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Sputtering Process of Aluminum in Ar/He Mixtures

S. Ibrahim, A. Caillard, P. Brault, T. Lecas and A.L. Thomann

GREMI UMR 7344 CNRS/Université d'Orléans, Orléans, 45067, France

sara.ibrahim@univ-orleans.fr

Introduction

In the frame of fusion research, the interaction of helium with various materials has been widely studied. For instance, it has been proved that He implantation in tungsten at high substrate temperature and low ion kinetic energy leads to the formation of fiber-form nanostructures, called "fuzz" [1]. It has been observed that this nanostructure is formed at a kinetic energy below the atomic displacement threshold and exhibits high porosity (90 %), which could be of great interest for various applications (light absorption, catalysis etc.). Further investigations have evidenced the formation of various porous structures on molybdenum, nickel, iron or aluminum surfaces [2]. The underlying formation mechanism seems to be related to the very particular behavior of He inside metal lattices [3].

➔ In the present work, we investigated Al target sputtering in various He/Ar mixtures in the aim to synthesize nanostructured films for hydrogen production application.

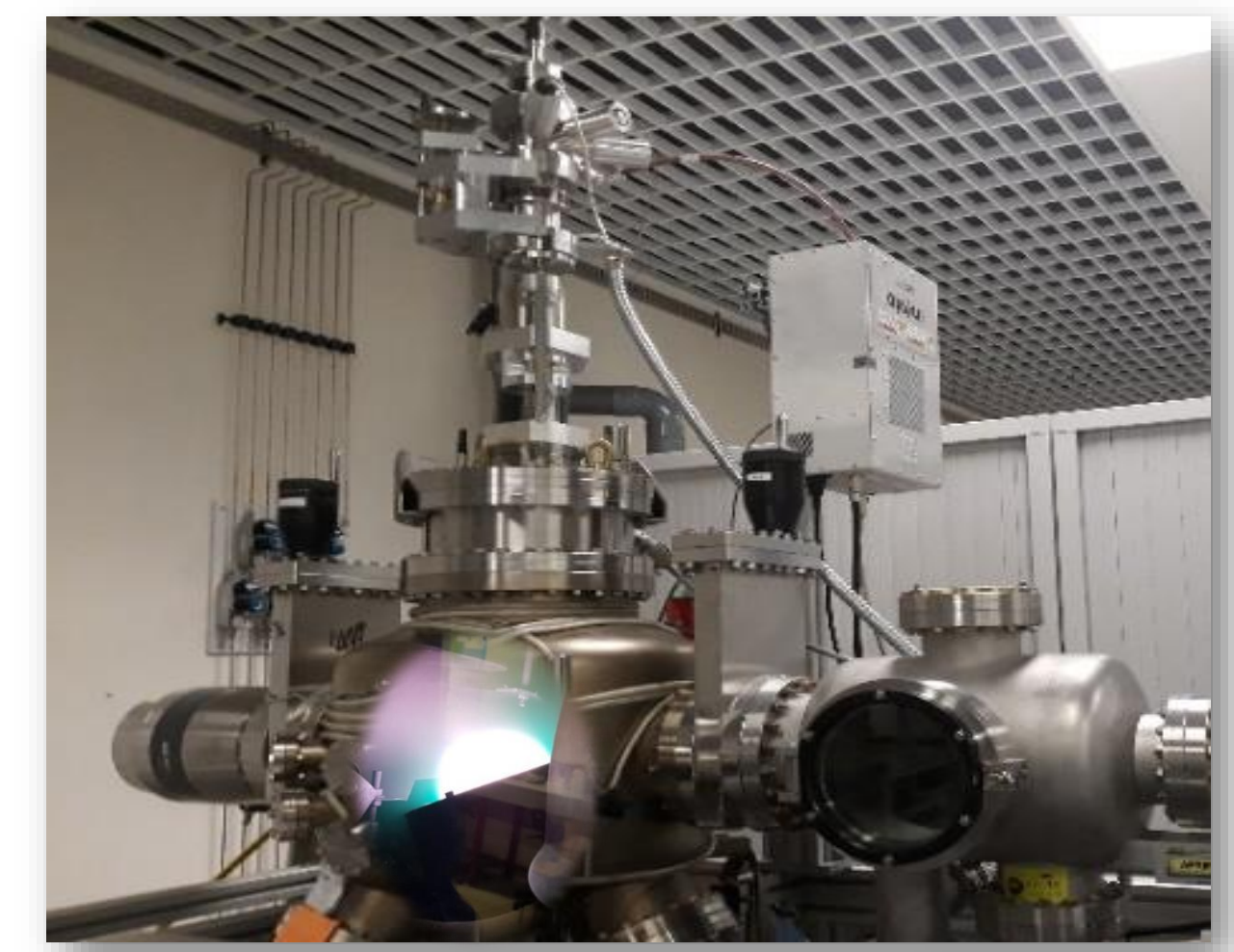
Deposition of Al thin films: DC magnetron sputtering

Al (metal)

- M: 27 amu
- T_f : 660°C
- H_{subl} : 3.36 eV
- R_{Al} : 1.25 Å

Experimental parameters

- P ≈ 400 W (350 - 410 V)
- d = 12 cm
- P = 1 Pa
- t_d = 30-120 min
- Different Γ_{He}

