

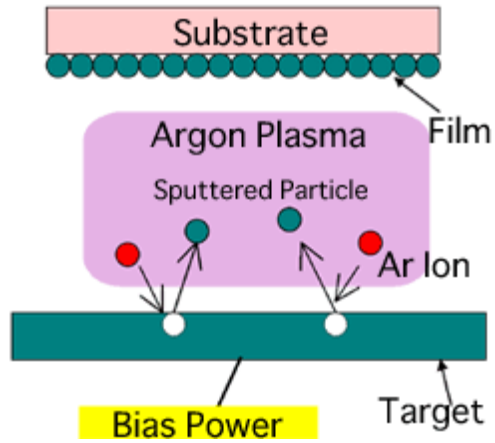


# Source magnetron (pulvérisation plasma) au GREMI

CNRS Researchers (100%): Amaël CAILLARD et Anne-Lise THOMANN

CNRS AI (30%) : Loic Gimenez

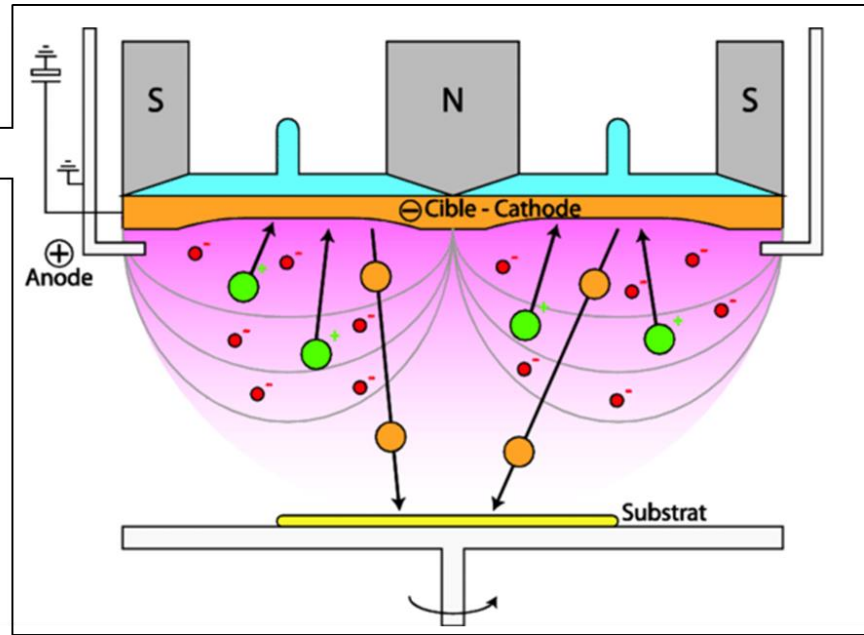
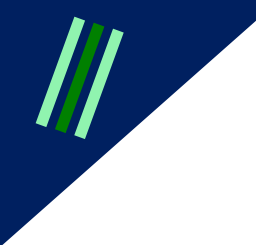
CNRS researcher (50%, MD simulation) : Pascal BRAULT



Le procédé de **pulvérisation magnétron** permet de déposer des couches minces (métallique, oxyde ou nitrure) sur une grande variété de substrat.

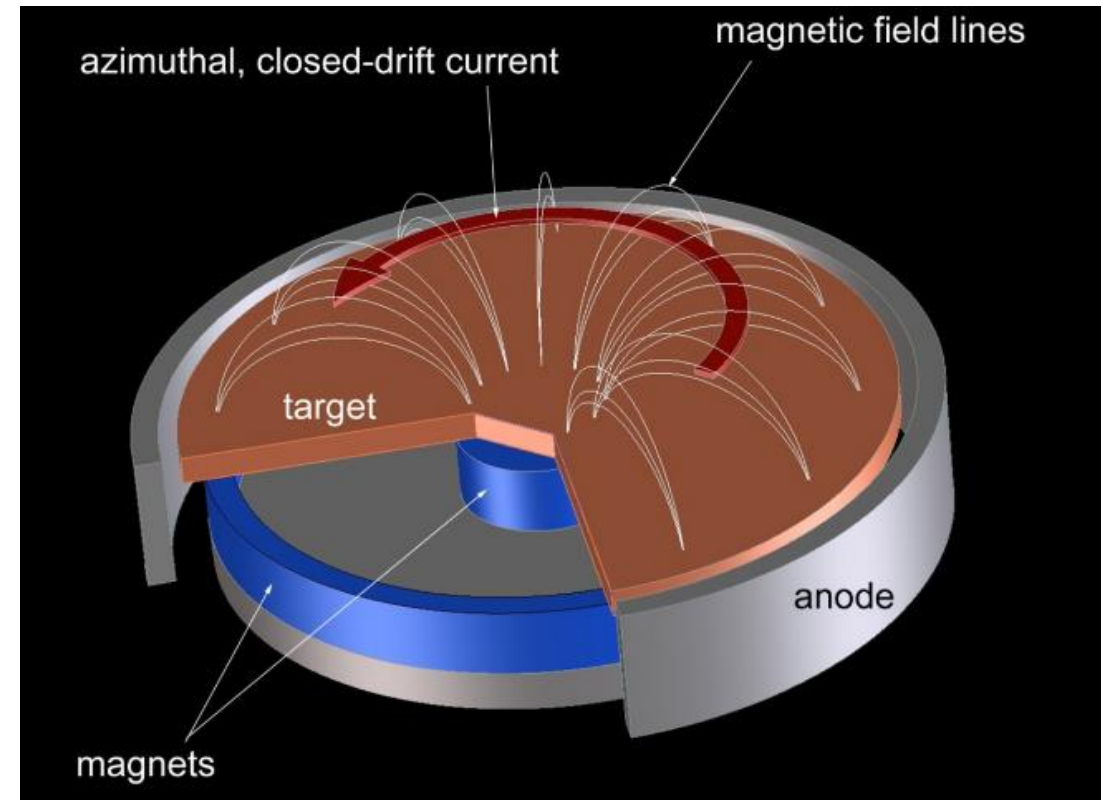
Des atomes sont éjectés d'une cible et viennent se condenser sur un substrat. Plasma (ions) nécessaire pour « éroder » la cible.

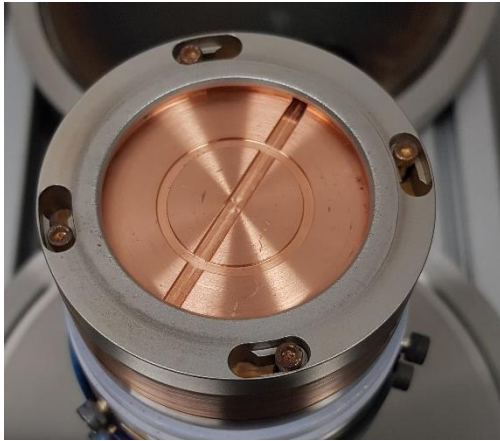




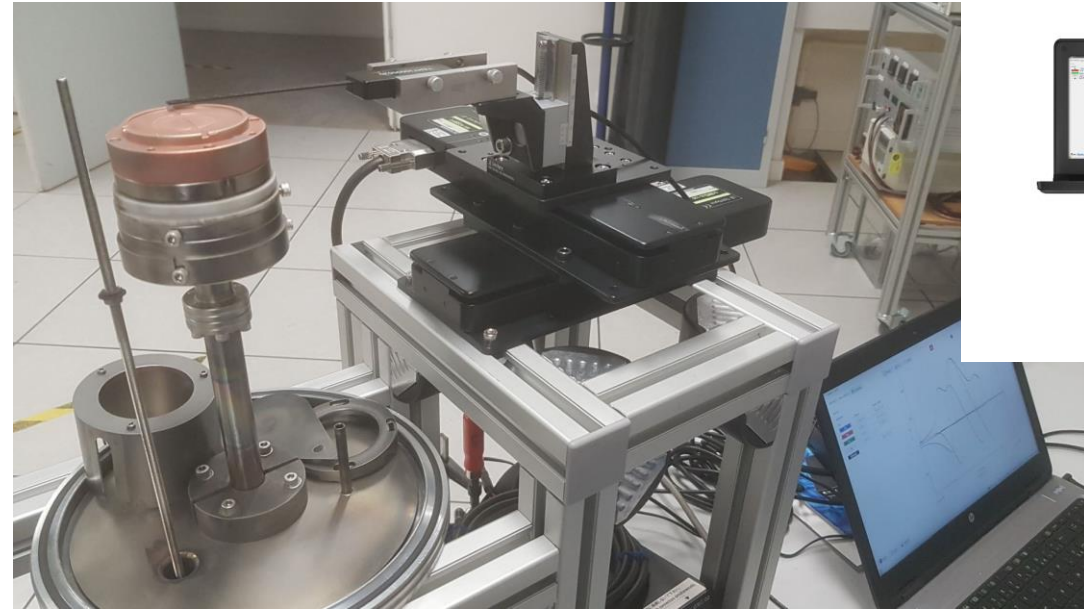
- Electron
- Cation
- Atome de la cible
- Ligne de champ magnétique
- Plasma

