First results from US/EU collaboration

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- Experimental setup
- Be plasma concentrations
- Fluence dependence of chemical erosion
- Influence of Be seeding on chemical erosion
- Temperature dependence of Be sputtering
- Summary and Outlook

Experimental setup

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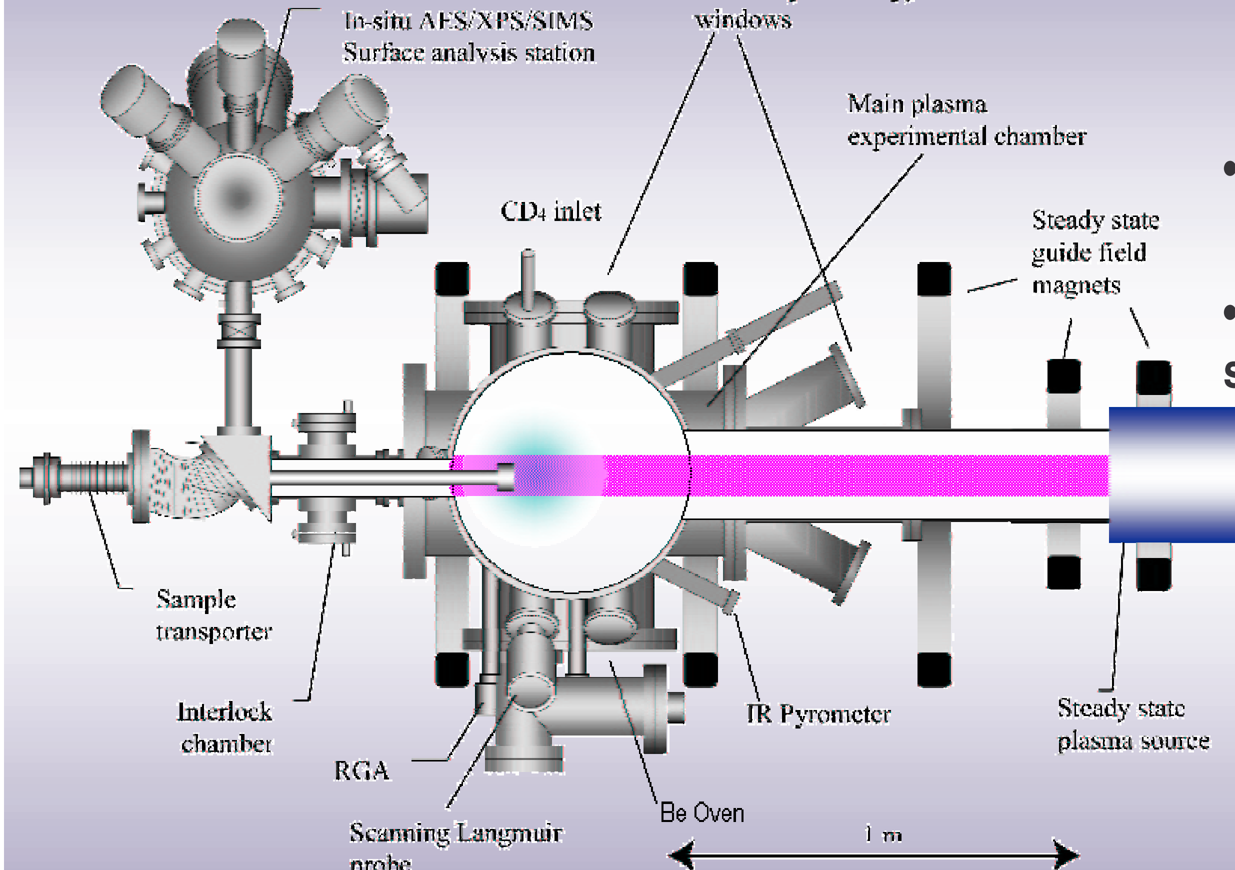
PISCES-B



