FOM Institute for Plasma Physics Rijnhuizen

Influence of discharge parameters on morphology evolution of plasma exposed graphite surfaces

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Introduction

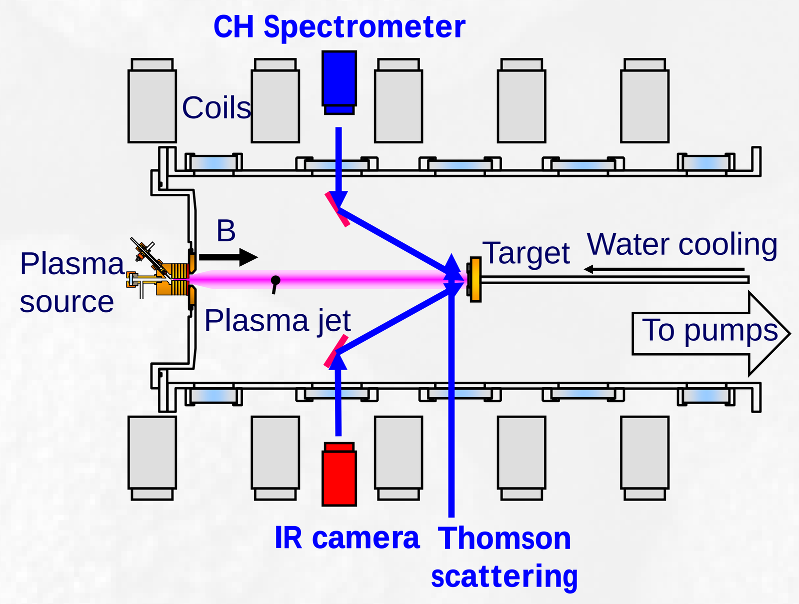
Processes which constitute material migration in fusion reactors influence the lifetime of plasma-facing components and have impact on safety issues (fuel retention, dust production).

There is still a number of open questions with respect to material migration in fusion devices, including:

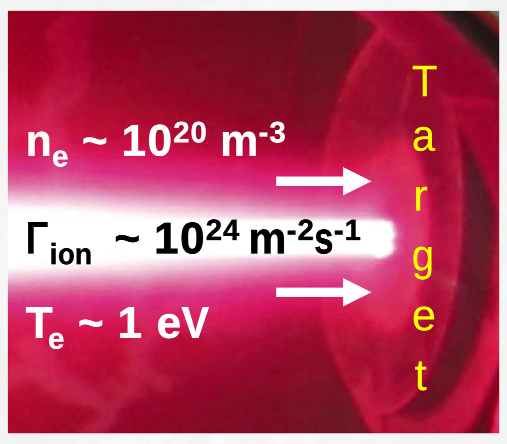
- Gross and net erosion rates of carbon;
- Importance of local re-deposition;
- Morphology of re-deposits, etc.

Experiments in linear plasma generator Pilot-PSI are aimed at addressing those points.

Pilot-PSI. Schematic lay-out

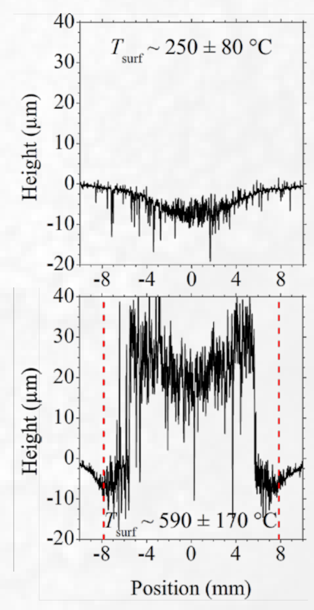


ITER divertor relevant regime



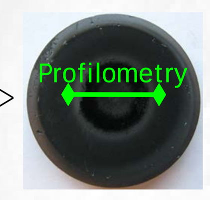
Operation in hydrogen, hydrogen/argon, nitrogen