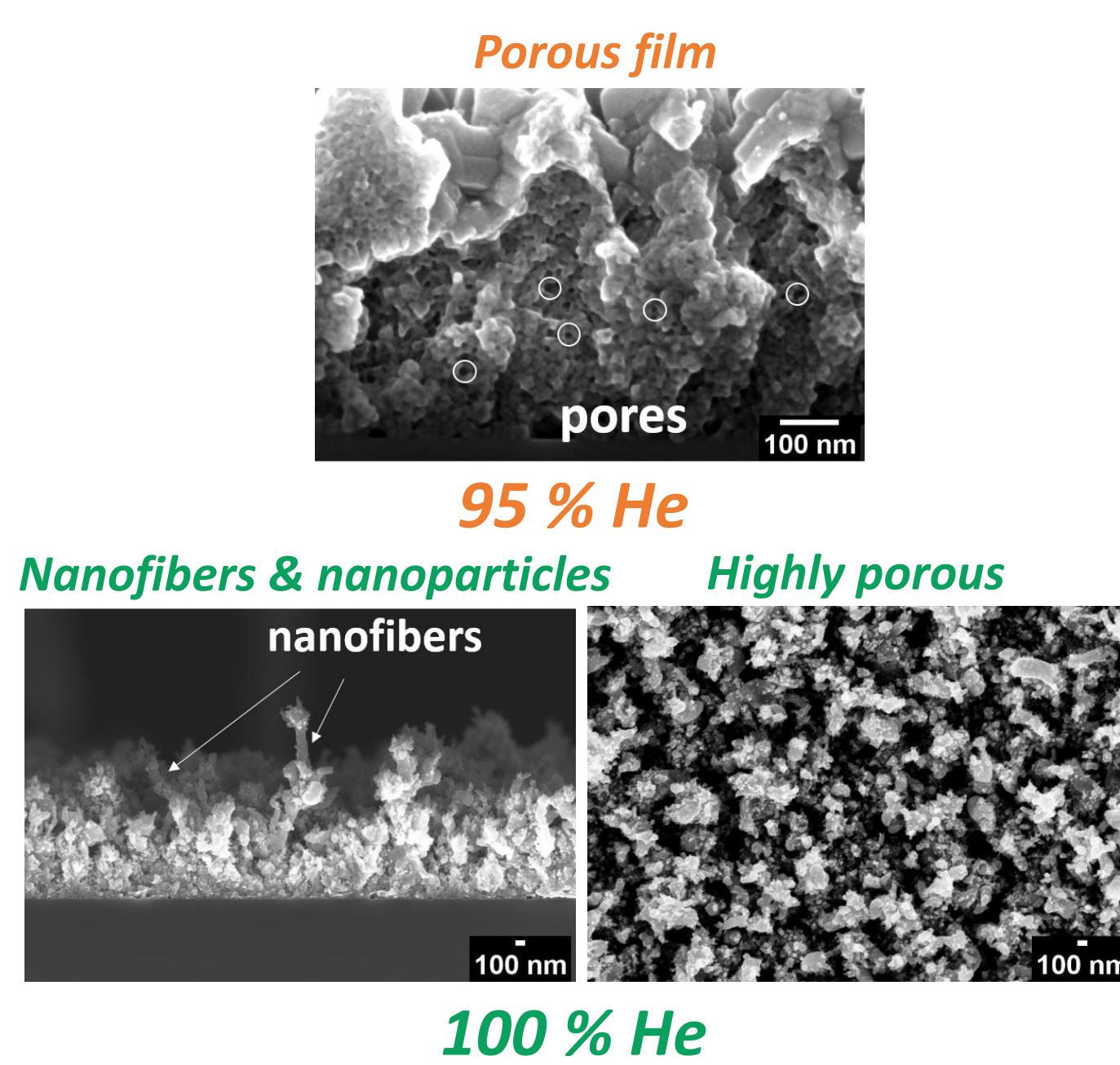
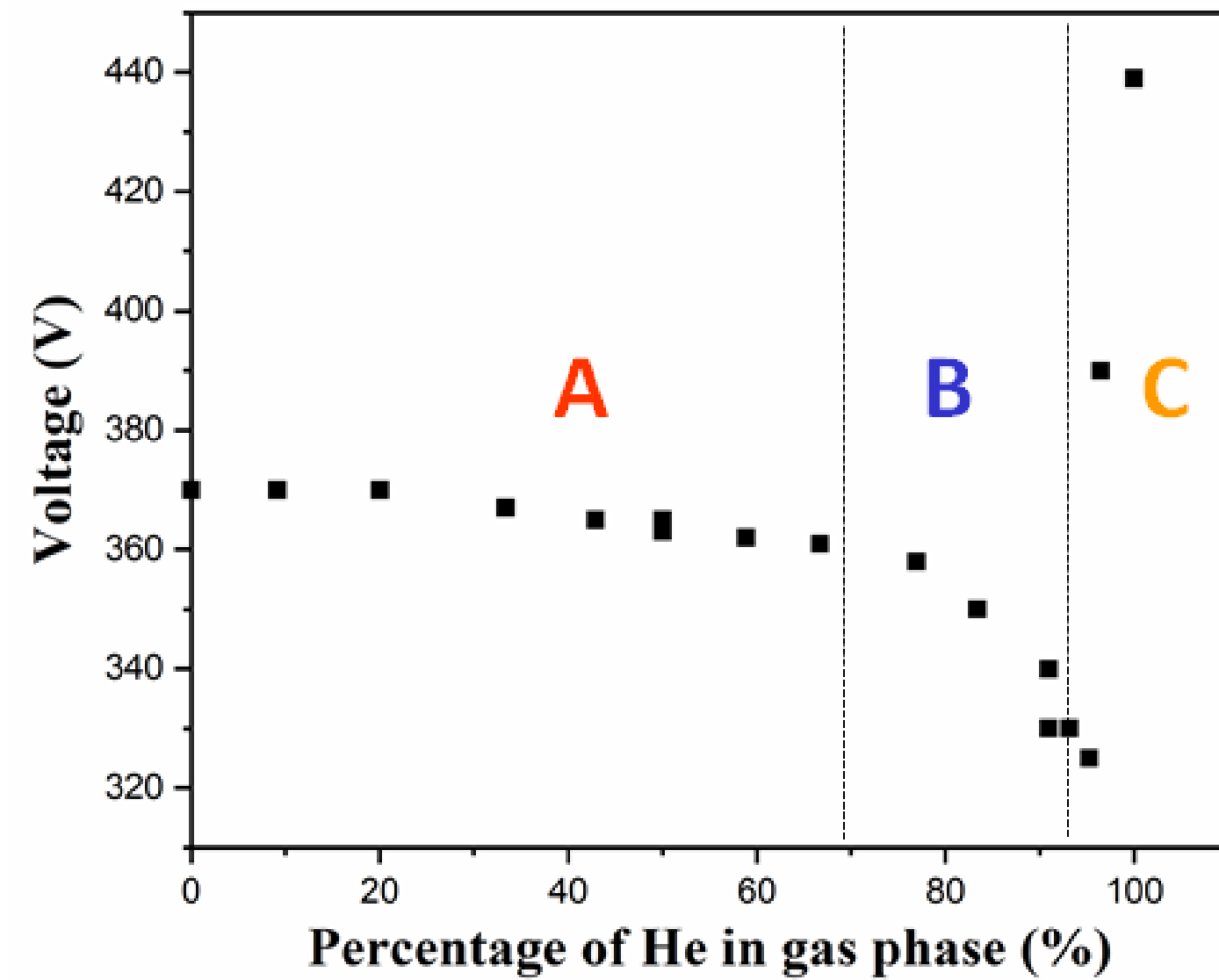