Ex-Situ: TDS, SEM + EDX & (soon) WDS

- Steady state plasma source.
  $\Gamma_D \sim 10^{18}$ cm^{-2} s^{-1}
  $T_e \sim$ 6eV
  $n_e \sim 10^{12}$ cm^{-3}
- MBE-Oven for Be seeding
  $C_{be} \sim$ 0.1% to 1%
- Quantitatively calibrated visible spectroscopy
- In-situ surface analysis chamber.
- Reciprocating double Langmuir Probe
- Sample can be biased up to 200 V
- Sample is Plasma heated
  $T_S \sim 60°C$ to $1000°C$

Schmid Klaus, 2002

Experimental setup

Sample change

Decontamination

Be plasma concentrations

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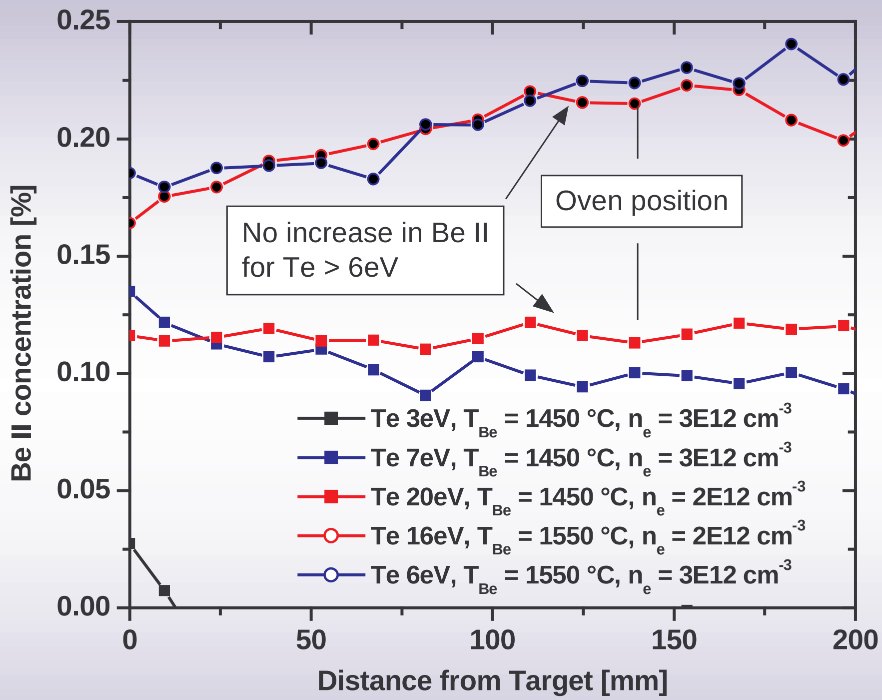
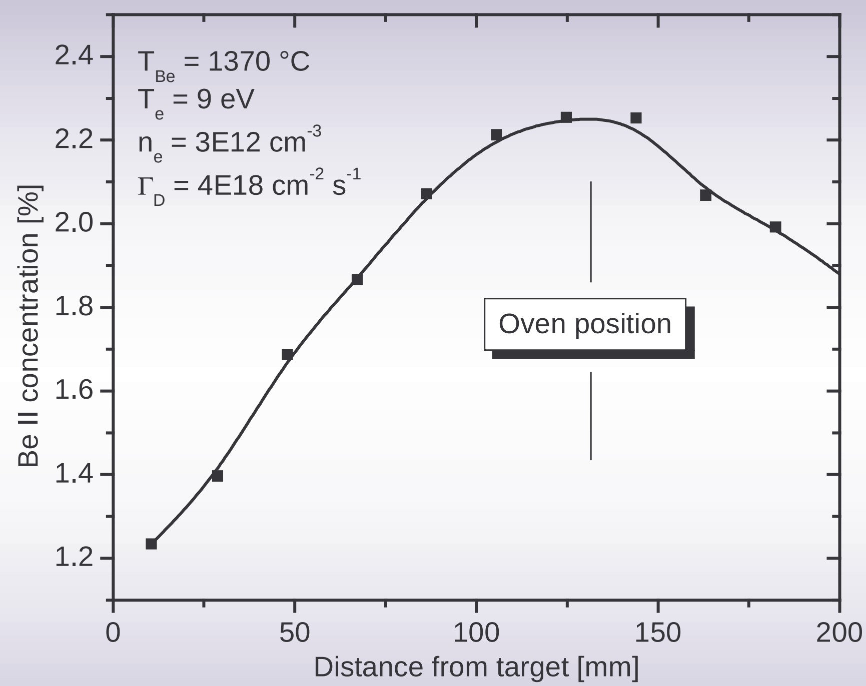
Spectroscopically measured axial Be II (Be 1+) concentrations scans