$H_2 \rightarrow$ Fine grain graphite



$T_e < 0.5$ eV

Net erosion ~ Gross erosion
No deposits



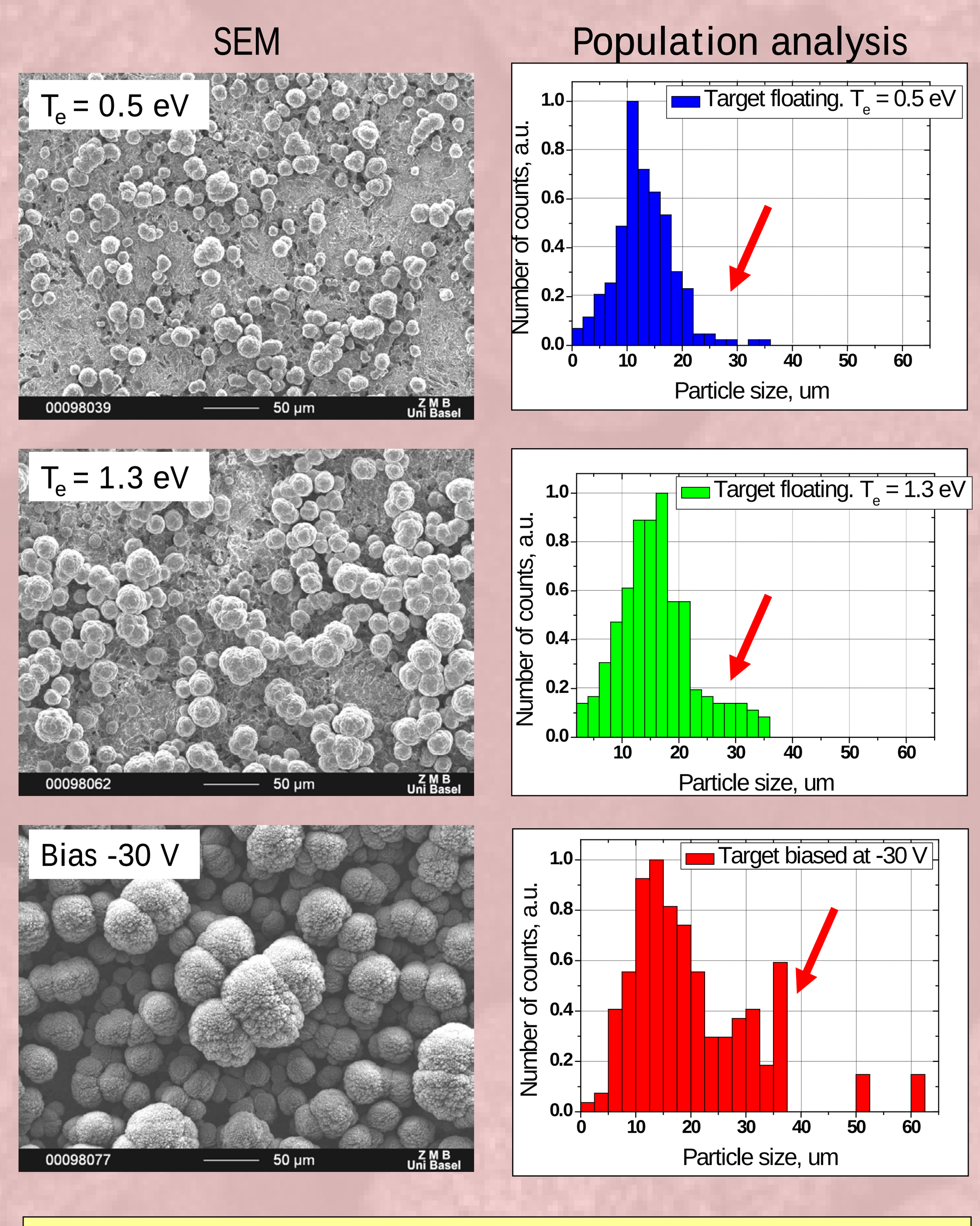
$T_e > 0.5$ eV

Net erosion ~ 0.1 × Gross erosion
Effective re-deposition drives formation of deposits

Which parameters influence re-deposition efficiency?