→ Pompage





**Magnétron circulaire  
(2 et 4 pouces)**



**Station capteur magnétique 3 axes**

*Une dizaine de sources commerciales circulaires  
300 gauss (surface cible)  
0.1 – 30 Pa (Ar, O<sub>2</sub>, N<sub>2</sub>)  
DC, RF, HiPIMS  
Intégration dans 7 bâtis « maison » pour la  
synthèse de couches minces et nanostructures*

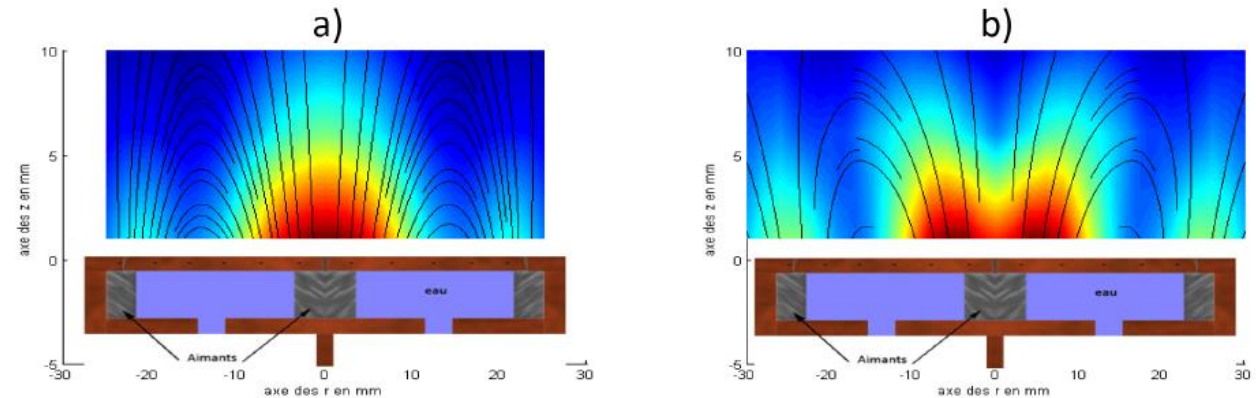


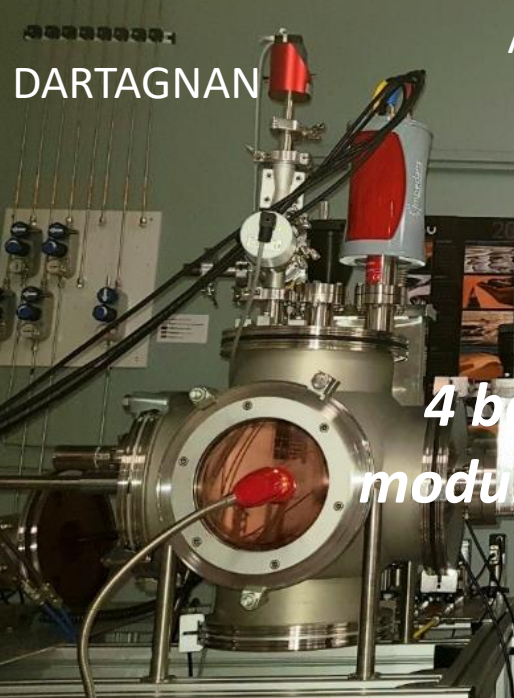
FIGURE 2.7 – Modélisations des mesures effectuées sur trois différentes topologies du champ magnétique du magnétron. Magnétron équilibré a), magnétron fortement déséquilibré b), magnétron déséquilibré c).