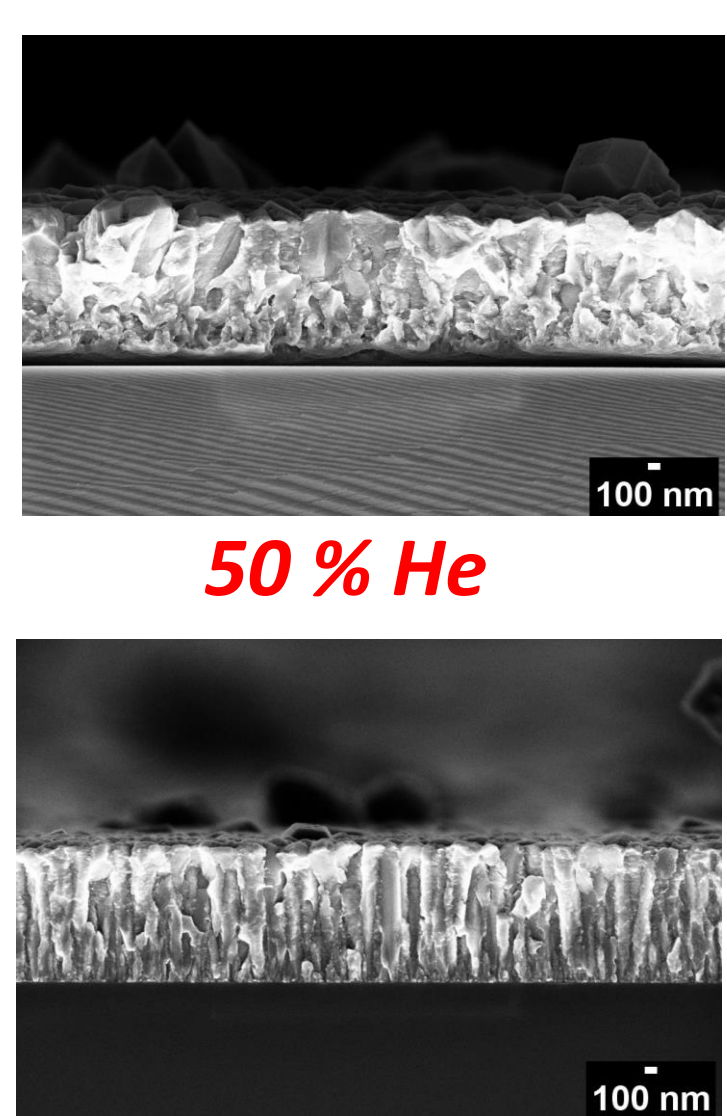


