19th International Conference on RF Superconductivity
SRF 19 DRESDEN
June 30th – July 5th 2019

Nb/Cu coatings characterization in HiPIMS with biased substrate and application of a positive pulse

F. Avino[1], S. Calatroni[2], A. M. Charlety[1], D. Fonnesu[3], A. Grudiev[4], P. Naisson[5], H. Neupert[1], A. T. Perez Fontenla[6], T. Richard[1], G. Rosaz[1], A. Sublet[1], M. Taborelli[1]

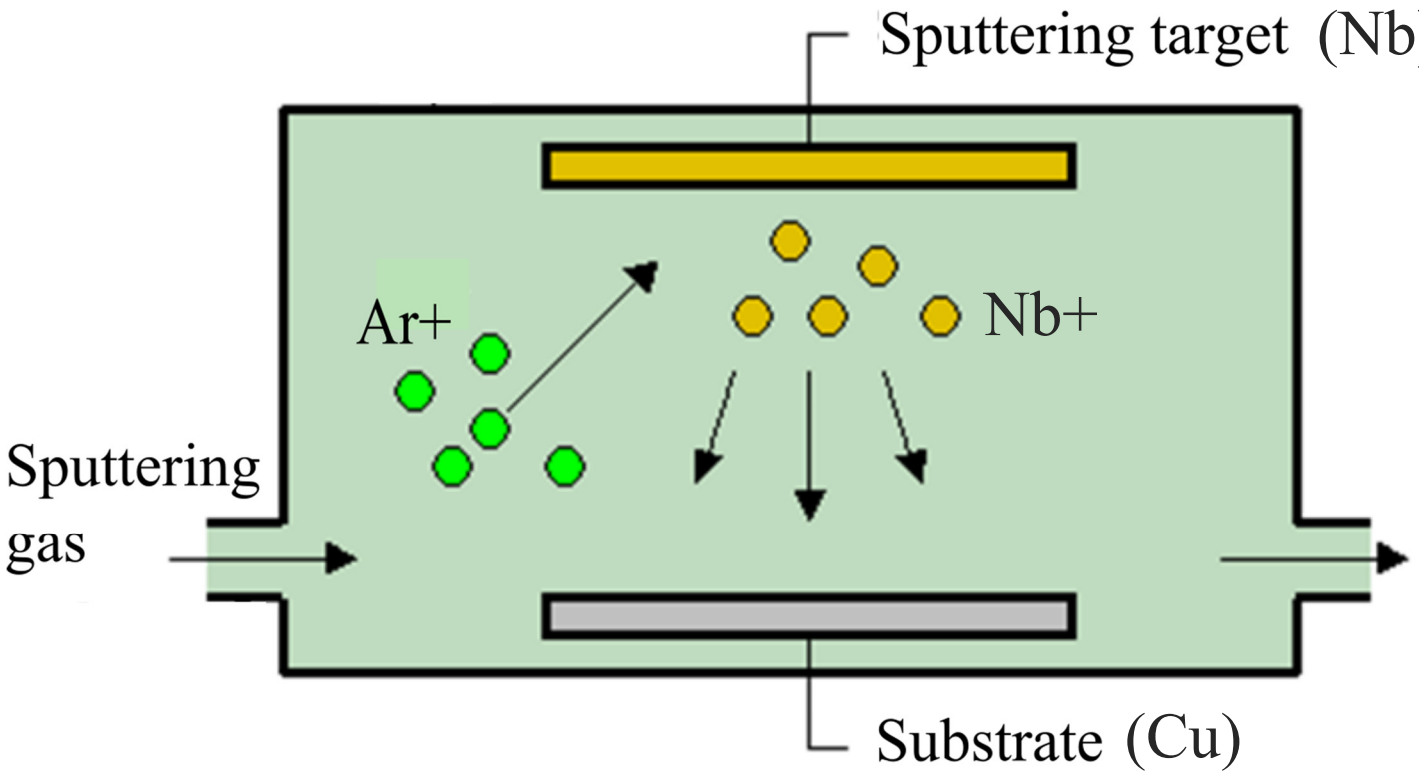
[1] CERN, TE/VSC-SCC
[2] CERN, TE/VSC-VSM
[3] CERN, TE/CRG-CI
[4] CERN, BE/RF-LRF
[5] CERN, EN/MME-MA
[6] CERN, EN/MME-MM

Outline

- Why biased substrate & positive pulse?
- HiPIMS studies with positive pulse
  - Film morphology at grazing angles of incidence
  - Nb/Cu WOW crab cavity R&D
- HiPIMS studies with negatively biased substrate
  - Gas content with sync. biased substrate
  - Residual stress
- Conclusions

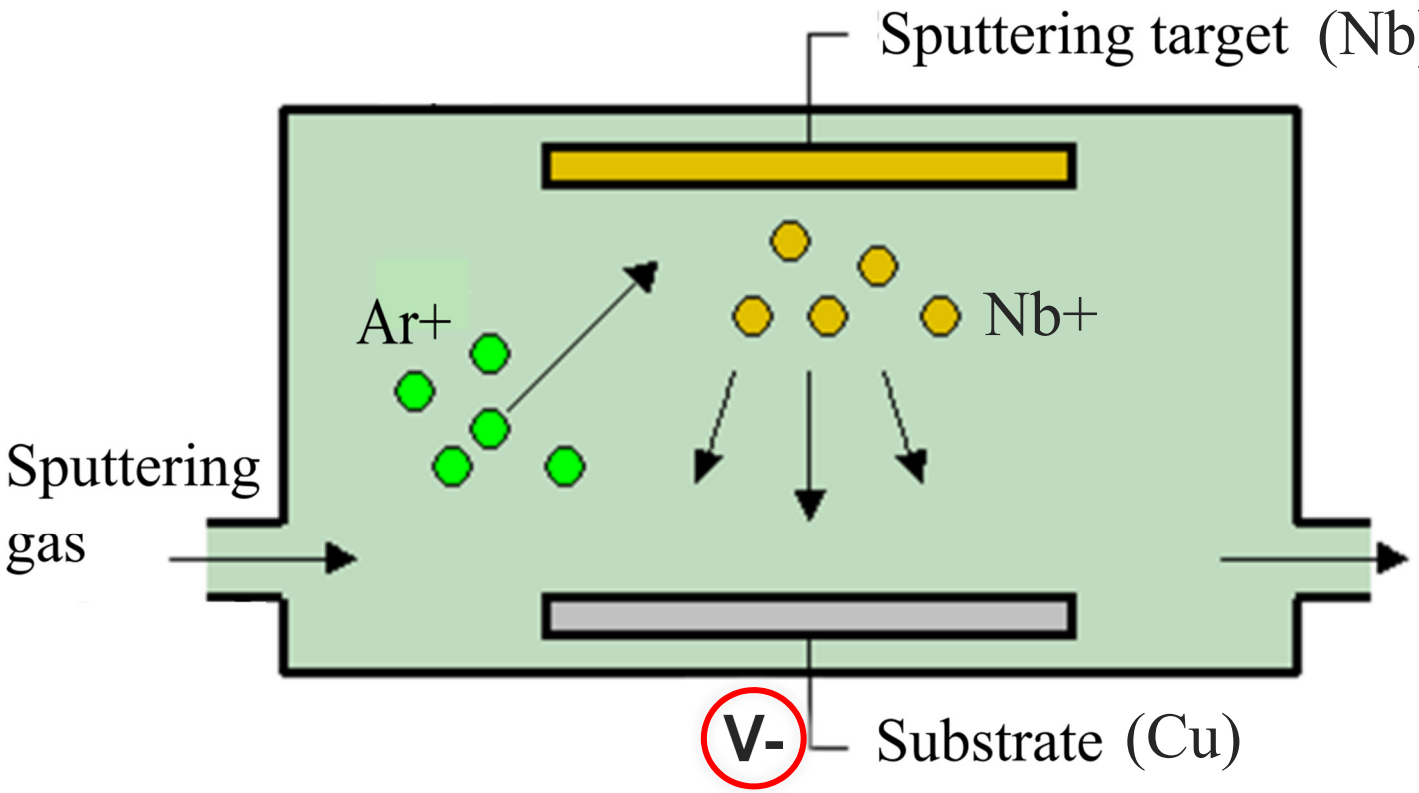
Why biased substrate / positive pulse?

