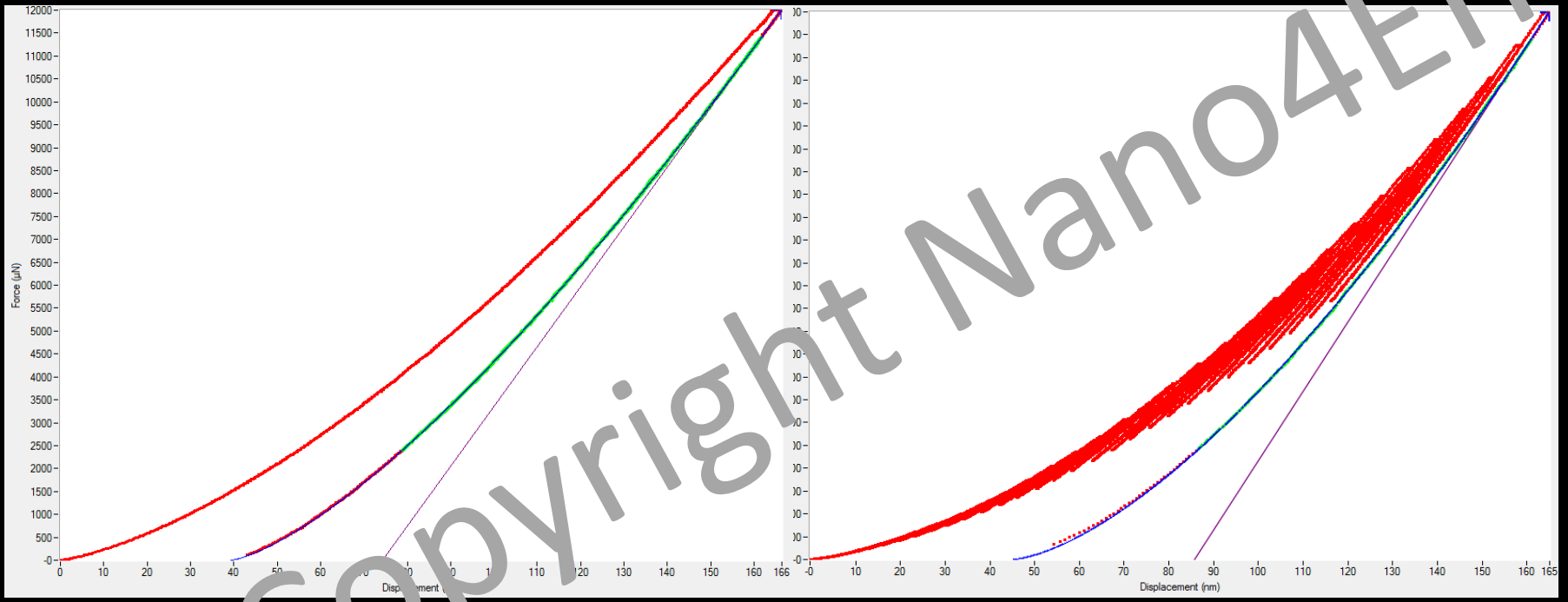
Film thickness 10nm

500mN critical load – 5 micron tip radius



DLC coating on Glass

Coating Hardness:
above 30GPa on insulating substrate



Hardness = 32 GPa

Young modulus = 220 GPa

500nm thick DLC

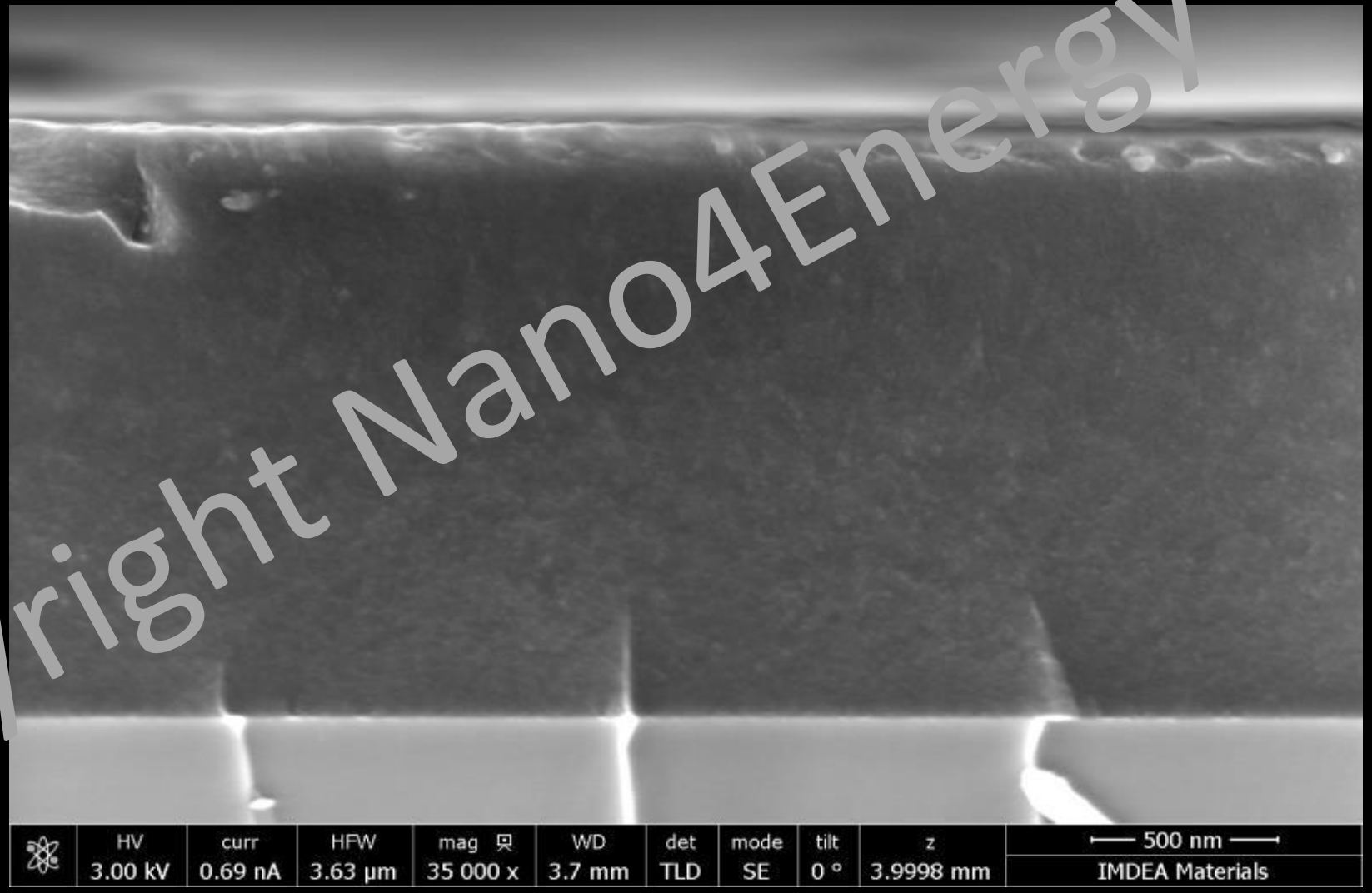
Si substrate

Hysitron TI950 Triboindenter
Berkovich tip indenter BKL4

SEM image: Dense DLC film

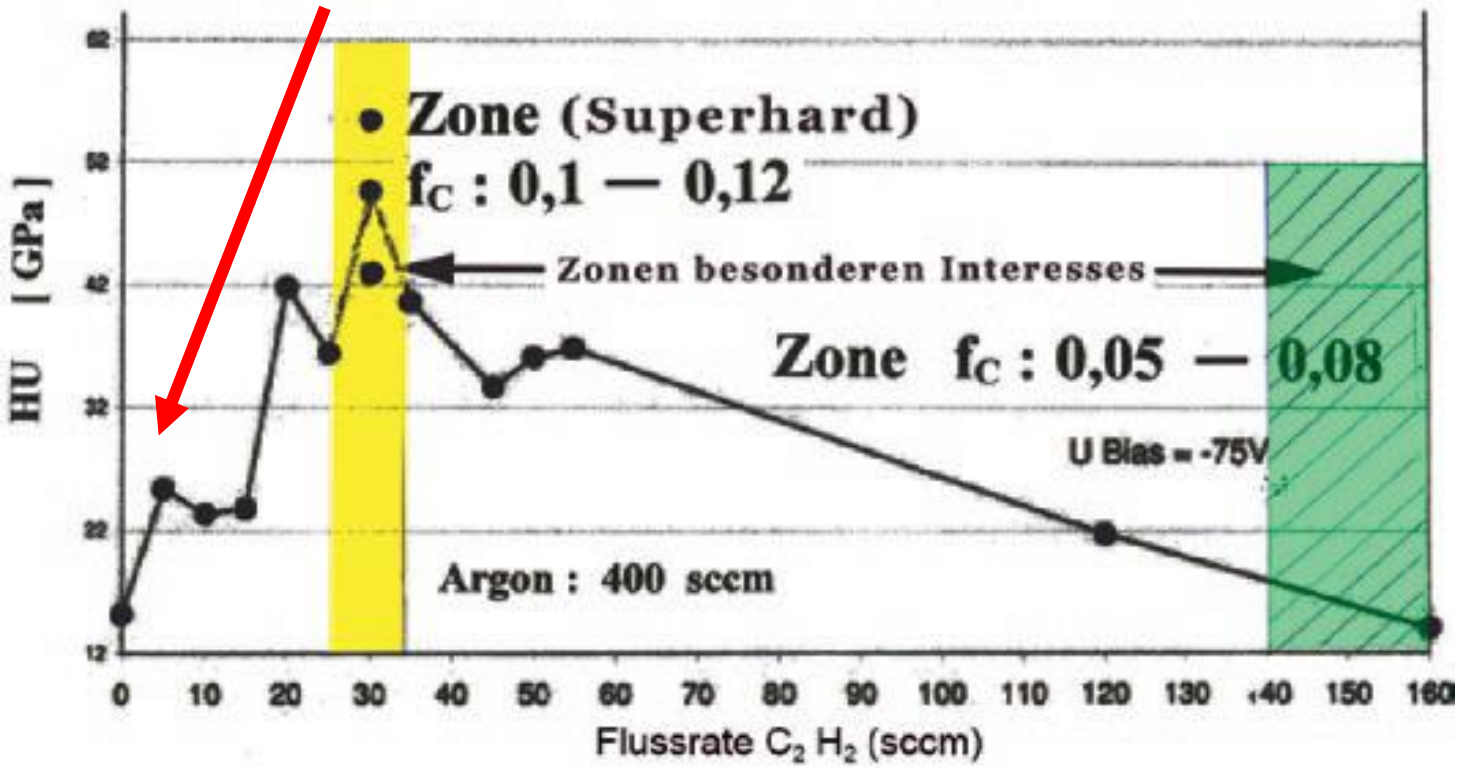