DePhy reactor
GREMI, Orléans



How does He proportion in the gas phase affect the sputtering process, the energy distribution functions & film growth???

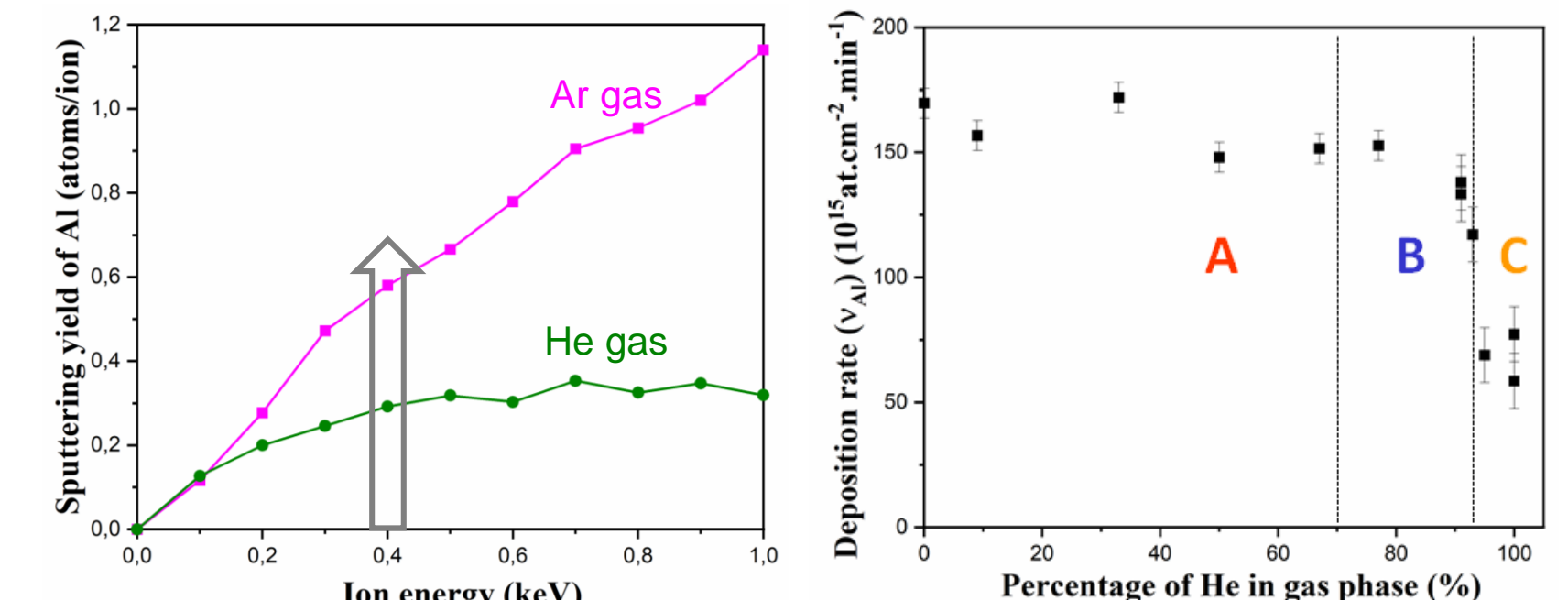
Plasma regimes & film morphology



➔ The plasma regime is modified for $\Gamma_{He} > 93$ %, influencing film morphology.

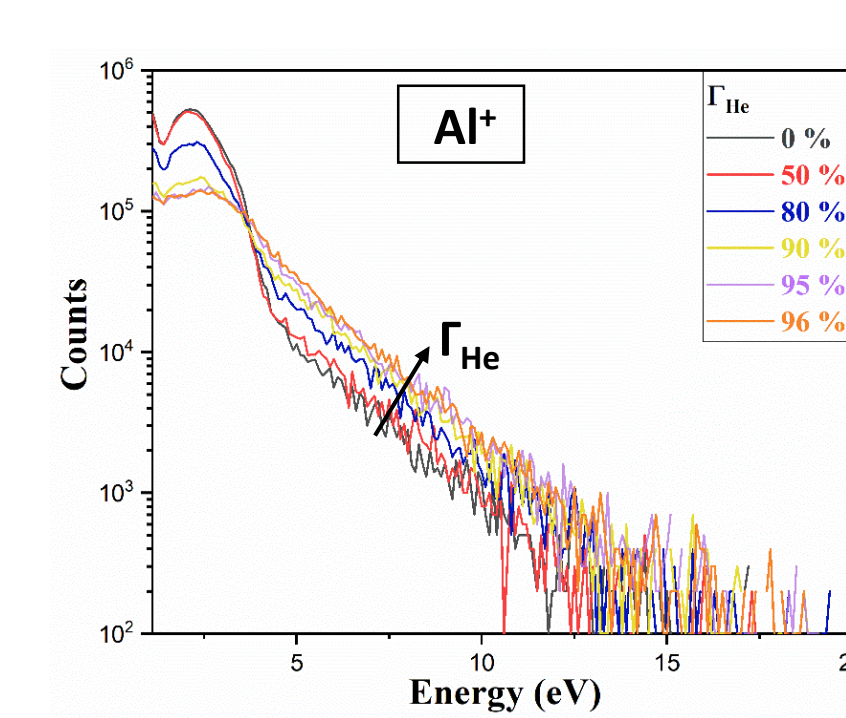
Sputtering yield & deposition rate

The sputtering yield of Al is affected by the nature of the ion (Ar^+ or He^+).