HiPIMS allows to get a higher fraction of metal ions wrt Direct Current Magnetron Sputtering.
How to accelerate the ions towards the substrate?



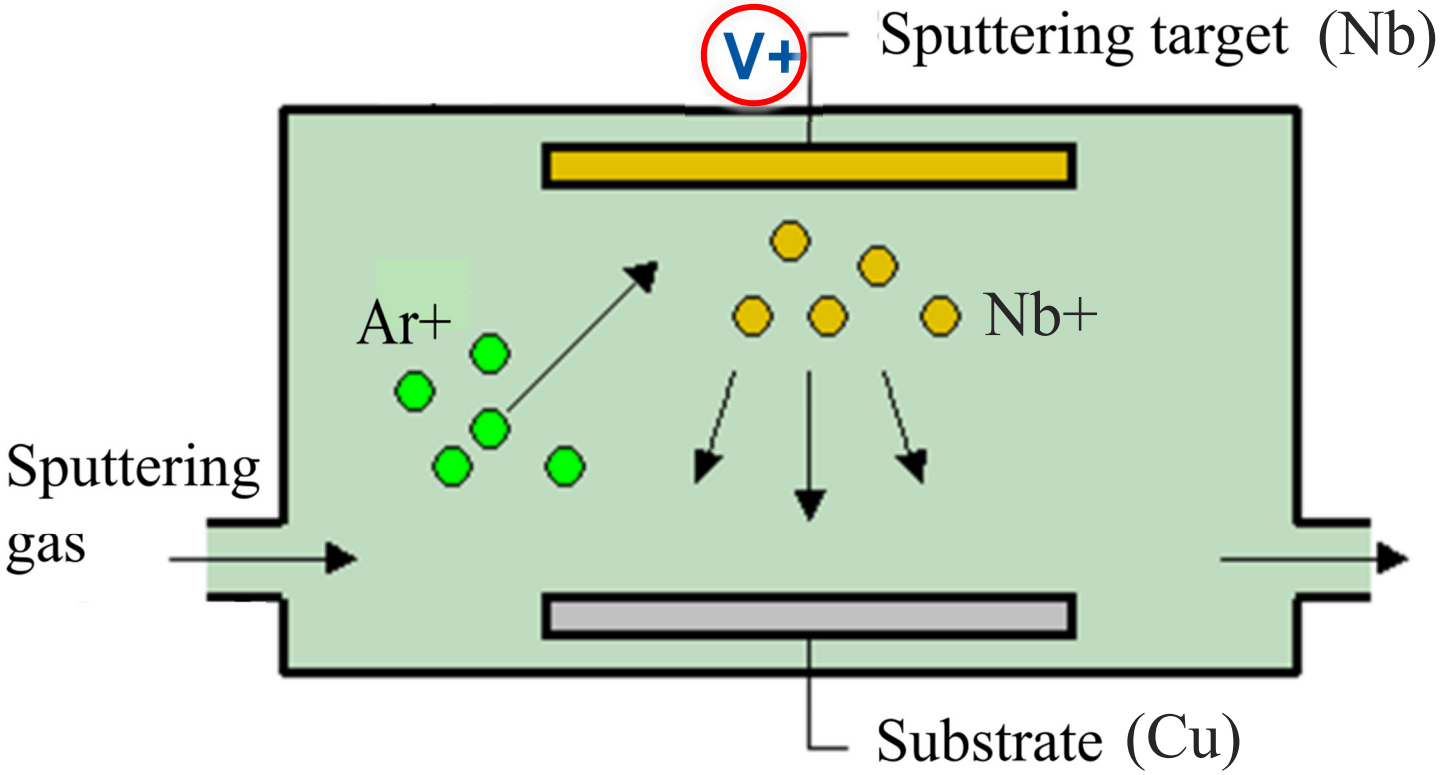
Why biased substrate / positive pulse?

- By negatively biasing the substrate



Why biased substrate / positive pulse?

- By negatively biasing the substrate
- By positive pulse (PP)