Oven II (clogged)



Oven II (repaired)



- For T_e >= 6 eV all Be is ionized, (as expected from ionization length of ~ 1 cm @ Te = 6eV)

- Be concentration up to several percent possible (green plasma incident)

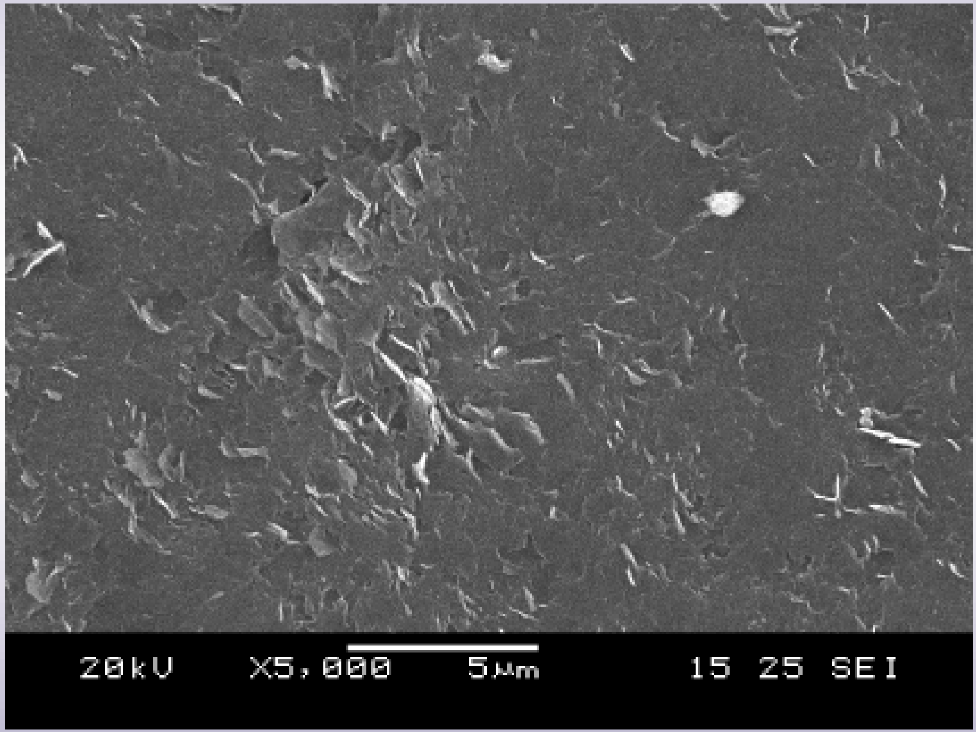
Schmid Klaus, 2002

Fluence dependence of chemical erosion

Initial conditions

SEM image before exposure

- Polished, pyrolythic graphite samples
- Only detectable (EDX) impurity O
- Samples are cut parallel to graphite planes
- Degassed at 1000°C for 20 min