What is the form of the deposits?

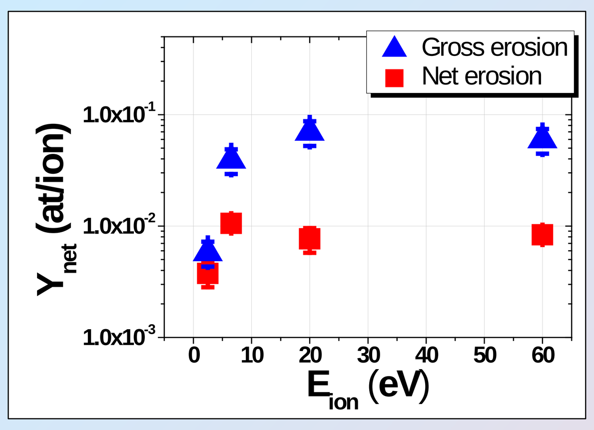
Hydrogen plasma. Ion energy scan

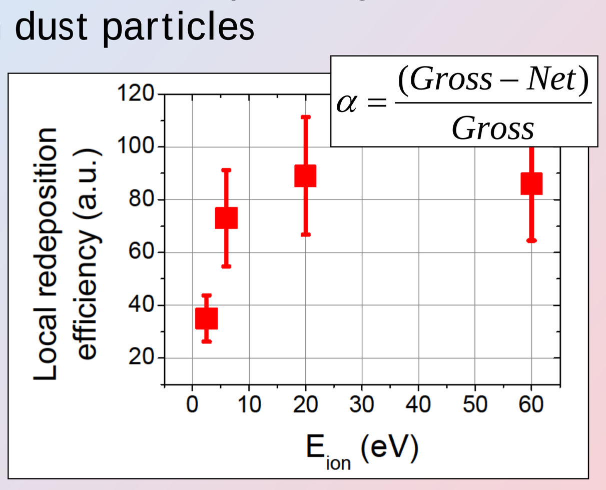


Formation of large (D>30 μm) dust particles at higher energies

Local re-deposition efficiencies

Comparison of gross and net erosion enables determination of local re-deposition efficiency. Naturally, one would expect higher efficiency for samples, covered with dust particles