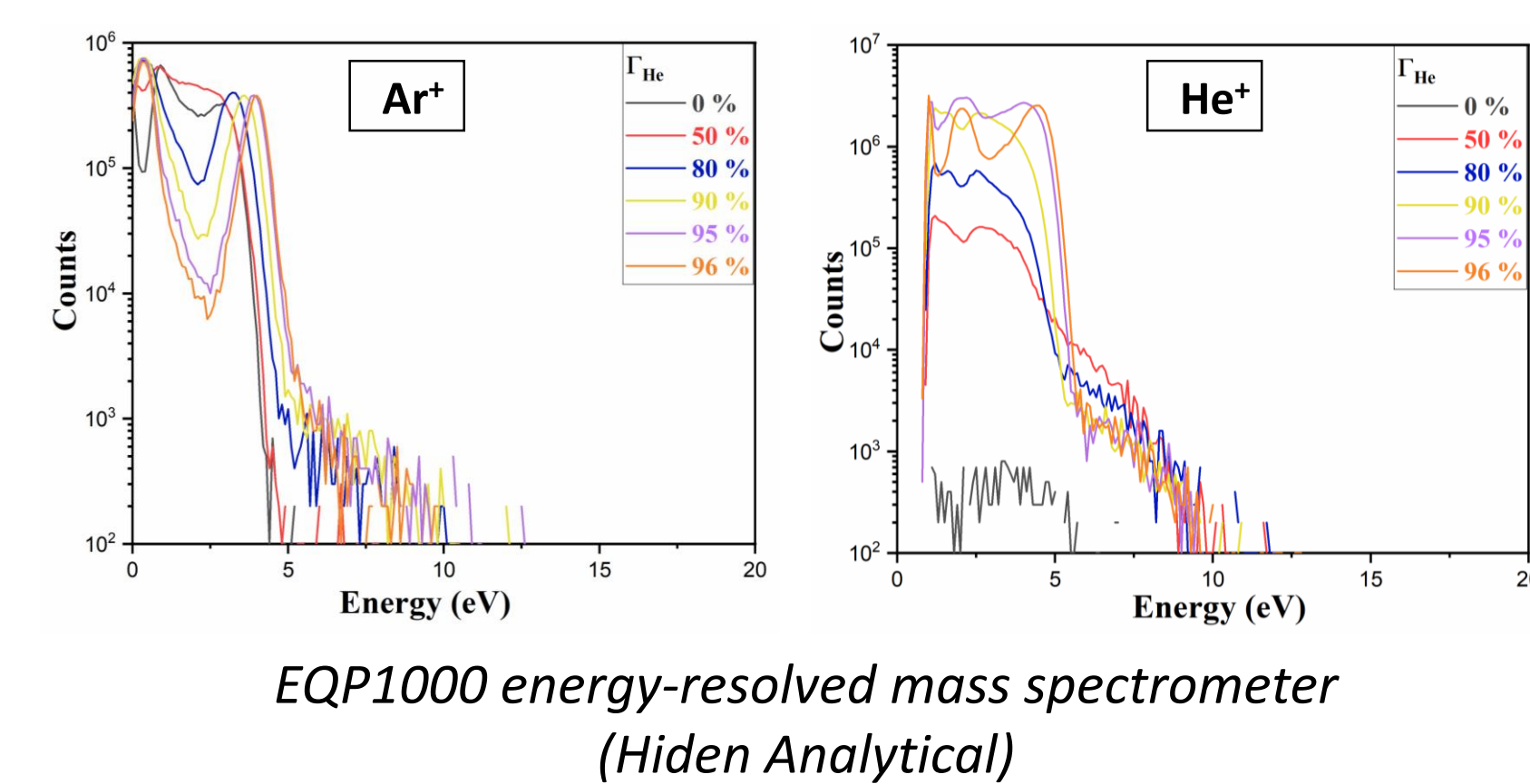


➔ For $\Gamma_{He} > 93$ %, He ions start contributing significantly to the sputtering of Al.

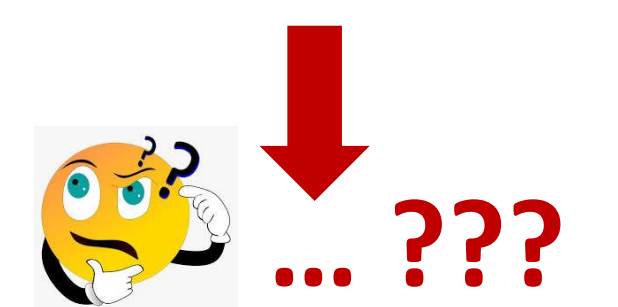
Ion energy distributions: Mass spectrometry