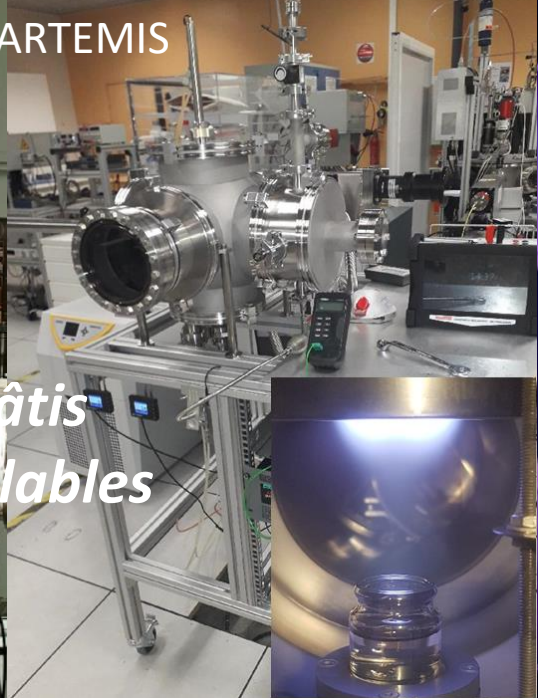
PHARAON



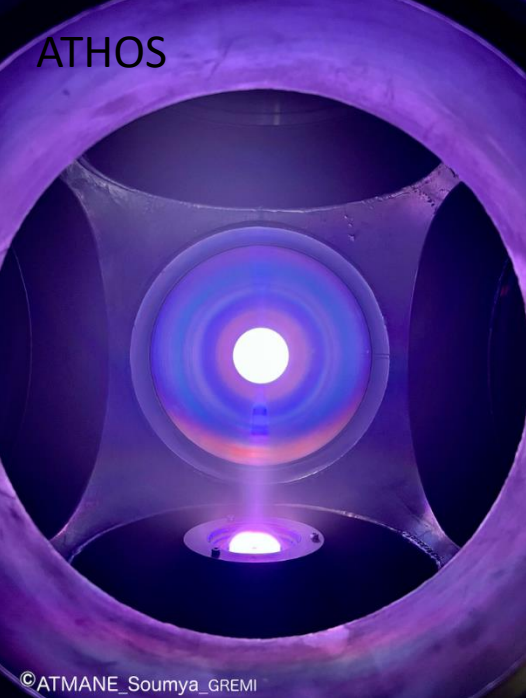
DARTAGNAN



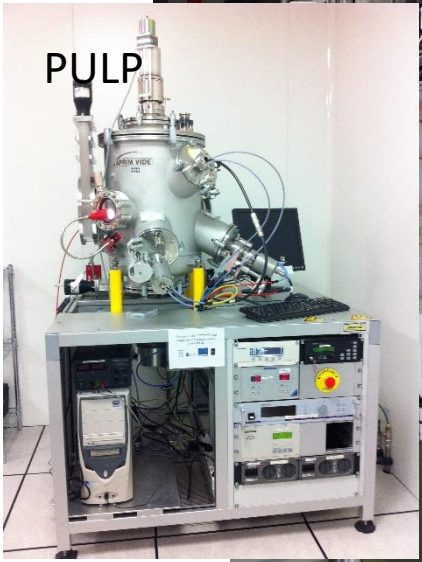
ARTEMIS



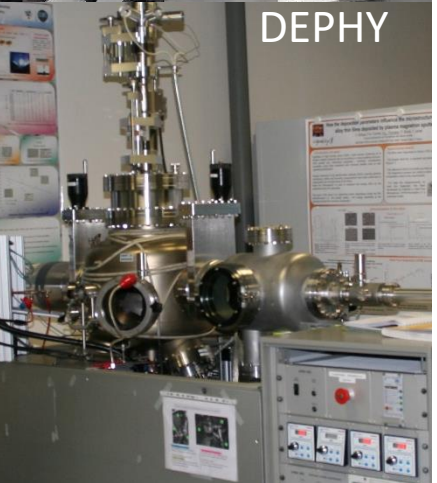
ATHOS



PULP

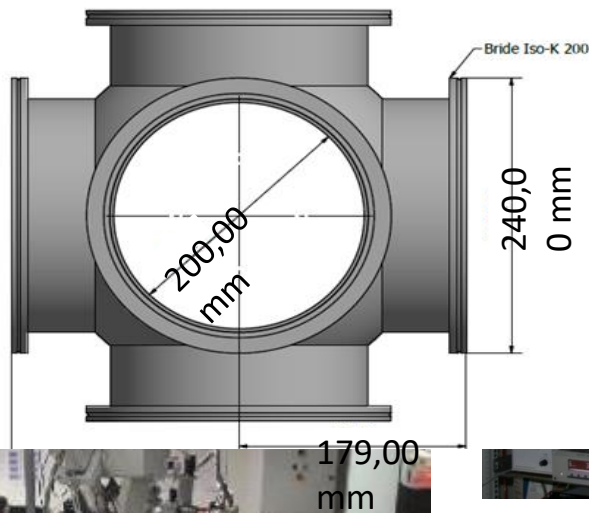


DEPHY

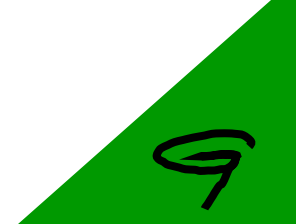
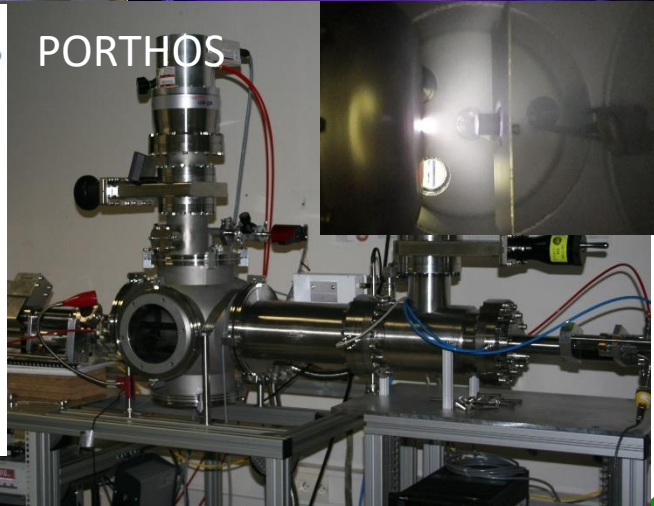


4 bâtis  
modulables

6 bâtis  
« magnétron »  
(+1 mutualisé)