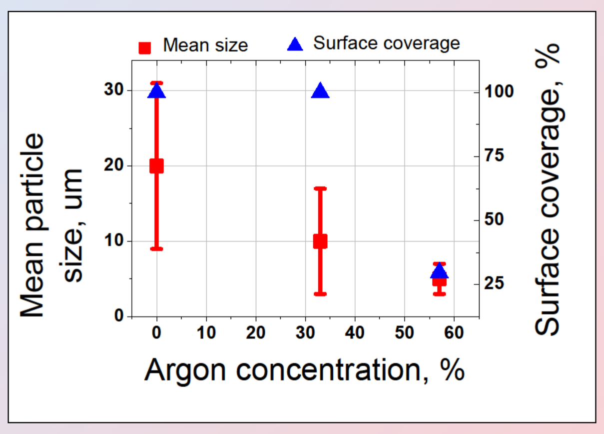


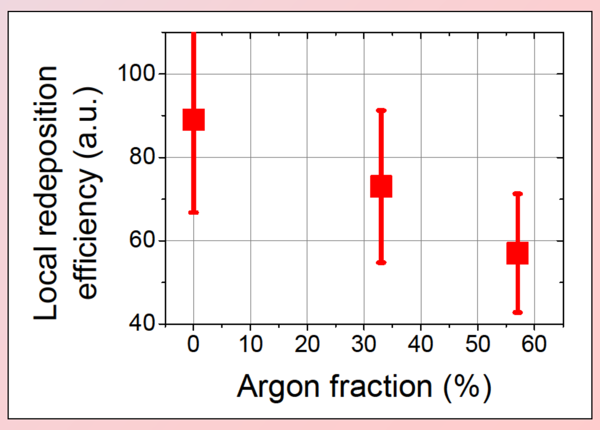


Local - on the surface of 30 mm target

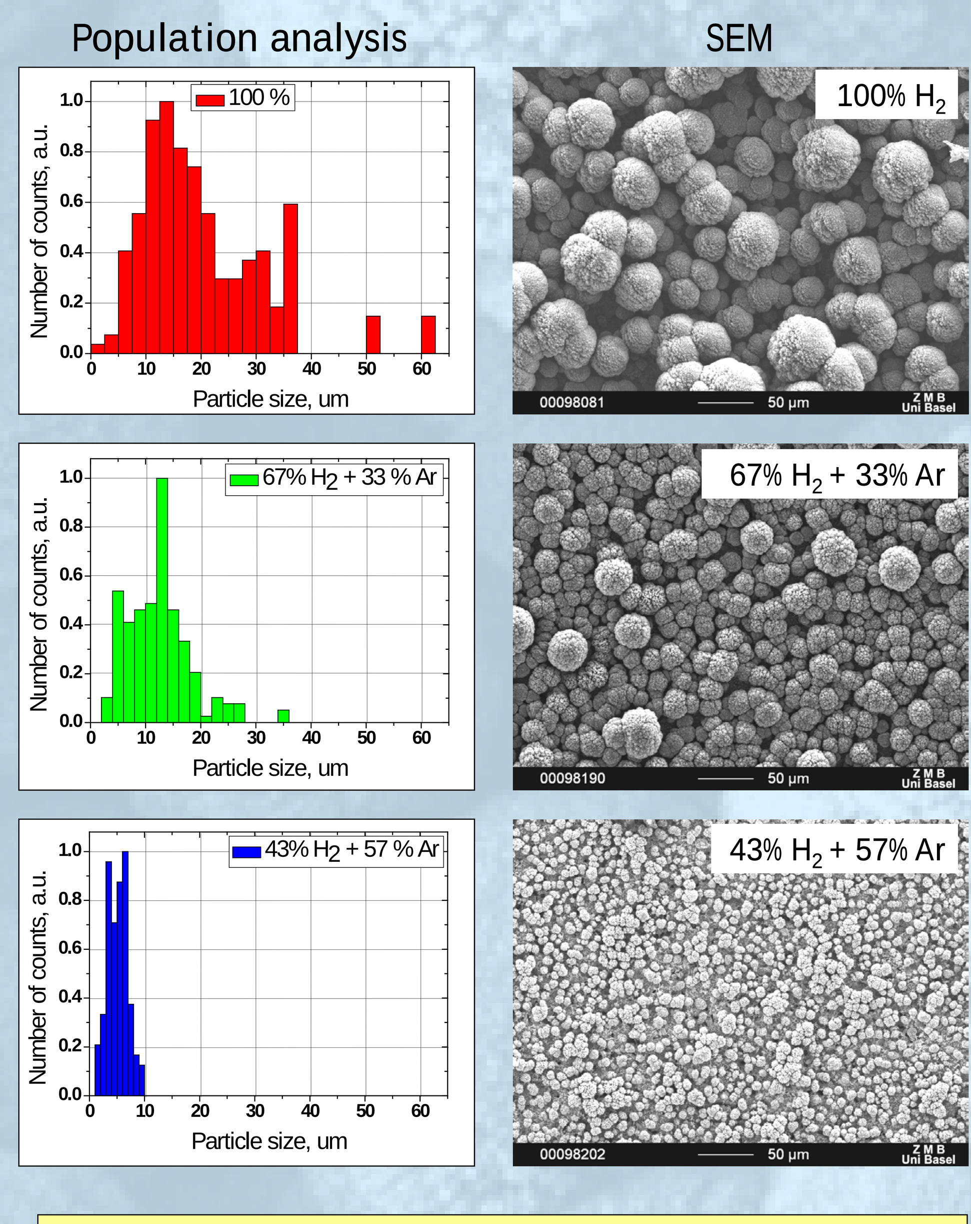
Despite more efficient re-deposition at higher energies, local net erosion yield is ~1% and is not decreasing