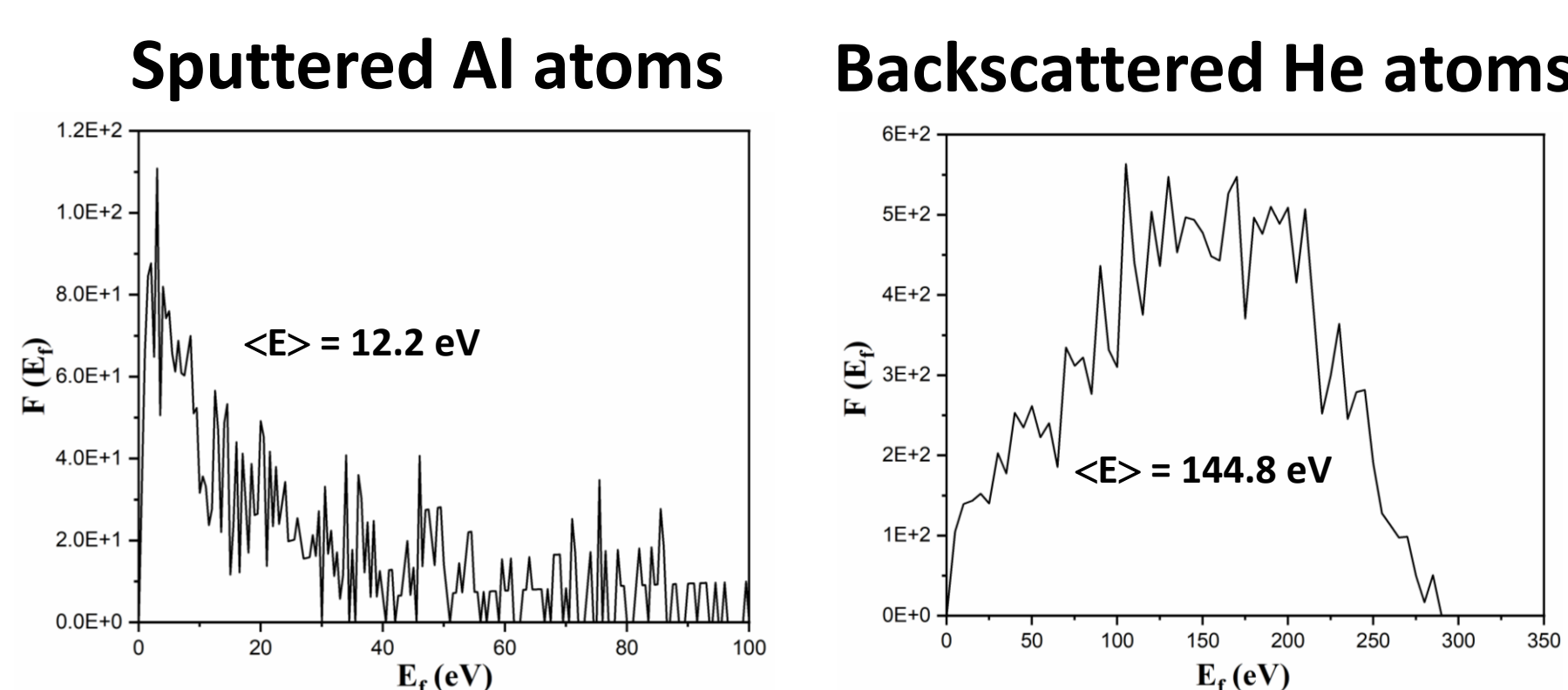
As Γ_{He} ↑ above 70 %, the high energy tail /
➔ Sputtered Al atoms lose less energy by collision during their transport towards the substrate.



Significant changes are observed in the energy distribution function of Ar^+ and He^+ at $\Gamma_{He} > 77$ %.