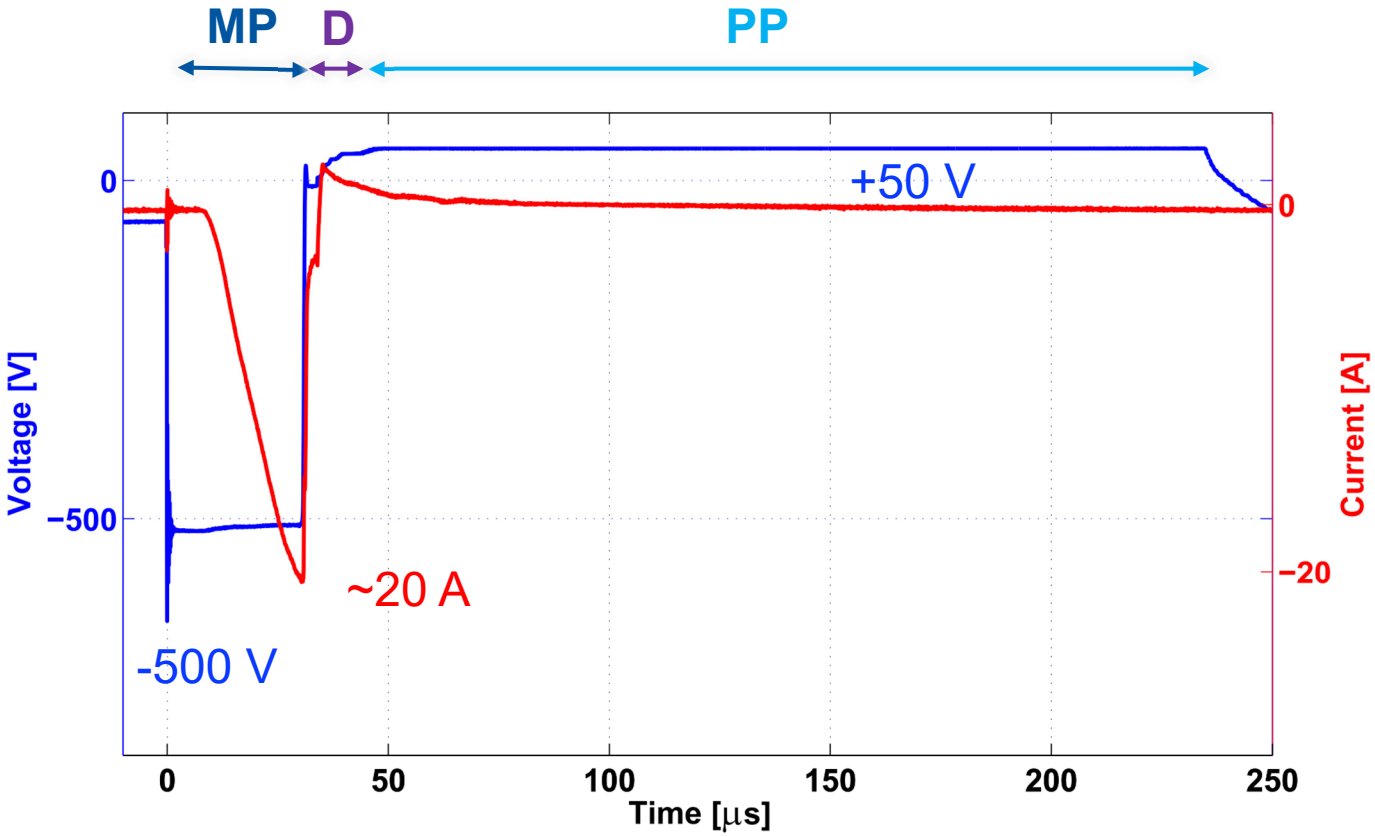


HiPIMS configuration with PP

- Duty cycle : 1 kHz
- Main pulse (**MP**) : 30 μs
- Delay (**D**) : 4 μs
- Positive pulse (**PP**) : 200 μs

PP advantages wrt biased substrate:

- Simplified magnetron design
- Grounded substrate

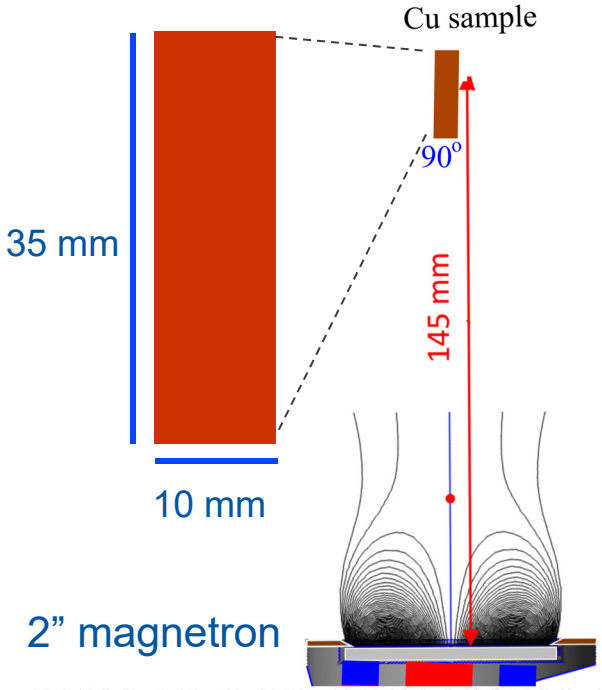


F. Avino *et al* 2019 *Plasma Sources Sci. Technol.* **28** 01LT03

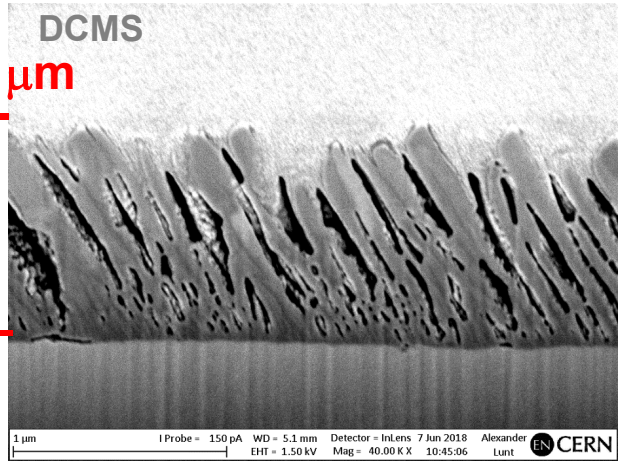
Outline

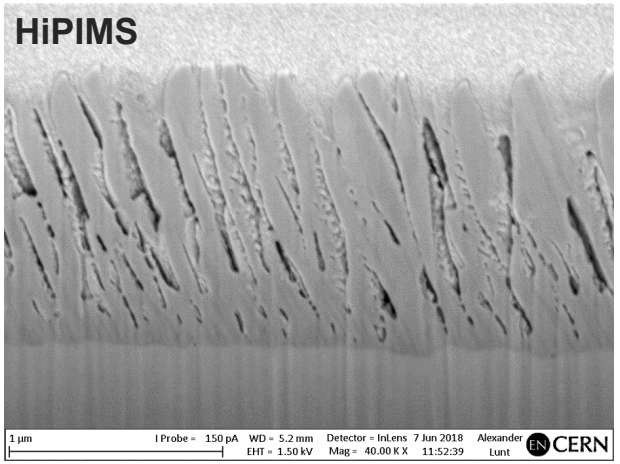
- Why biased substrate & positive pulse?
- HiPIMS studies with positive pulse
  - Film morphology at grazing angles of incidence
  - Nb/Cu WOW crab cavity R&D
- HiPIMS studies with negatively biased substrate
  - Gas content with sync. biased substrate
  - Residual stress
- Conclusions