PORTHOS



# 5 current sputtering research activities at GREMI Orleans

**A. CAILLARD**  
A-L THOMANN

**A. CAILLARD**  
A.-L. THOMANN

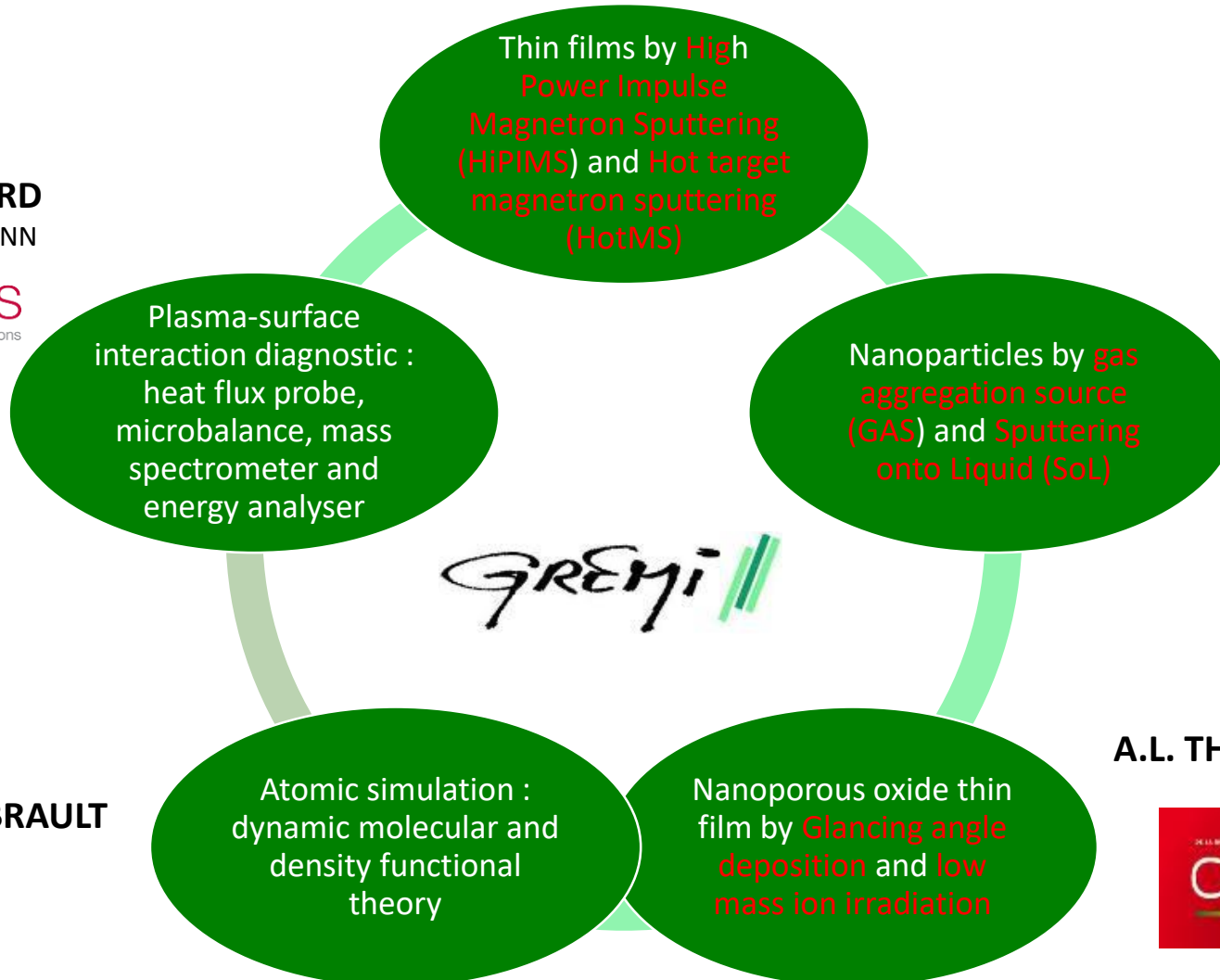


**A. CAILLARD**



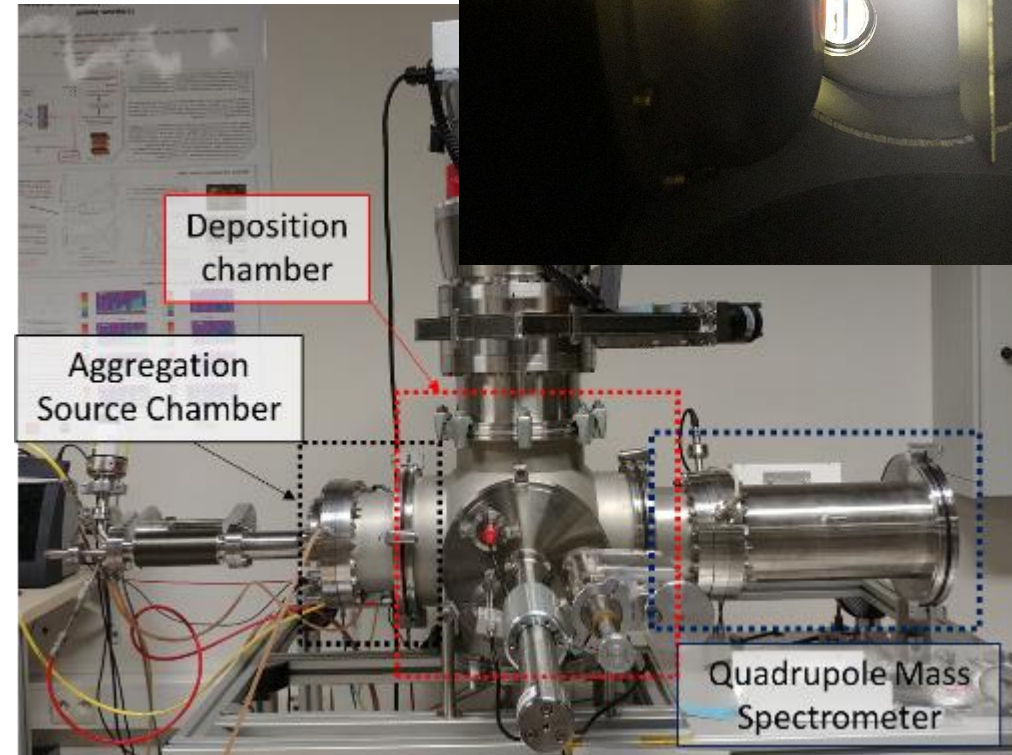
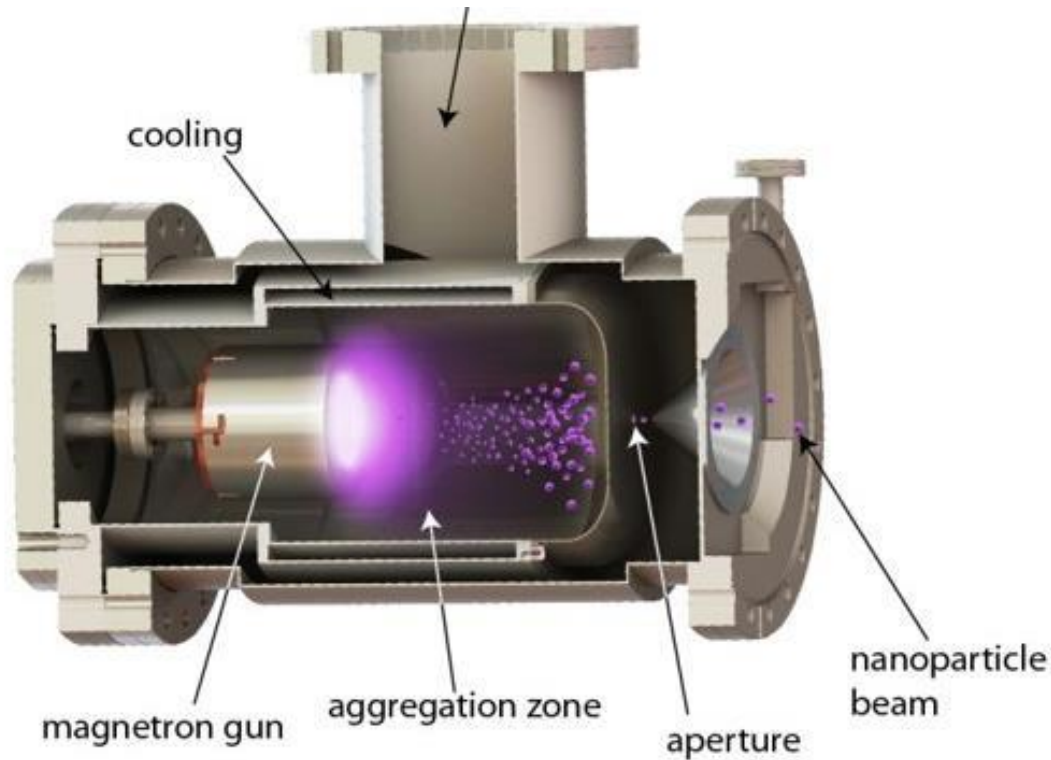
**P. BRAULT**

**A.L. THOMANN**



9

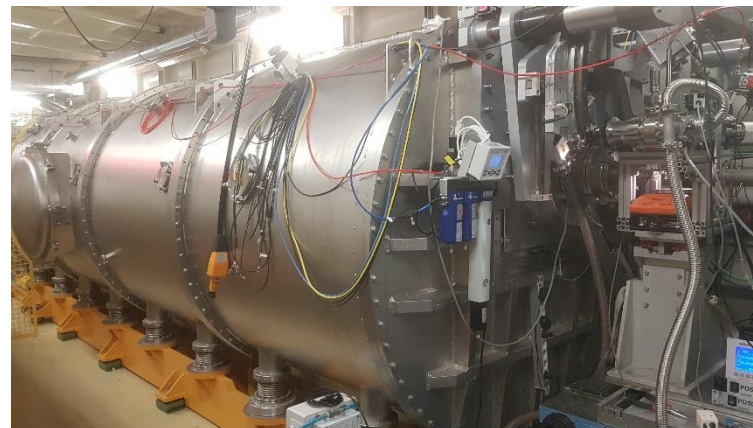
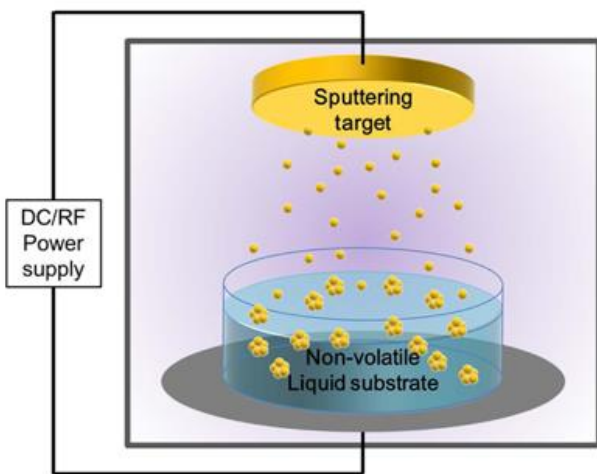
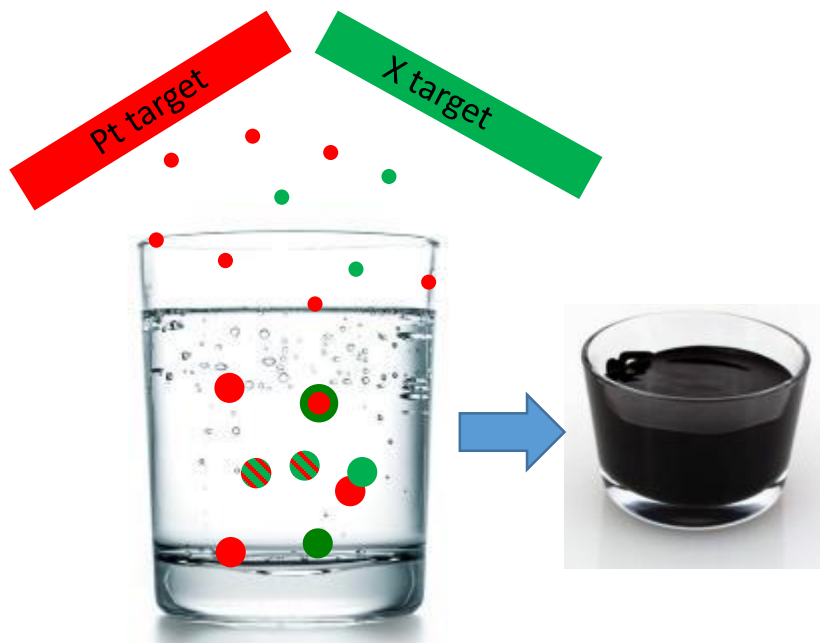
# Gas aggregation source (GAS)