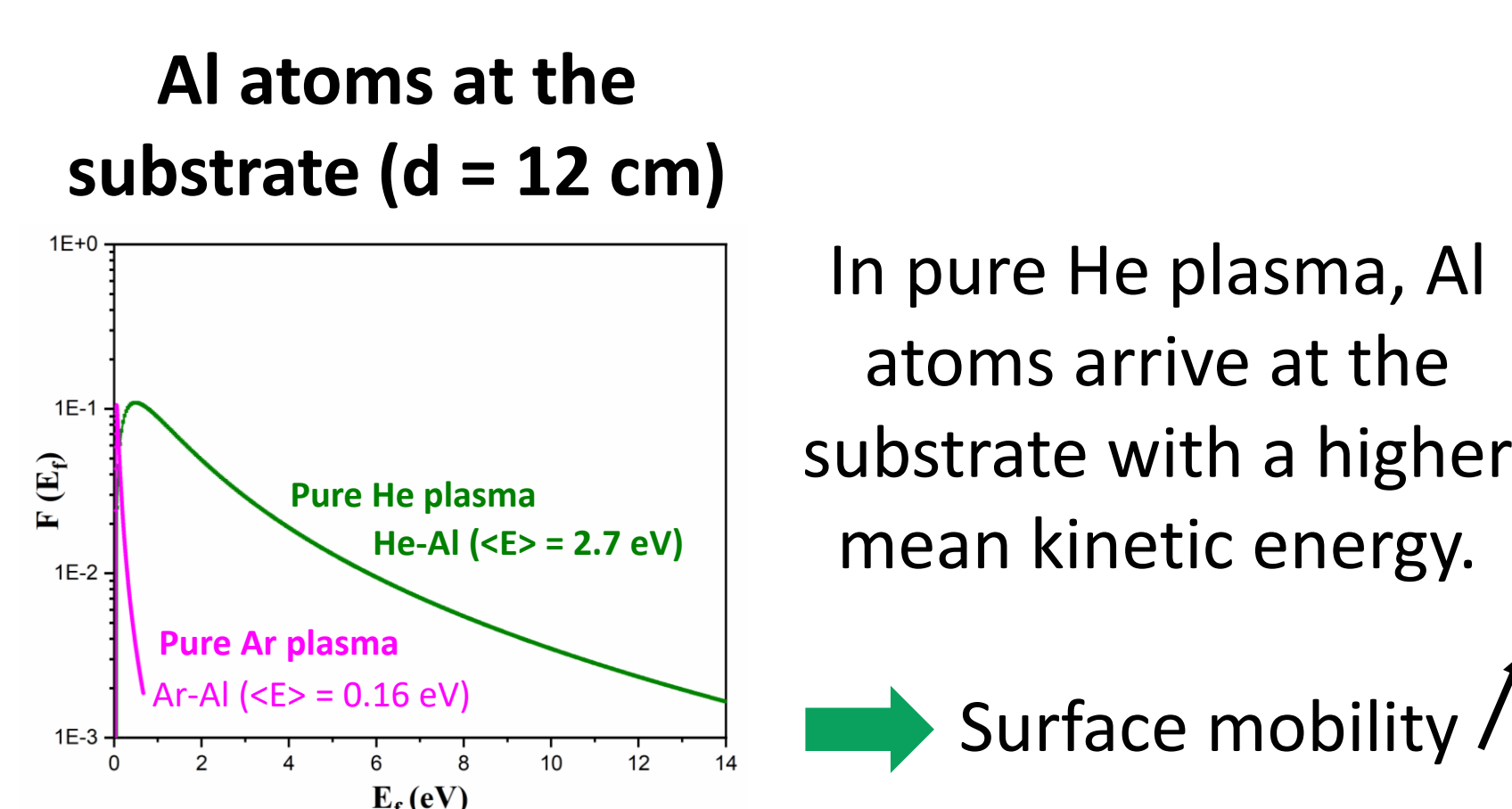


Energy distribution functions at the target in pure He plasma: SRIM



Backscattering yield = 0.18 ➔ High energy backscattered He atoms

Energy distribution functions at the substrate (after transport): Thomson & collision model

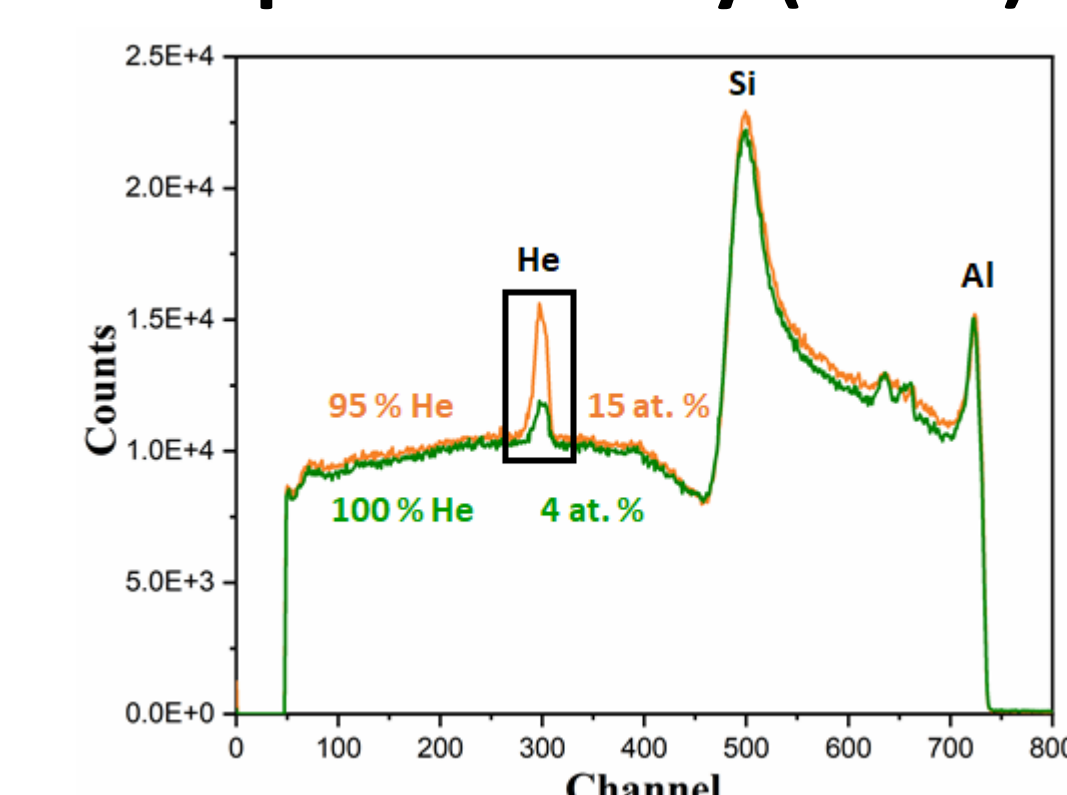


In pure He plasma, Al atoms arrive at the substrate with a higher mean kinetic energy.