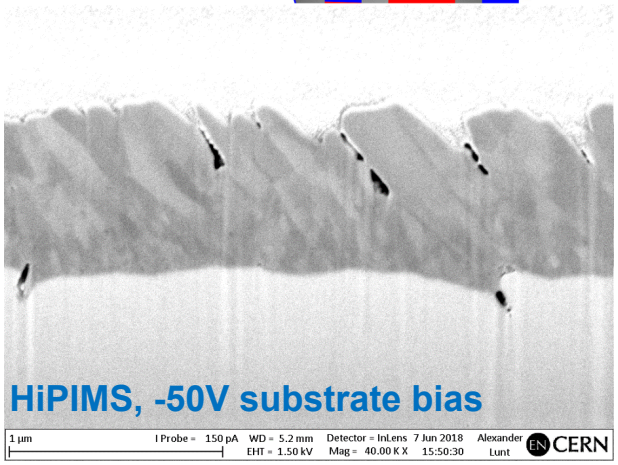
FIB / Tc for samples at 90°

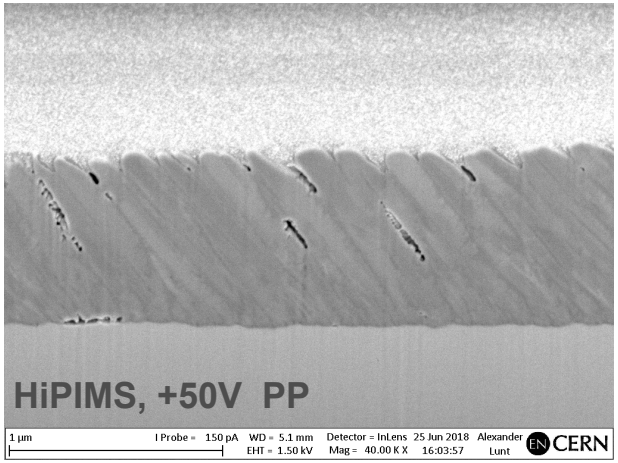


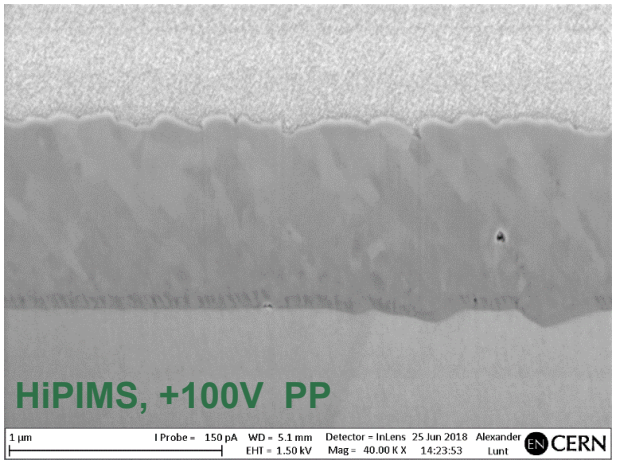
Ar pressure : 8×10^{-3} mbar











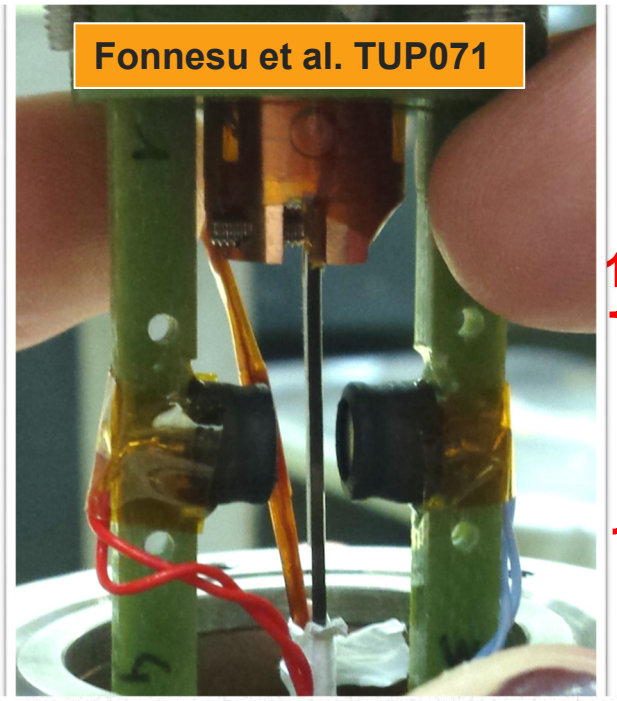
Films coated in HiPIMS + PP similar to HiPIMS + substrate bias!