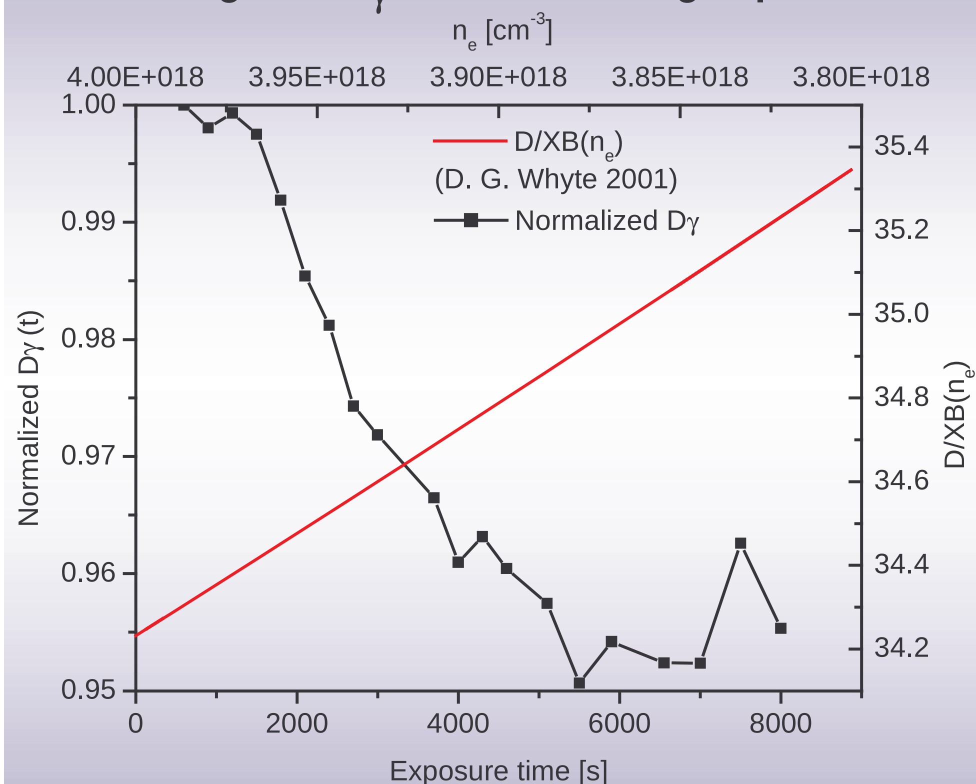


Fluence dependence of chemical erosion

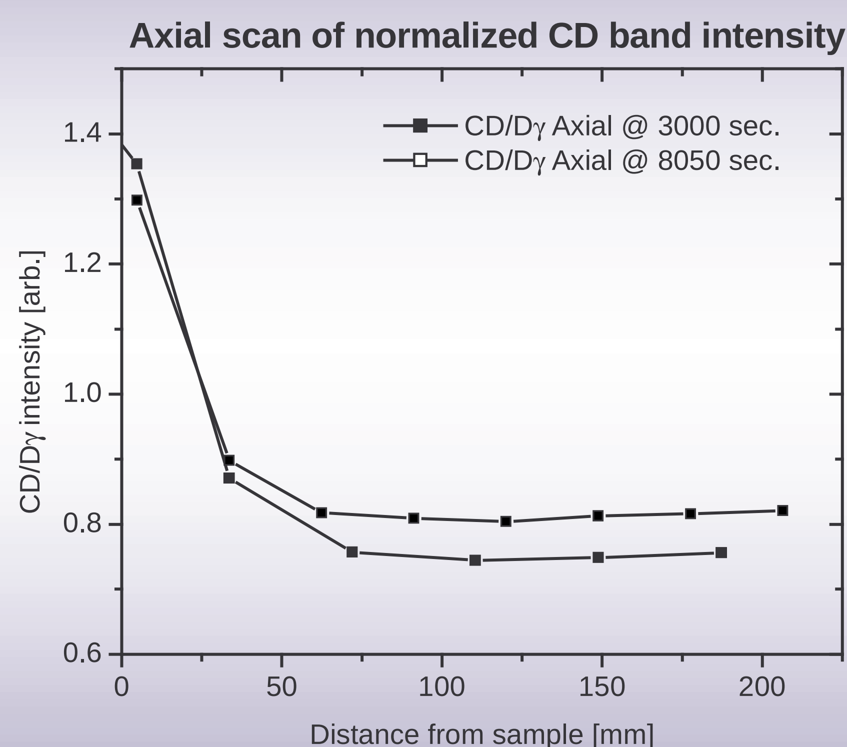
Plasma stability

Plasma is constant through out exposure within error bars of the Langmuir probe

Changes in D_γ and D/XB during exposure



Changes in CD background



- Changes in n_e result in a ~ 3% change in D/XB

- CD-Band background increases (~8 %) due to heating/erosion of a-CH from vessel walls