Dilution of hydrogen beam with argon makes re-deposition less efficient resulting in smaller dust particles observed on the surface



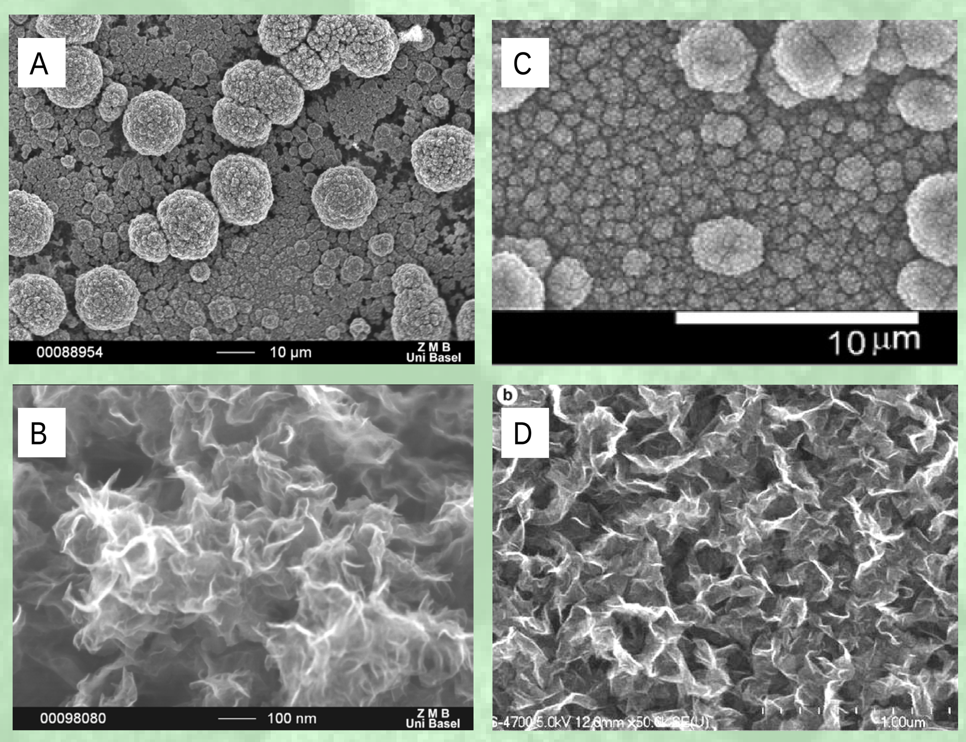


Mixed H_2/Ar plasma. Ar fraction scan



Addition of argon into the hydrogen plasma beam shifts the particle size distribution towards smaller values ($D_{max} \leq 10$ μm)