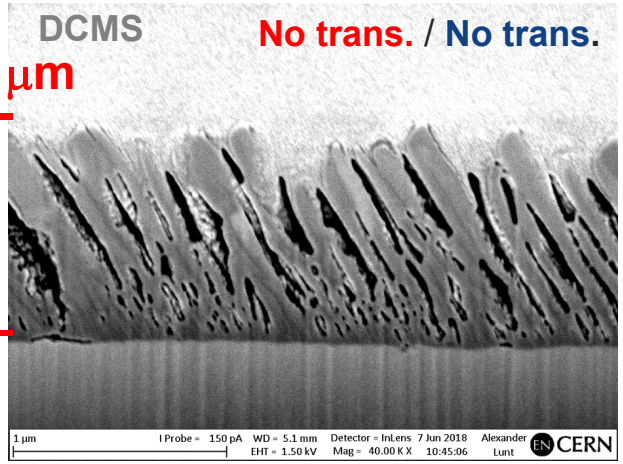
FIB / Tc for samples at 90°

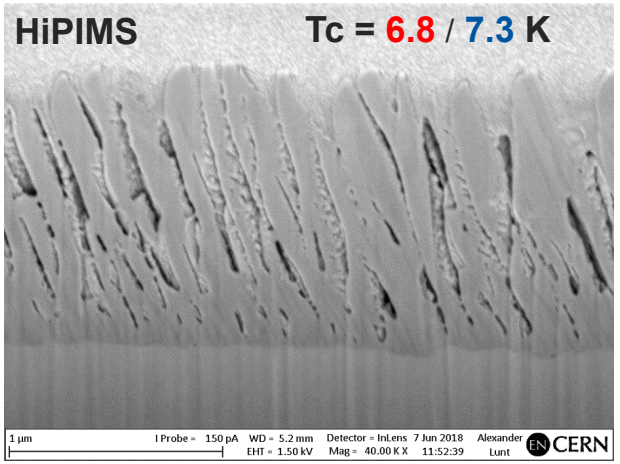
UNIVERSITÉ DE GENÈVE

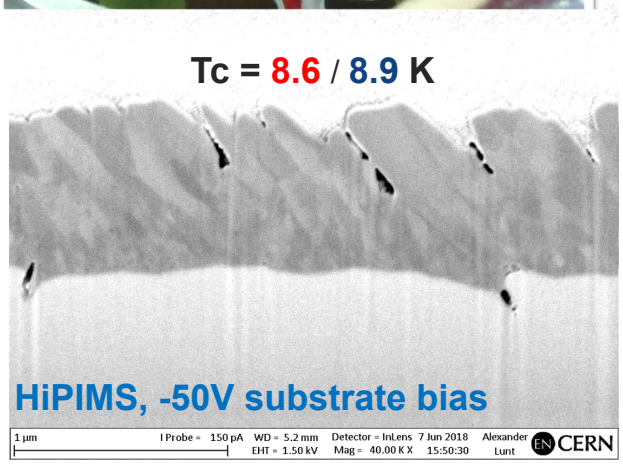
Ar pressure : 8×10^{-3} mbar

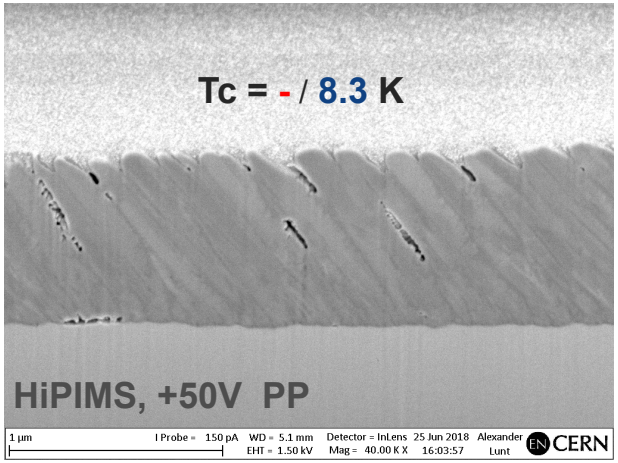
Coils / **SQUID**

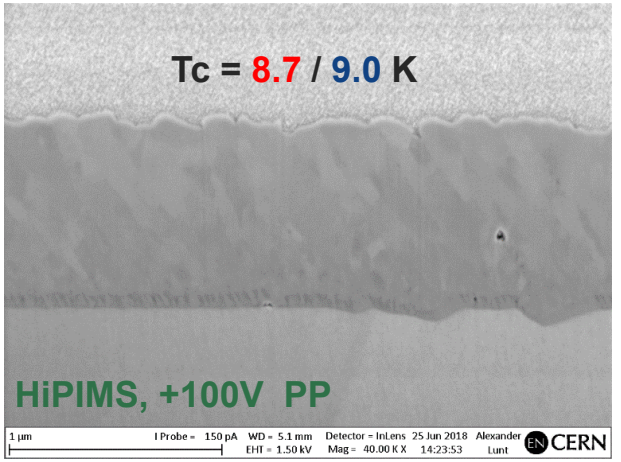






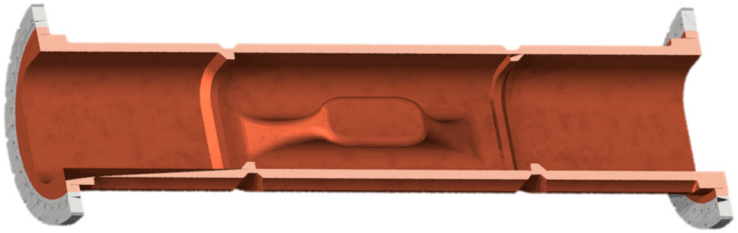




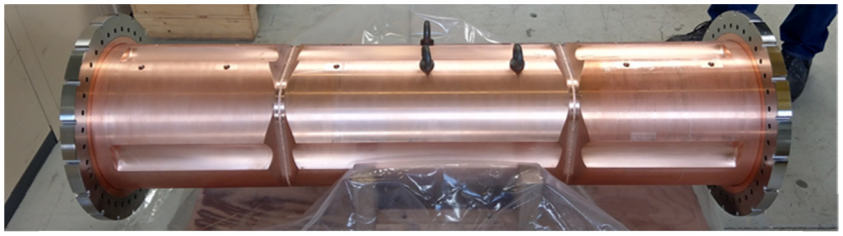


Films coated in HiPIMS + PP similar to HiPIMS + substrate bias!

Nb/Cu Wide Open Waveguide crab cavity R&D



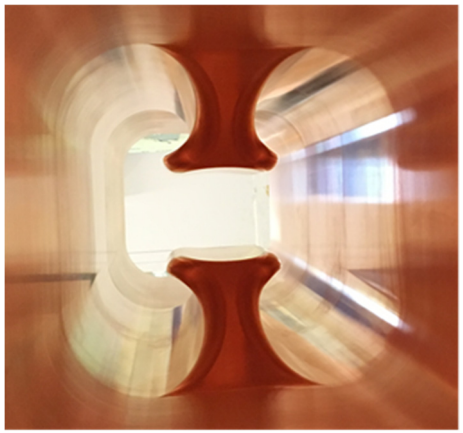
1st prototype in bulk Cu 290kg



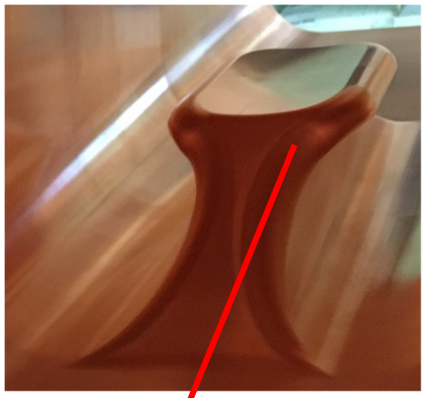
1.4m

Naisson et al. MOP061

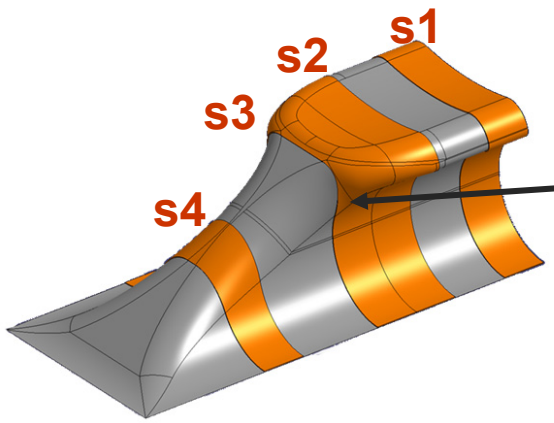
Front view



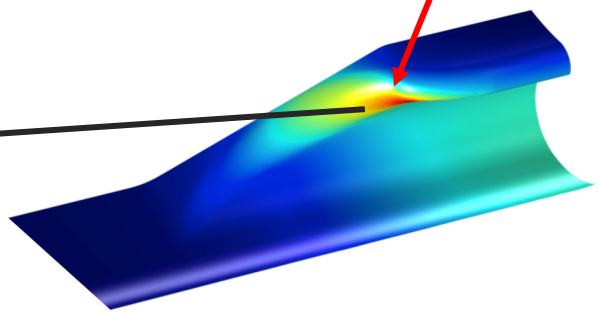
Detail of tapering



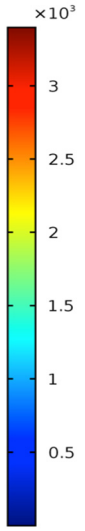
Mockup of 4 sections for coating R&D



Critical location of highest peak dissipated power

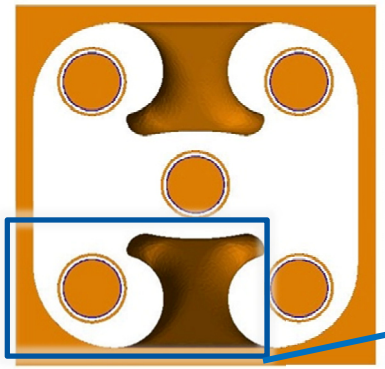


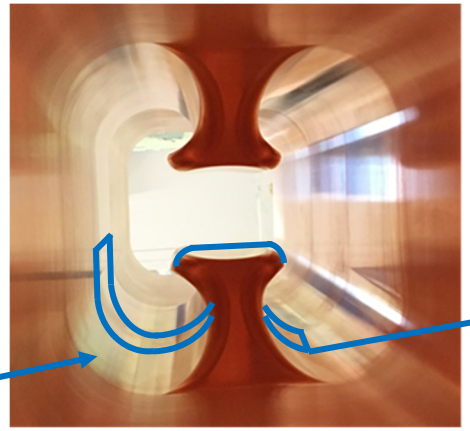
Total power loss ~ 60W
@ Q_0 = 4x10^8 / 3 MV deflection