Schmid Klaus, 2002

Fluence dependence of chemical erosion

Experiment I

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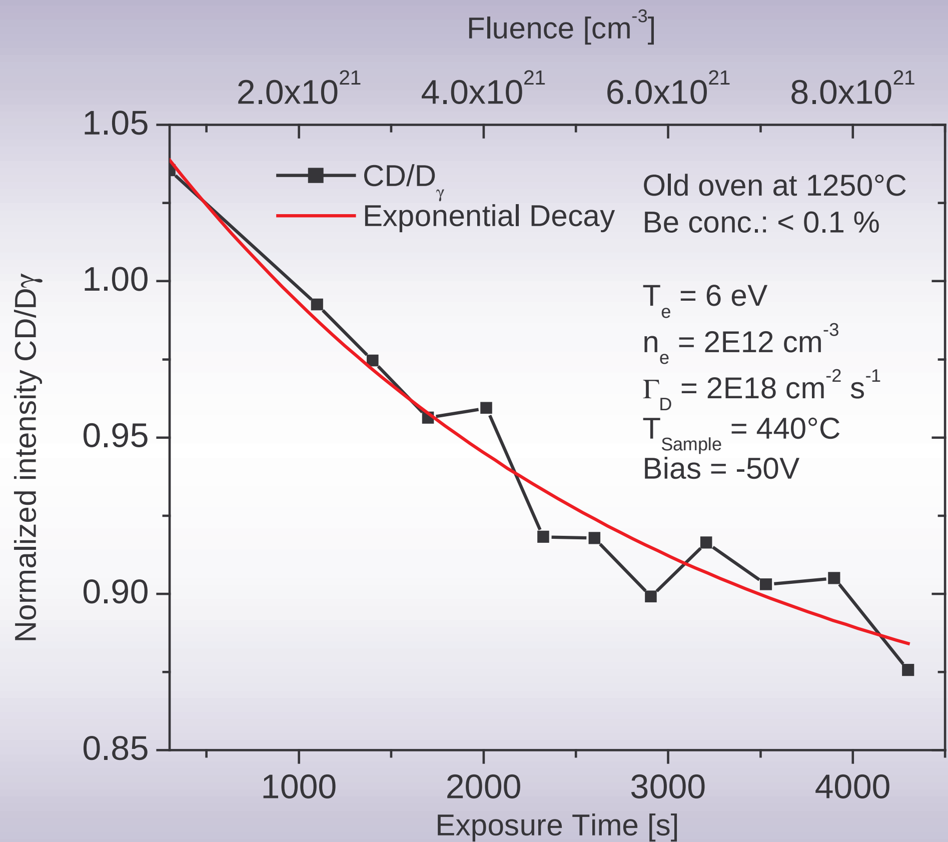
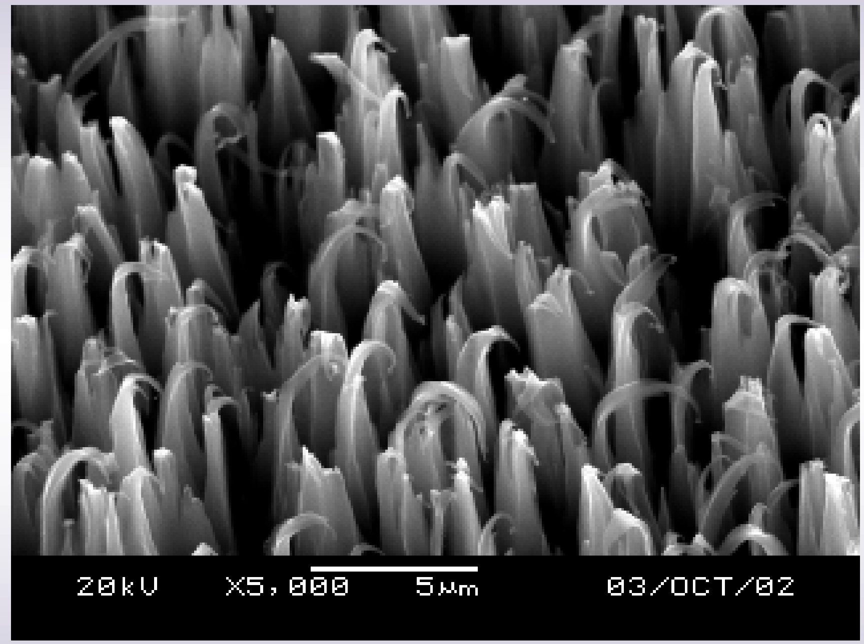
Normalized intensity CD/D_γ vs. exposure time