Peculiar surface morphology



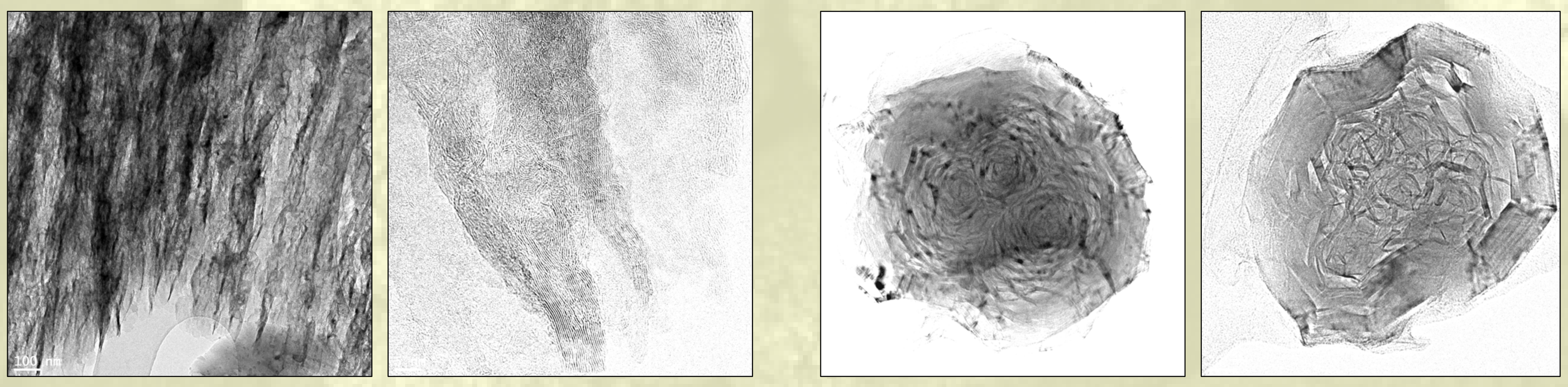
A & B - Pilot-PSI

C & D – PECVD discharges [2,3]

Very different treatment conditions, but obvious similarities in morphologies

It is likely, that structures observed in Pilot-PSI are formed on the surface (as in PECVD)

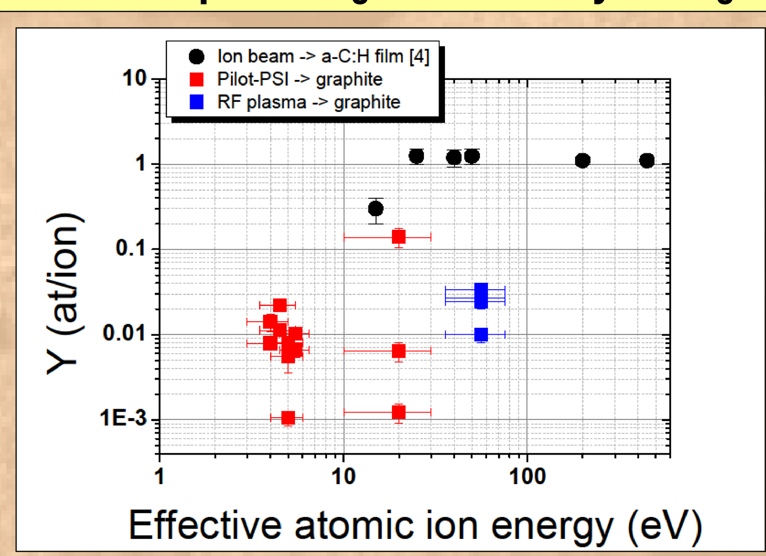
Transmission electron microscopy



TEM images reveal presence of nano-sized conical structures as well as spherical nanoparticles on plasma exposed surfaces. Onion shape of the latter suggests formation in the plasma