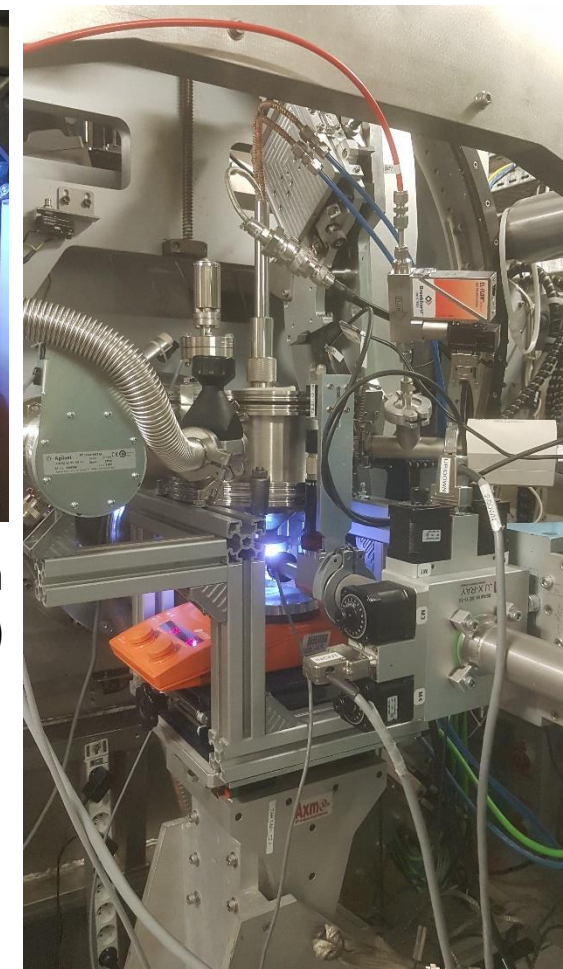
Magnetron sputtering of a 2 inches target in a high pressure (30 Pa) chamber connected to a low pressure (0,1 Pa) through a orifice  
→ Gas-phase NPs growth, NPs beam formation and NPs deposition

# Magnetron sputtering on liquid (SoL)

Forte interaction entre le plasma et le liquide (chauffage, évaporation, modification des propriétés plasma)



+ bâti pour synchrotron SOLEIL (SAXS in situ)

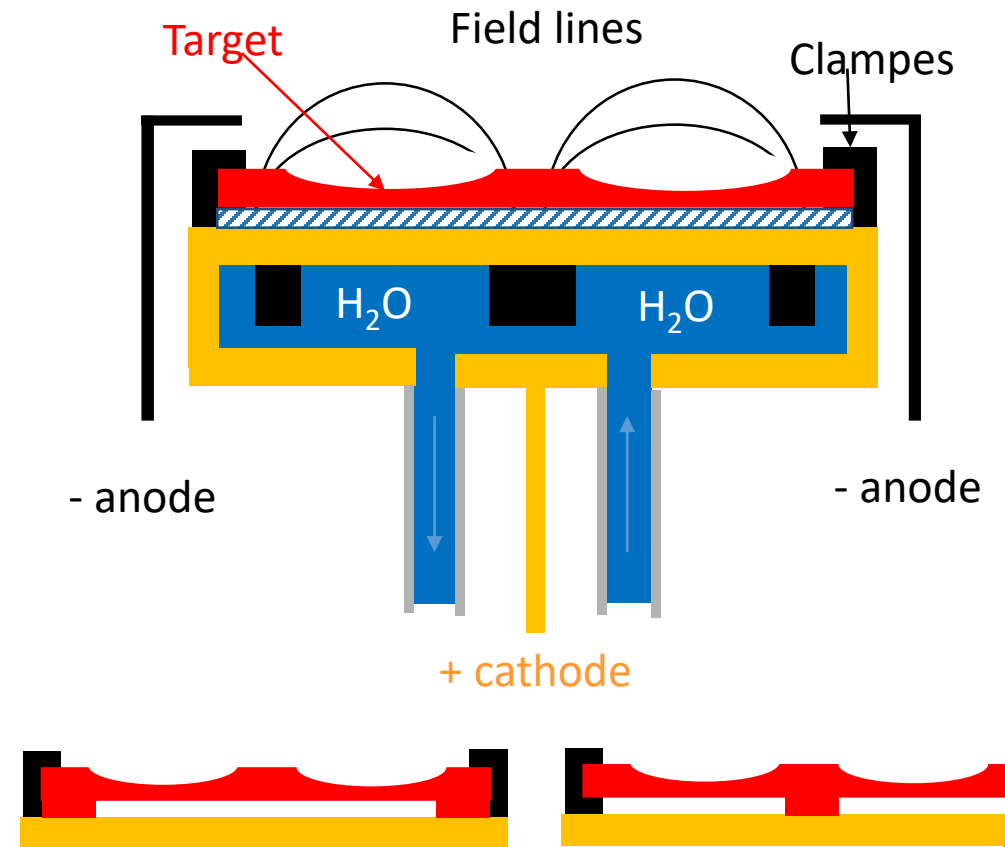




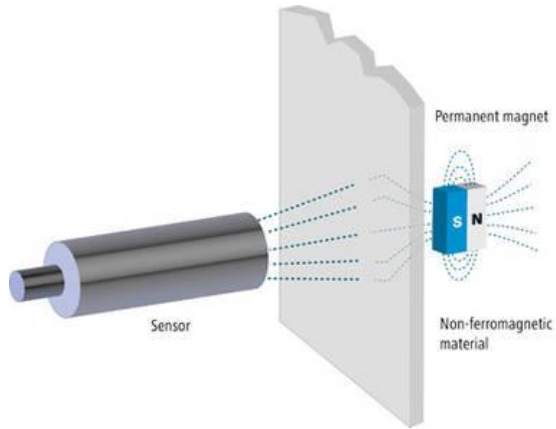
# Hot target magnetron sputtering



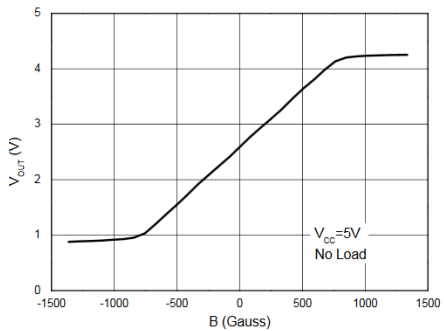
**Hot target magnetron sputtering (HotMS)**  
Low pressure hot target reactive magnetron (LP-HTRS)  
Ionized magnetron evaporation



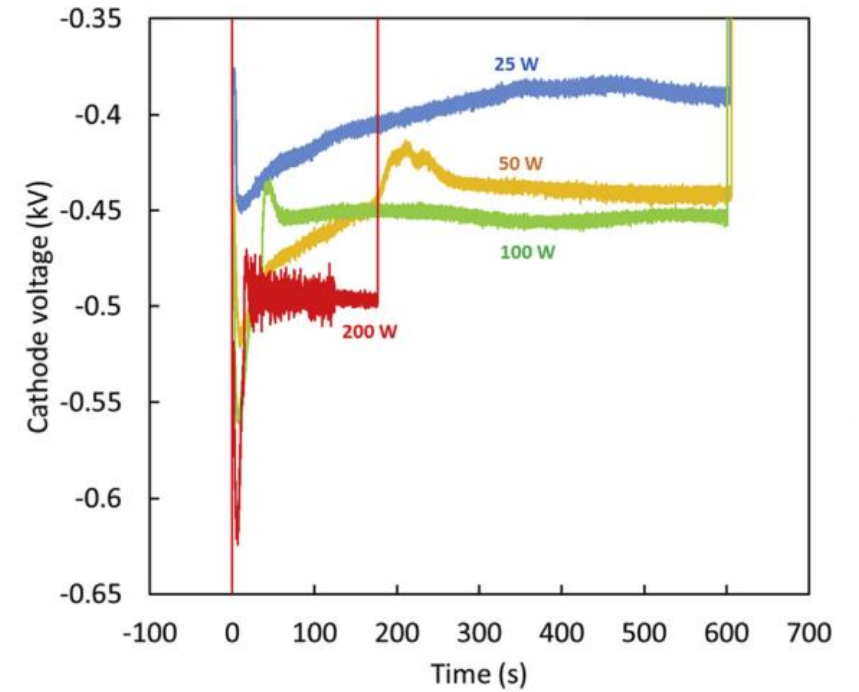
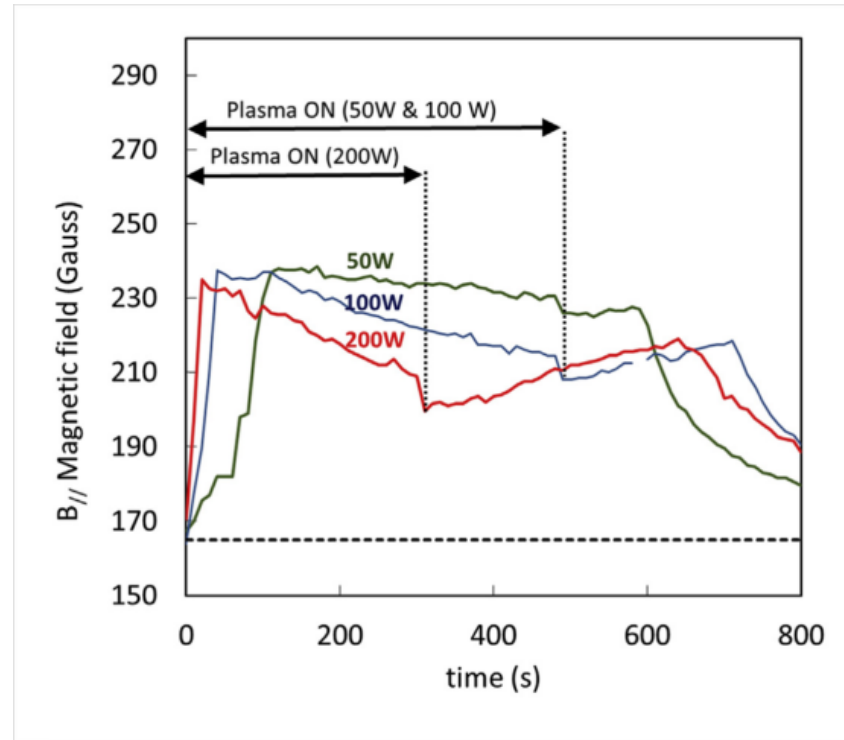
# Hot target magnetron sputtering