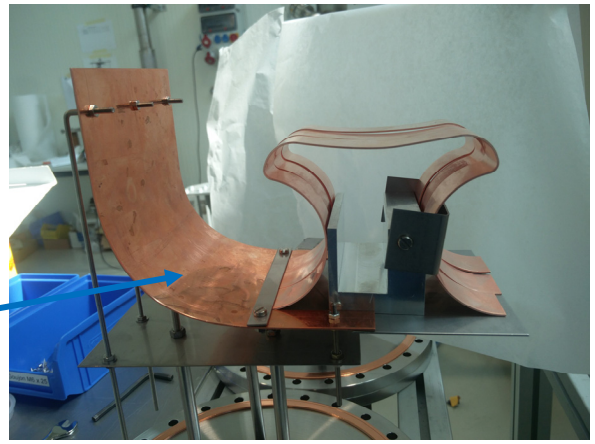
First results on WOW crab cavity samples

Cathode positions
under investigation

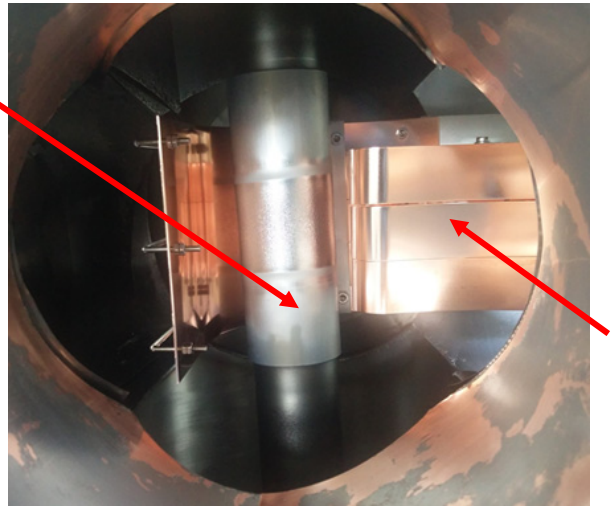




s1 sample: ¼ of cavity

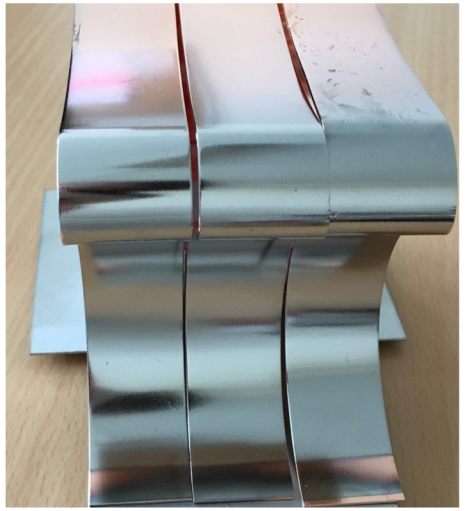


Cathode



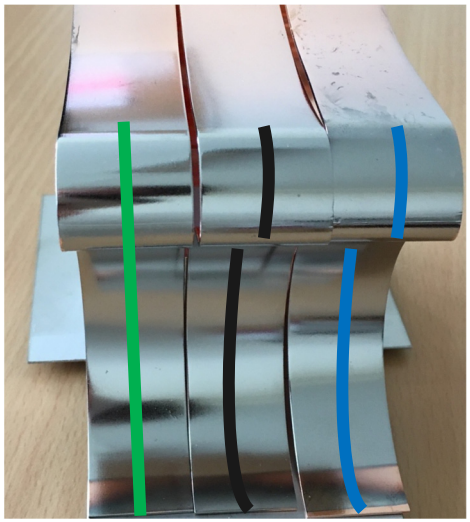
Sample

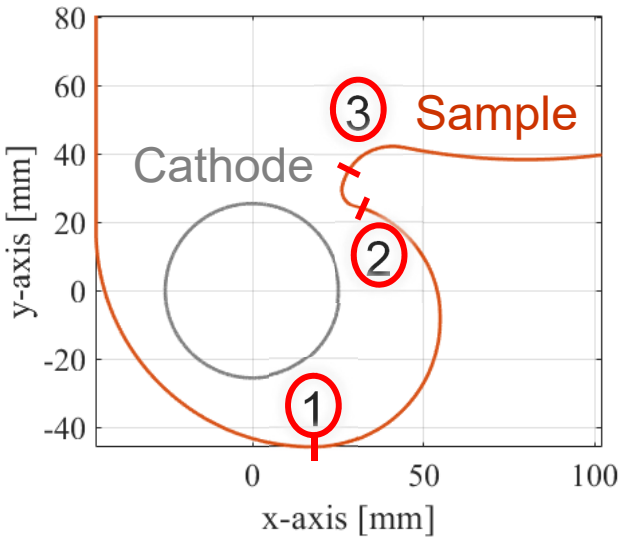
Assembly in coating chamber

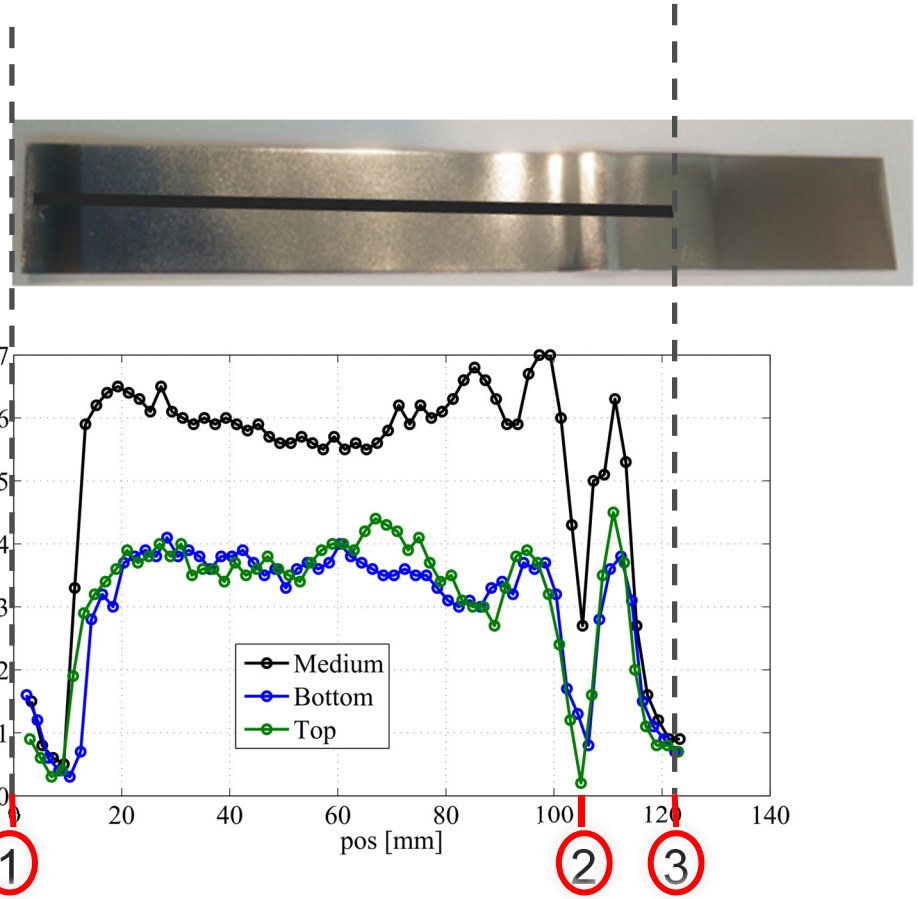


Samples after coating
HiPIMS+PP
1kW, 6 minutes coating,

XRF thickness profiles along sample length





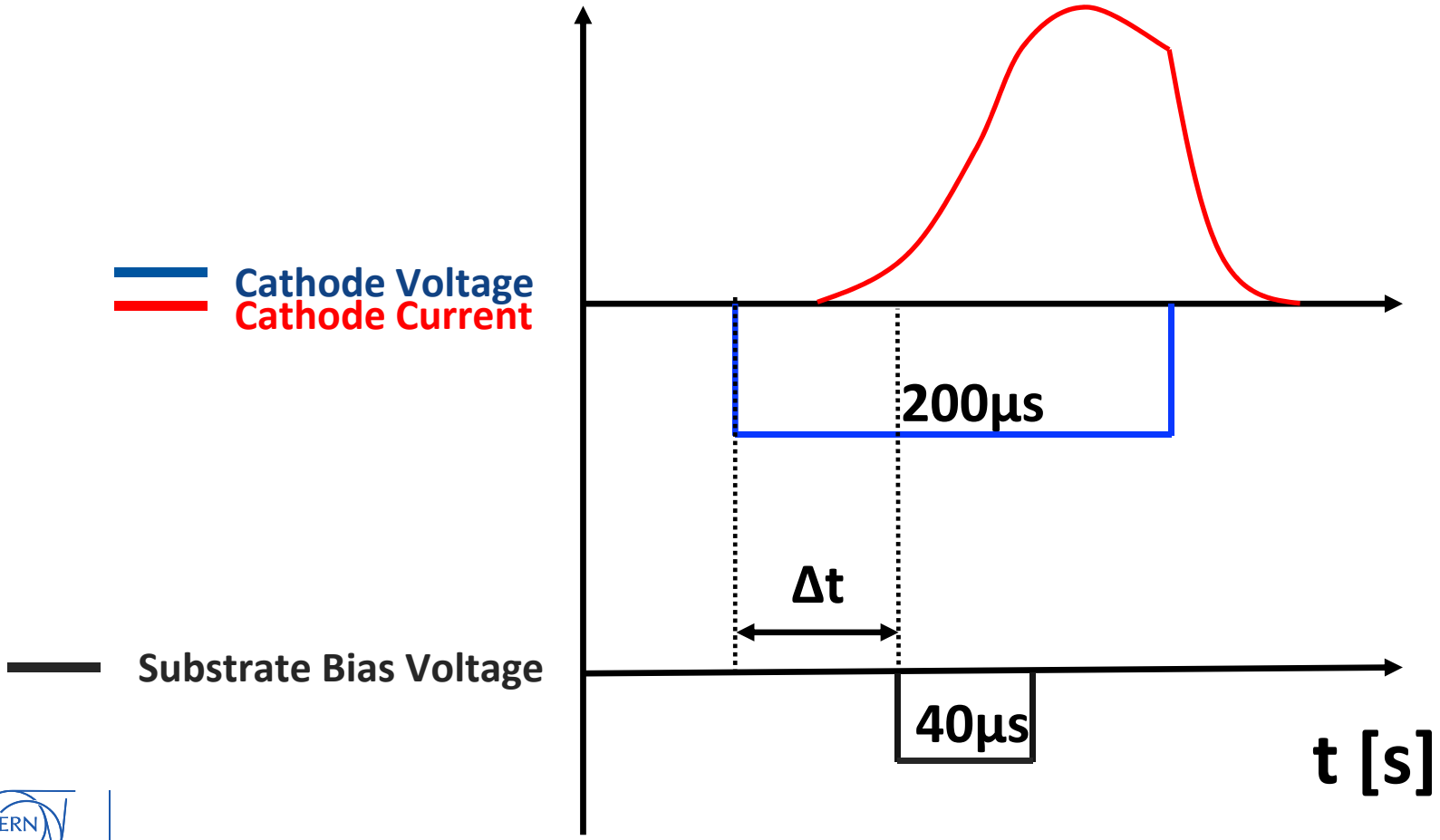


Outline