SEM image of sample after exposure



- CD-Band intensity drops ~ 20 % and continues to drop
- Formation of „grass" like structures
- Exp. fit indicates e-folding time of ~ 3000 s
- EDX/XPS/AES Show **no Mo, Be, B** on surface

Fluence dependence of chemical erosion

Experiment II

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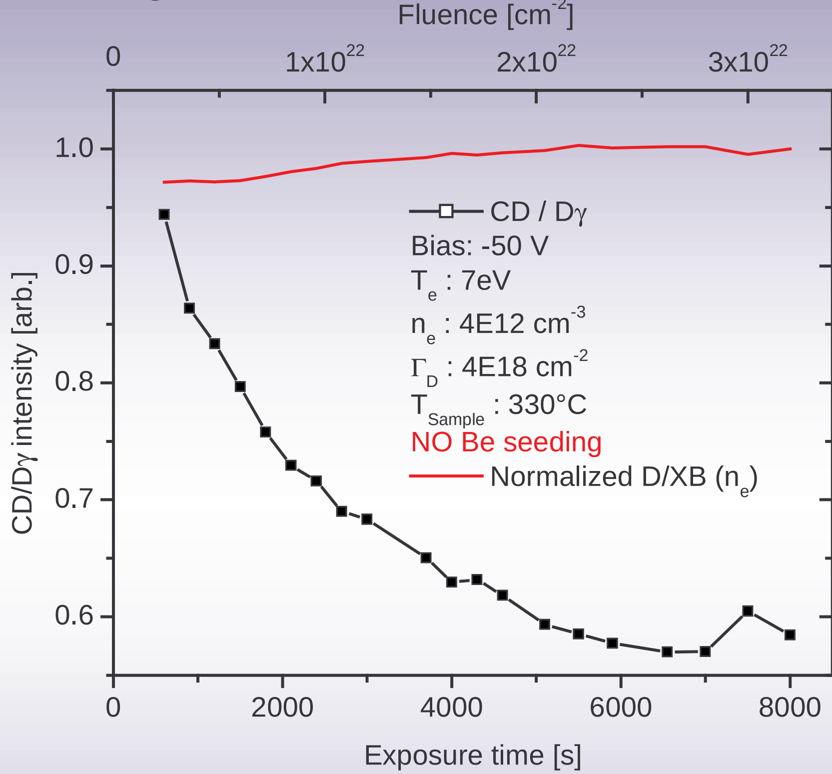
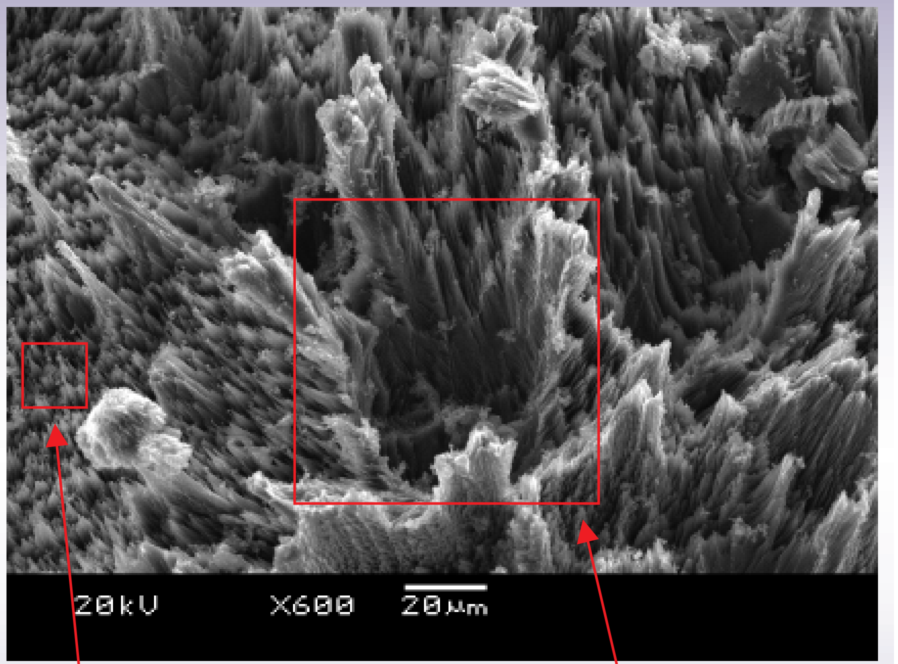
Background subtracted, normalized CD band signal