Nitrogen plasma

Chemical sputtering of carbon by nitrogen

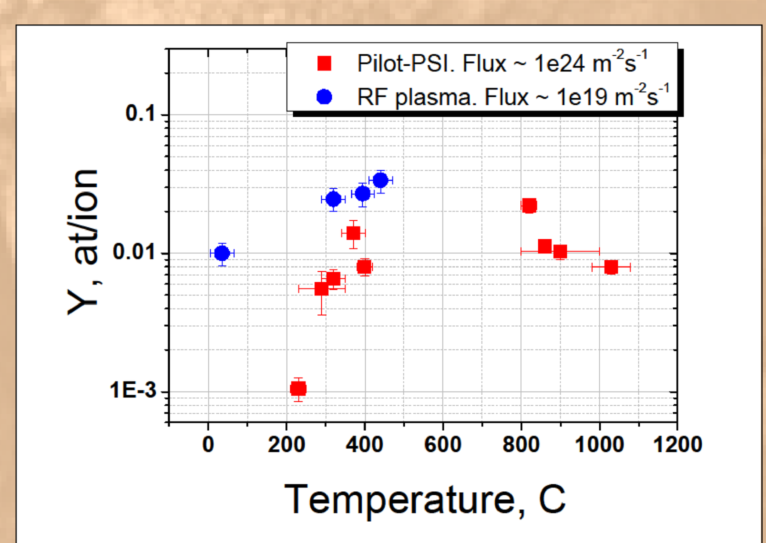


Nitrogen – proposed gas for injection into divertor to aid radiative cooling of the plasma.

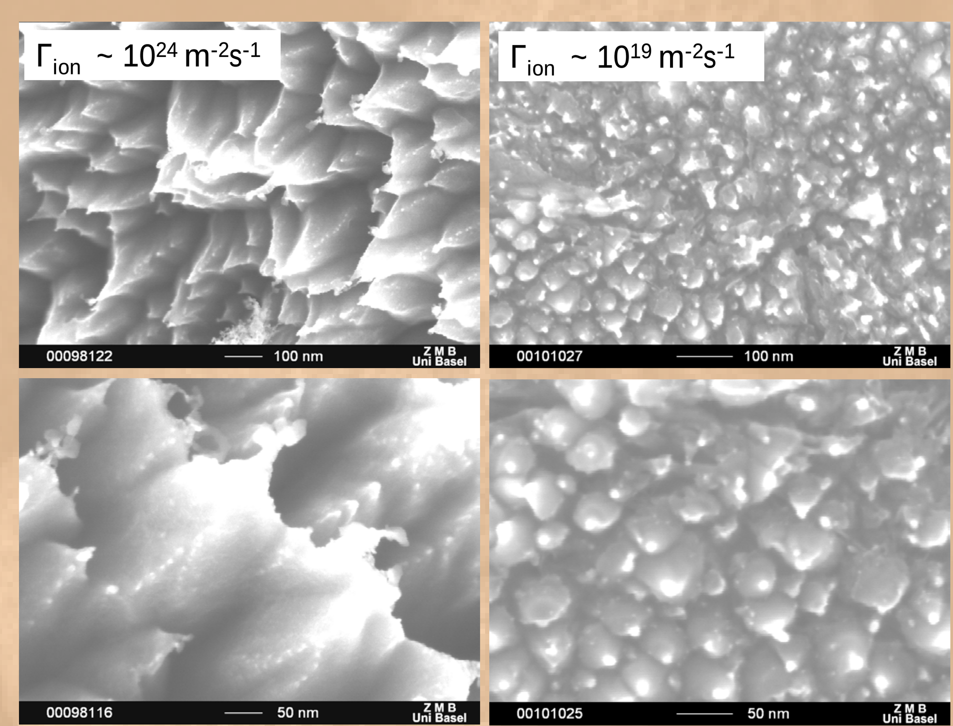
Nitrogen sputters carbon chemically. There is a lack of data on sputtering yields for divertor relevant conditions ($\Gamma_{ion} \sim 10^{24}$ m^{-2}s^{-1}).

Experiments in Pilot-PSI and with RF plasmas are aimed at assessment of nitrogen seeding impact on PFCs.

Surface temperature dependence



Strong surface modification



Acknowledgement

This work was supported by the European Communities under the contract of Association between EURATOM/FOM and carried out within the framework of the European Fusion Programme with financial support from NWO and the NWO Grant No. RFBR 047.018.002. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

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