➔ Surface mobility /

Composition & structure:

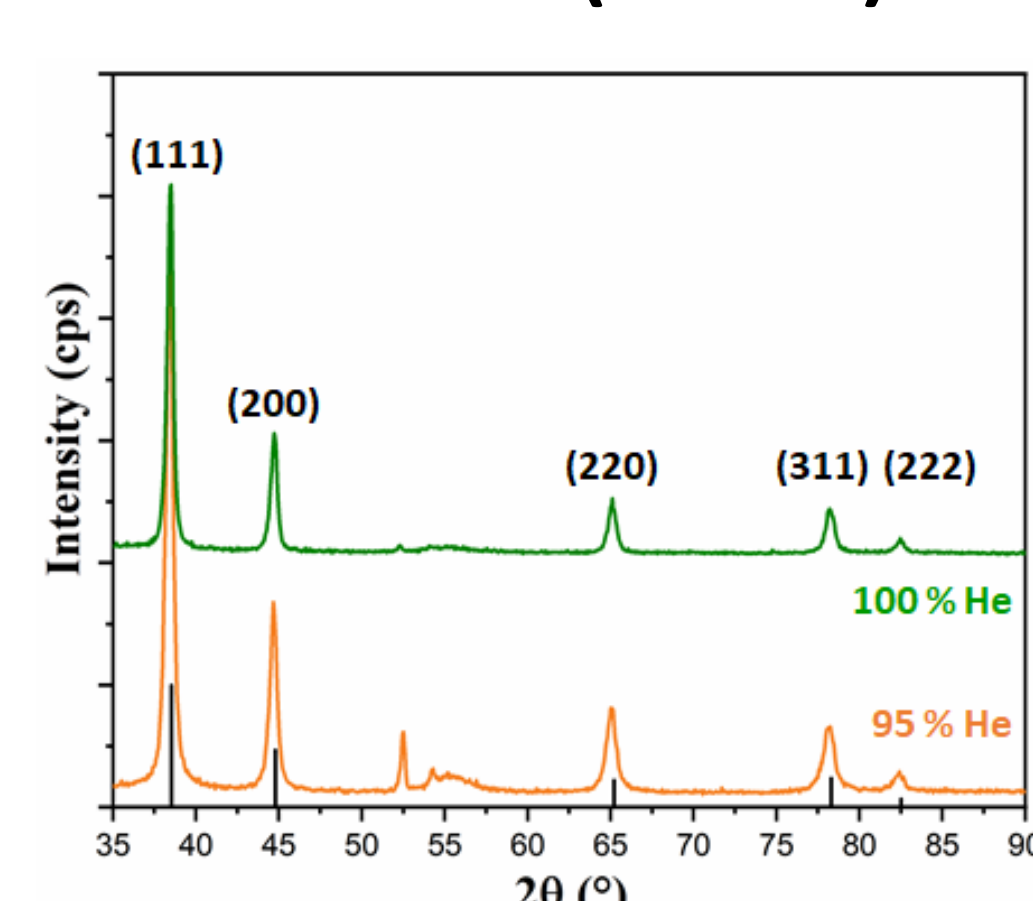
Proton elastic backscattering Spectrometry (PEBS)



For $\Gamma_{He} = 95$ %, the film is rich in He.

For $\Gamma_{He} = 100$ %, He is no more efficiently inserted or it is desorbed during growth.

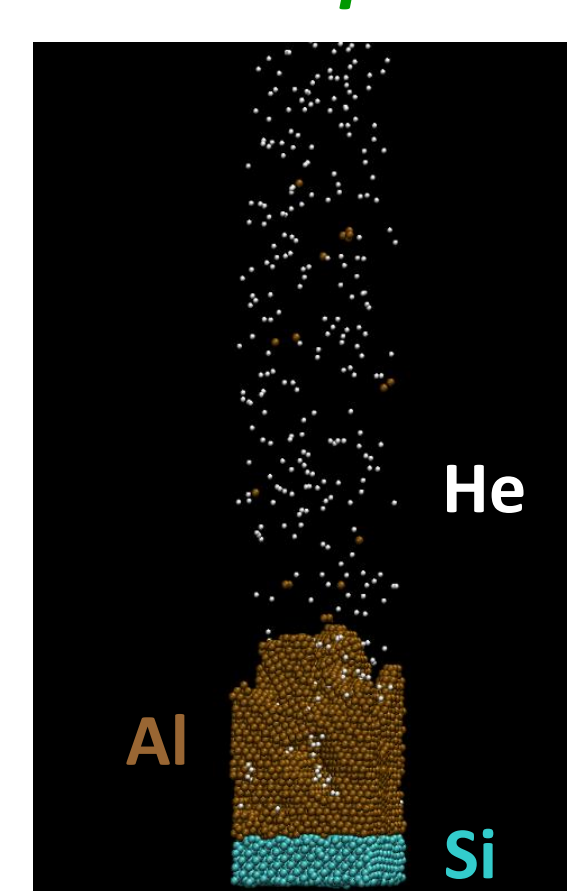
Grazing incidence X-ray diffraction (GIXRD)



Al fcc crystal structure

Molecular dynamics simulations

Pure He plasma



- ✓ Al dimers and trimers are formed in the gas phase.
- ✓ The film is crystalline and porous.
- ✓ He is trapped into the pores.

Conclusions

- All Al films are crystalline, exhibiting the fcc crystal structure.
- The percentage of He in the gas phase influences the sputtering efficiency and film growth.
- In pure helium plasma:
 - SRIM reveals that high energy He atoms (145 eV at the target and 60 eV at the substrate) are backscattered.
 - The low fusion temperature of Al and the high kinetic energy brought by Al depositing atoms enhance adatom mobility during growth and promote the formation of fiber-like nanostructure.
 - The release of He from the film induces porosity, and the presence of nanoparticles in the film could be related to the growth of nanoparticles in the plasma.

References

- [1] M. Tokitani et al, Nucl. Fusion **51** (2011) 102001
- [2] S. Kajita et al, J. Appl. Phys. **113** (2013) 134301
- [3] L. Pentecoste et al, Acta Materialia **141** (2017) 47-58