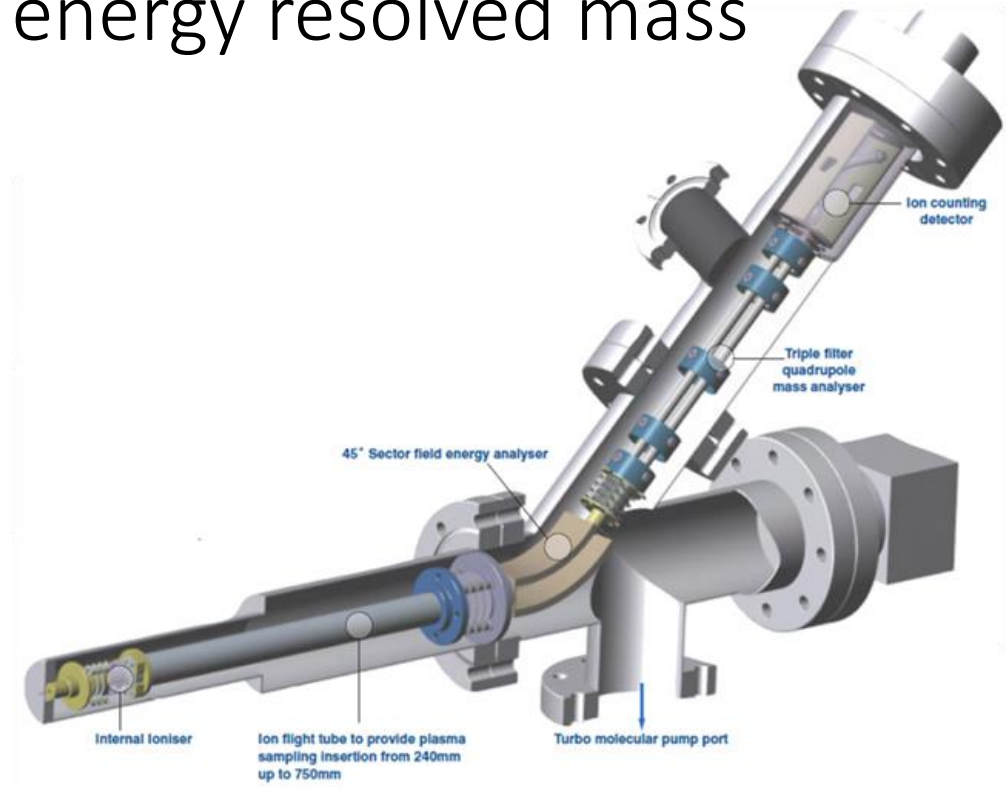
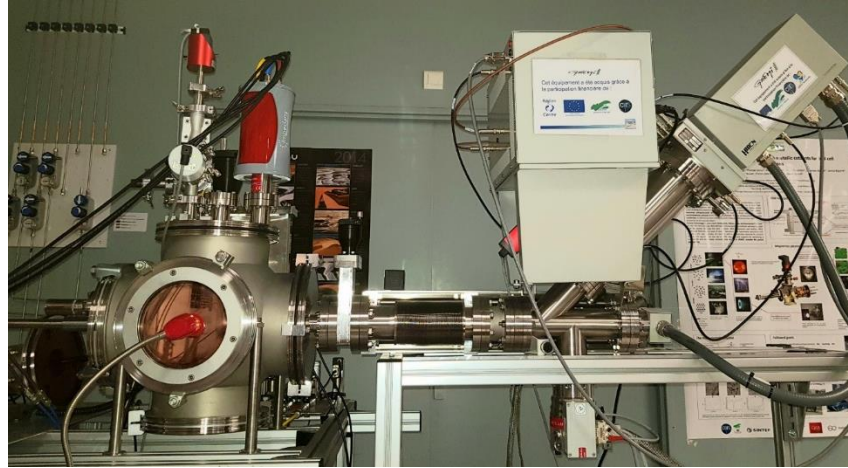
Output Voltage vs. Magnetic Field



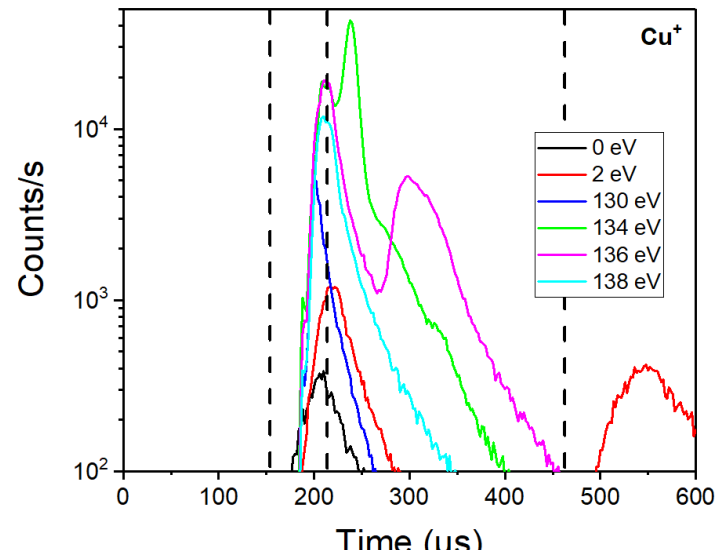
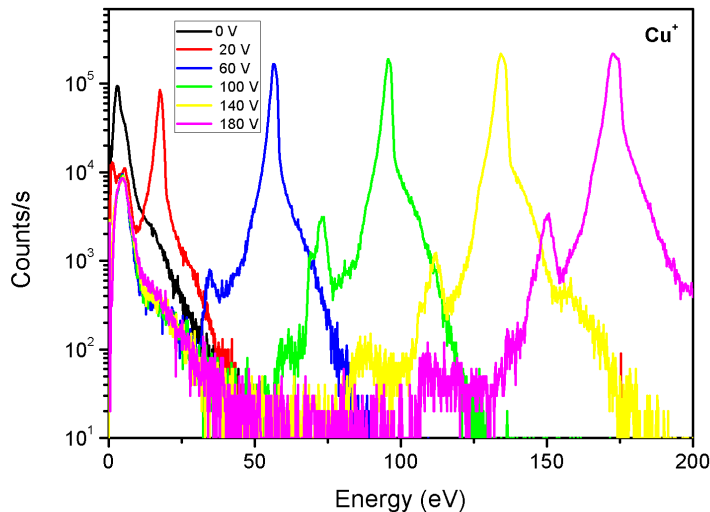
Small, linear Hall-effect device (AH49F, diodes). Output voltage varies in proportion to the strength of the magnetic field. Range temperature : -40/+105°C