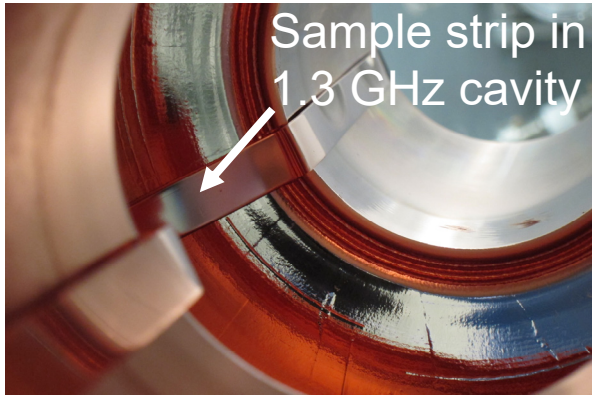
- Why biased substrate & positive pulse?
- HiPIMS studies with positive pulse
  - Film morphology at grazing angles of incidence
  - Nb/Cu WOW crab cavity R&D
- HiPIMS studies with negatively biased substrate
  - Gas content with sync. biased substrate
  - Residual stress
- Conclusions

HiPIMS configuration with sync. biased substrate

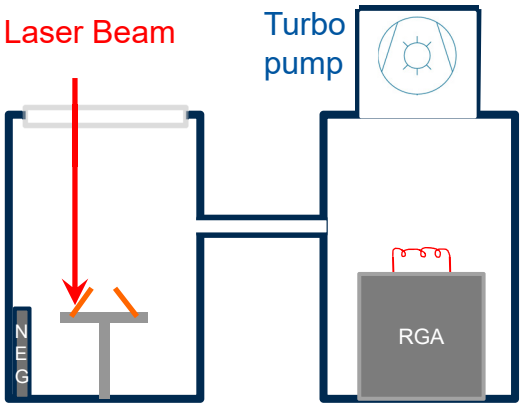
By accelerating metal ions, gas ions are accelerated too.
How is the gas content varying by changing the triggering of the substrate bias?