SEM cross section

of WC/DLC coating



DLC hard coating magnetron deposition

15GPa Microhardess with -75V Bias!



Bias required

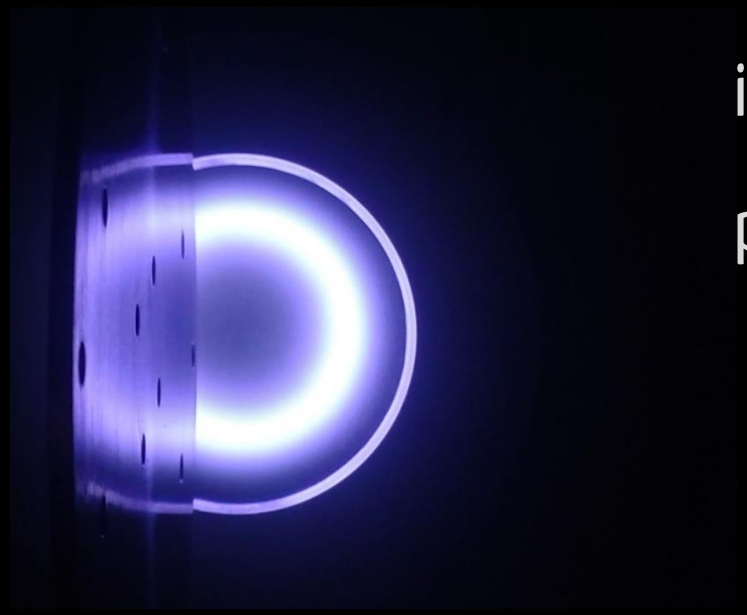
Conclusions

By optimizing the magnetic configuration and tailor the power delivery we have proven that:

- DLC deposited by magnetron sputtering can reach very high hardness levels without using Bias
- The thermal load of the substrate can be greatly reduced enabling deposition on temperature sensitive substrates

Conclusions

By optimizing the magnetic configuration and tailor the power delivery we have proven that:



- The process window as well as the deposition rate is increased, enabling less sensitive industrial production with higher production rates

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Thank you for your attention!

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