# Plasma-surface interaction diagnostic : energy resolved mass spectrometer



$U_{rev} = 140 \text{ V}$  d'une durée de  $250 \mu\text{s}$



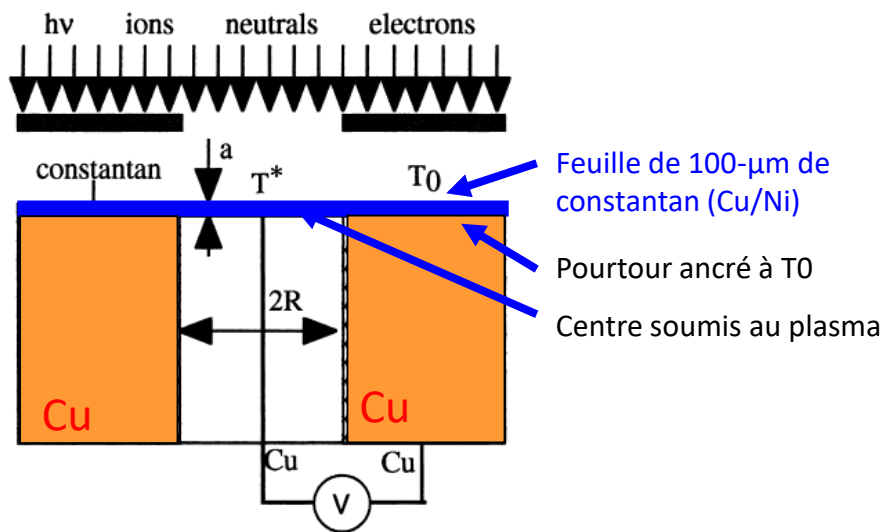
## EQP1000 Hiden analytical

- combined an ion energy analyser and quadrupole mass spectrometer
- The multi-channel Scaler (MCS) records the counting rate of events as a function of time.

# Plasma-surface interaction diagnostic : heat flux sensor

Permet de déterminer **la température et le flux d'énergie globale** (mW/cm<sup>2</sup>). Possibilité de discriminer certaines contributions (ions, radiation).

## Gardon probe

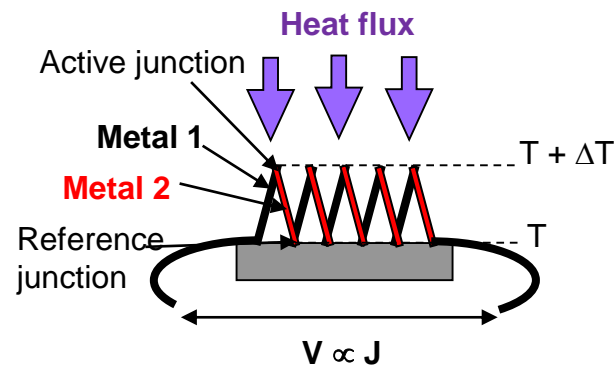
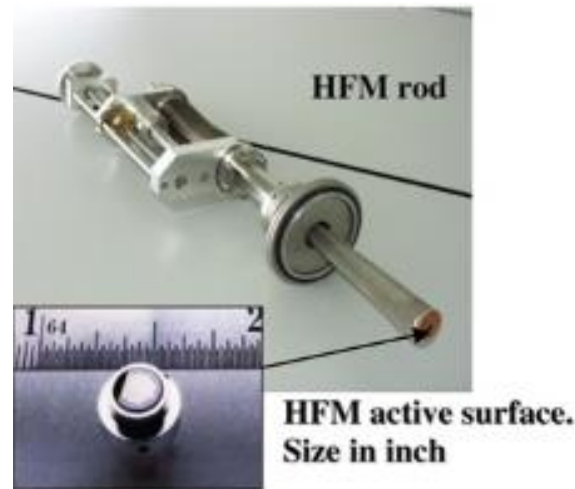


K. Ellmer et al (Surf. Coat. Technol. 116-119 (1999) 1102)

Mesure la différence de température entre le centre du disque et sa circonférence (ancré thermiquement)

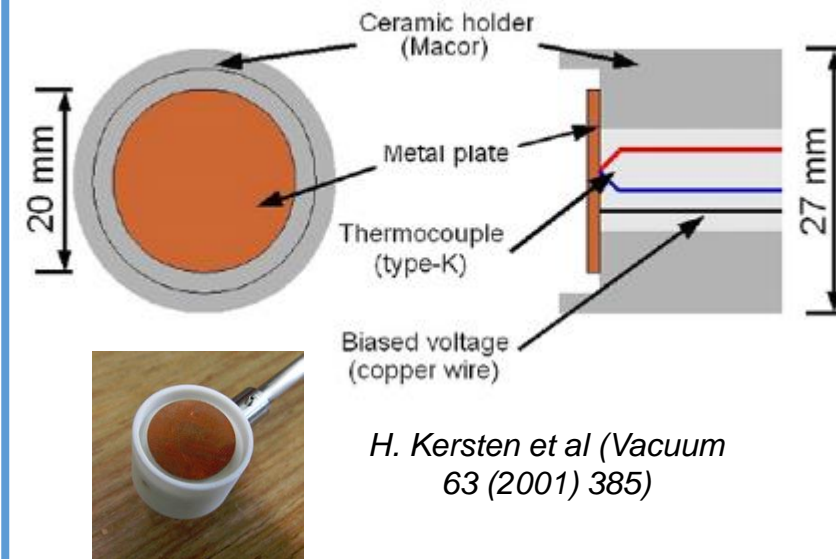
La différence de temp est directement proportionnelle à la **densité de flux**.

## Heat flux probe

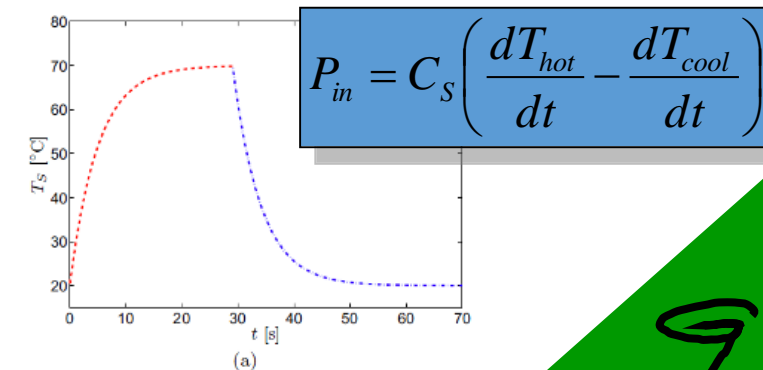


A.L. Thomann et al (Review of Sci. Instrum. 77 (2006)033501)