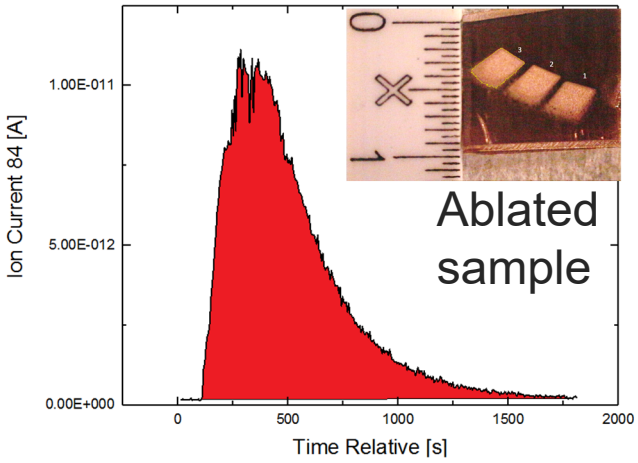
Gas content with sync. biased



Laser ablation setup

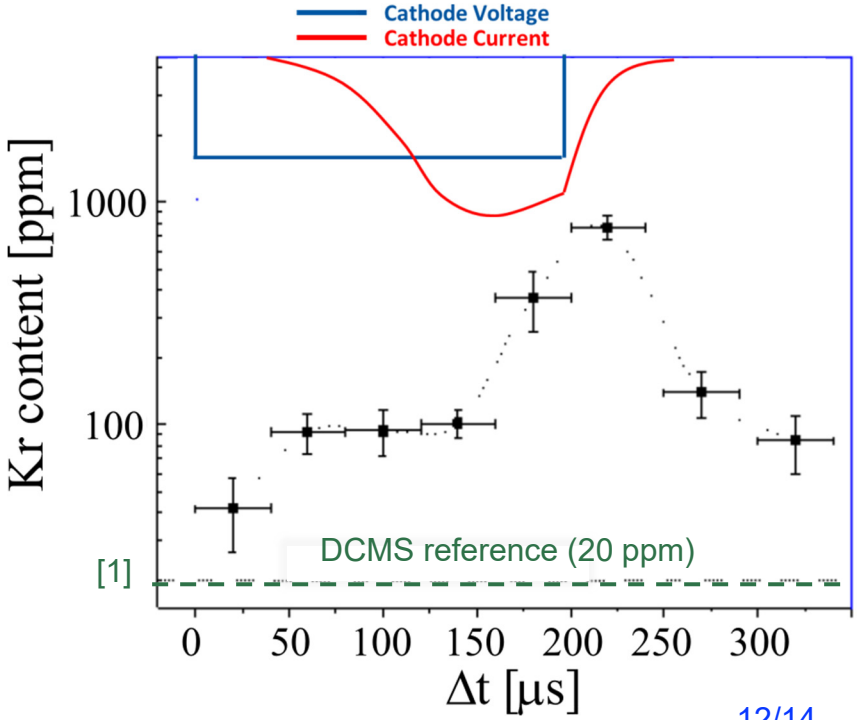


RGA time-trace



Conclusions:

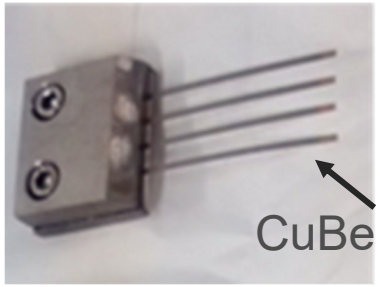
- Gas content can be « tuned » : variations within main pulse up to x22
- Impact on RF performances?

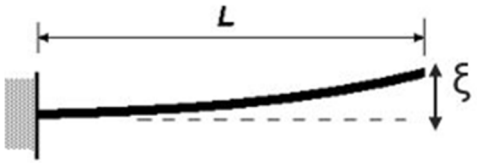


[1] AMOROSI, S., ANDERLE, Mariano, BENVENUTI, C., *et al.* Study of the discharge gas trapping during thin-film growth. *Vacuum*, 2001, vol. 60, no 1-2, p. 89-94.

Residual stress analysis

Is the stress responsible for the frequently observed peel-off in cavities?



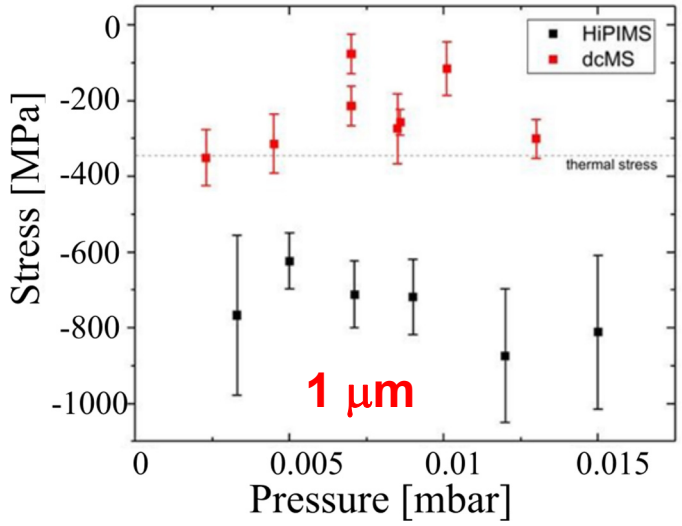


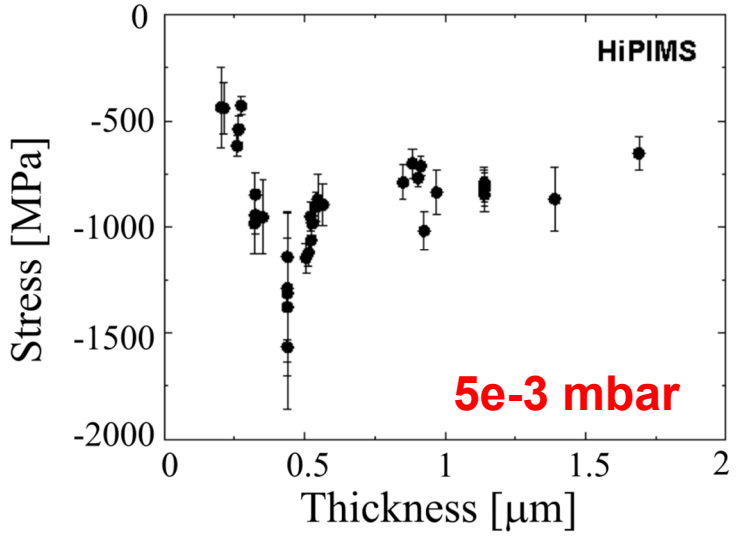
Stoney's equation

$$\sigma = \frac{1}{6}\frac{E_s t_s^2}{(1-\nu_s)Rt_f} \quad ; \quad R = \frac{L^2}{2\xi}$$

Young's modulus

Poisson's ratio





Conclusions:

Significant higher level of stress (x2) in HiPIMS films for all coating pressures, but NO PEEL-OFF

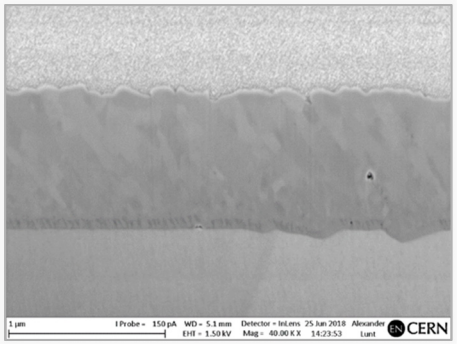
Beyond 500 nm residual stress saturates

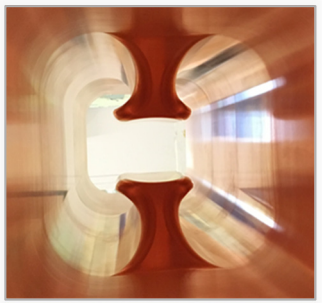
Rosaz FRCAB2

Conclusions

HiPIMS + positive pulse (PP):

- Film densification for samples coated at grazing angles (90°) with PP, similarly to biased substrate.
- Preliminary results of films coated on samples with WOW crab cavity inner shape.





HiPIMS + biased substrate:

- High Kr content in film with HiPIMS+biased substrate, but it can be tuned.
- Higher level of stress (up to x2) in HiPIMS films wrt DCMS for all coating pressures, but no peel-off.