## Calorimetric probe

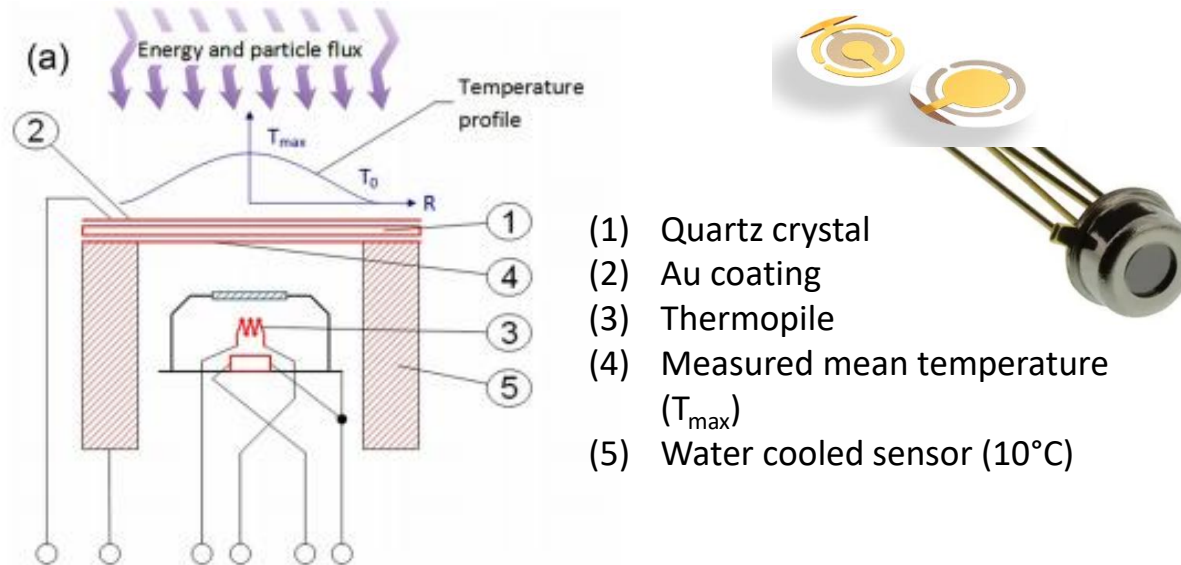


H. Kersten et al (Vacuum 63 (2001) 385)



# Plasma-surface interaction diagnostic : multifunctional probe

## Gardon probe, Langmuir probe and quartz microbalance

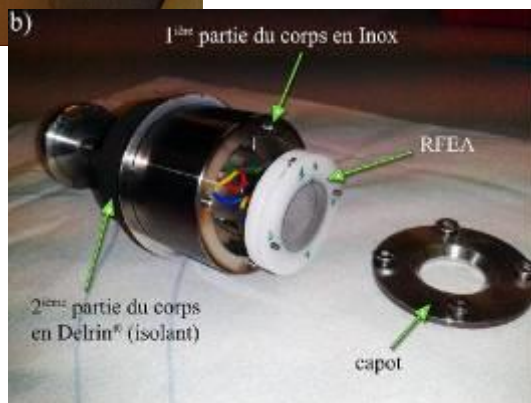
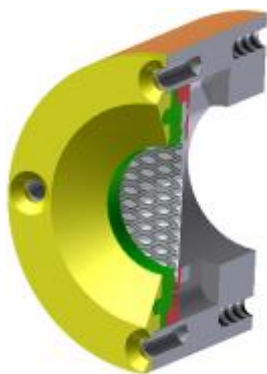
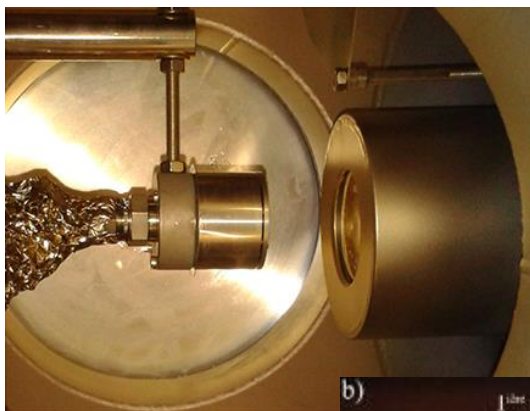


Basic drawing of the multi-functional deposition sensor made of :

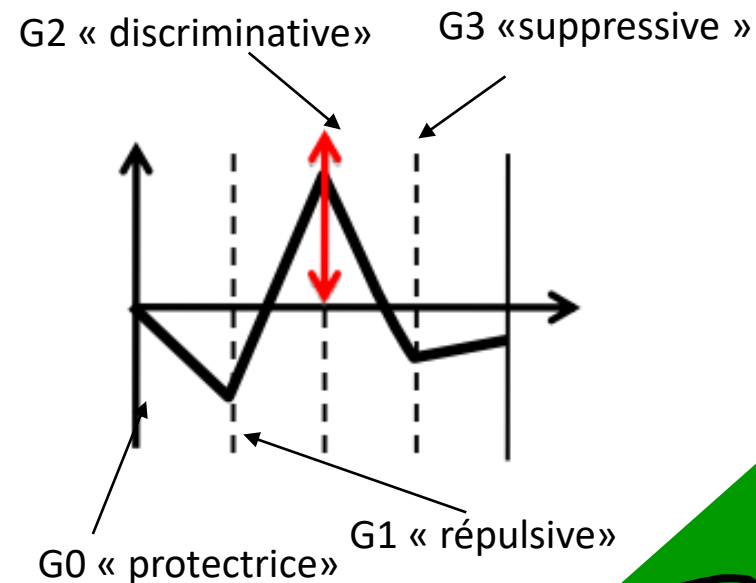
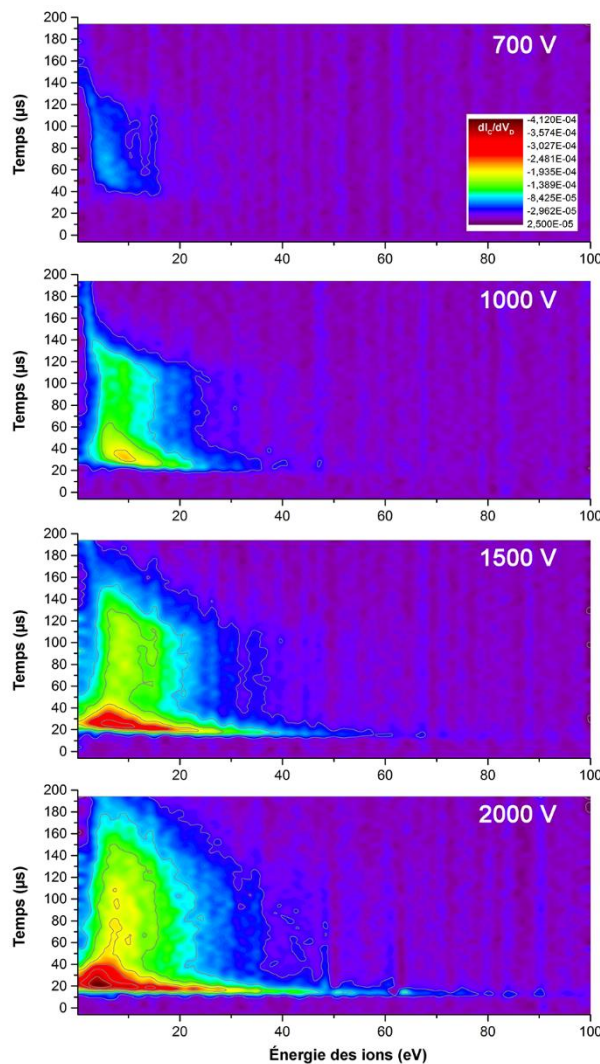
- a quartz crystal (1) cooled only at its circumference via the water cooled sensor body (5), coating by a Au front electrode (2) which is isolated against ground and can be used as a planar Langmuir probe
- a thermopile (3), which measures the mean temperature at the back side (4) of the quartz crystal in the wavelength range  $>5 \mu\text{m}$ .

Deposition rate, energy flux density, plasma density/potential and electron temperature

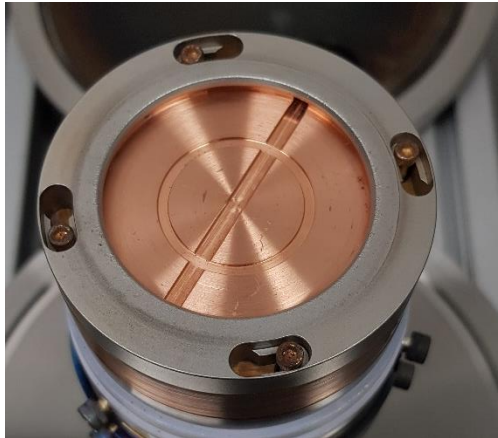
# Plasma-surface interaction diagnostic : energy analyzers



Dimensions : diamètre extérieur de 3 cm.  
 Grilles Inox de 100  $\mu\text{m}$  avec transparence de chaque grille = 35 %  $\rightarrow$  au total = 1.5%  
 Surface apparente de collection 1.54  $\text{cm}^2$ .  
 Séparateur Mylar de 300  $\mu\text{m}$ .



# Conclusion



***Magnétron circulaire  
(2 et 4 pouces)***

*Commerciale*

*0.1 – 30 Pa (Ar, O<sub>2</sub>, N<sub>2</sub>)*

*DC, RF, HiPIMS*

*Intégration dans des bâtis « maison » pour  
couches minces et nanostructures*

Caractérisation nanomatériaux (au GREMI et sur plateforme)

Caractérisation des interactions plasma / surface

Développement bâti basé sur magnétrons commerciaux

Corrélation interaction – propriétés nano

S'appuie sur des simulations par DM