- CD band drops by 40 %
- Can not be explained by D\XB(n_e)
- Drop levels off at about 2.5 10^{22} cm^{-2}
- Weight change indicated net erosion

SEM image after exposure

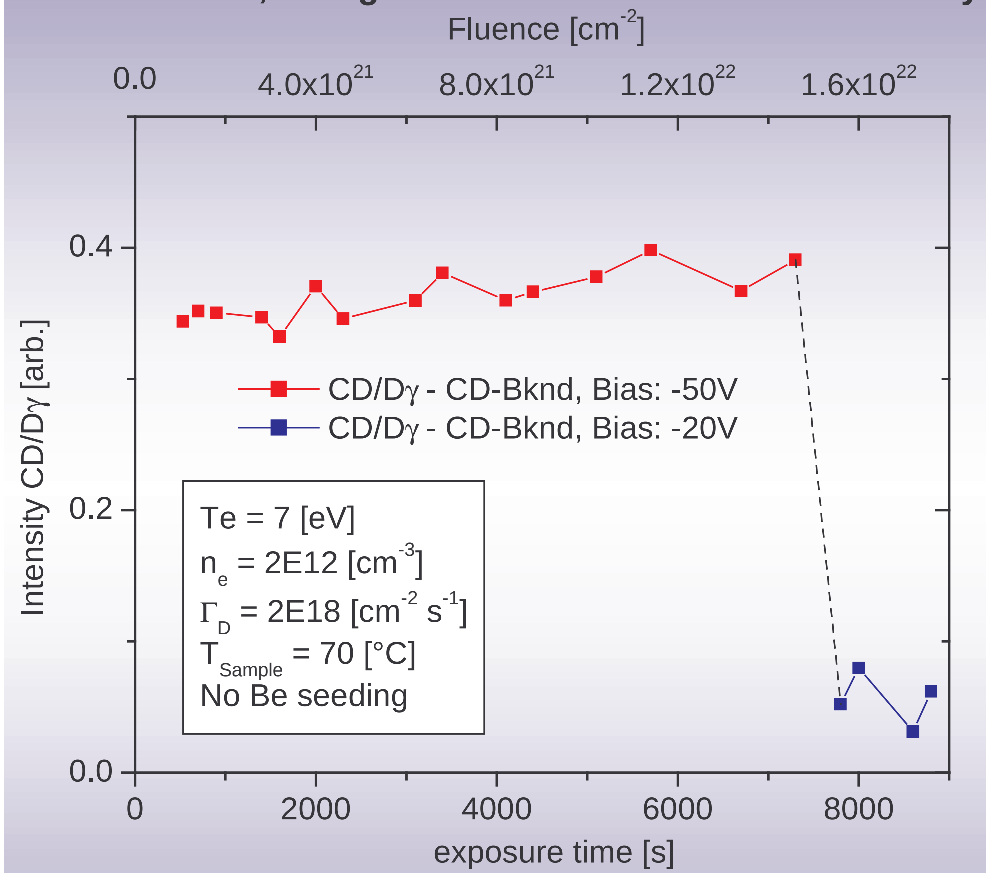


- Again „Grass“ formation
- Large crater like objects appear
- Traces of Mo (~ 1%) found on sample
- Sample surface is recessed

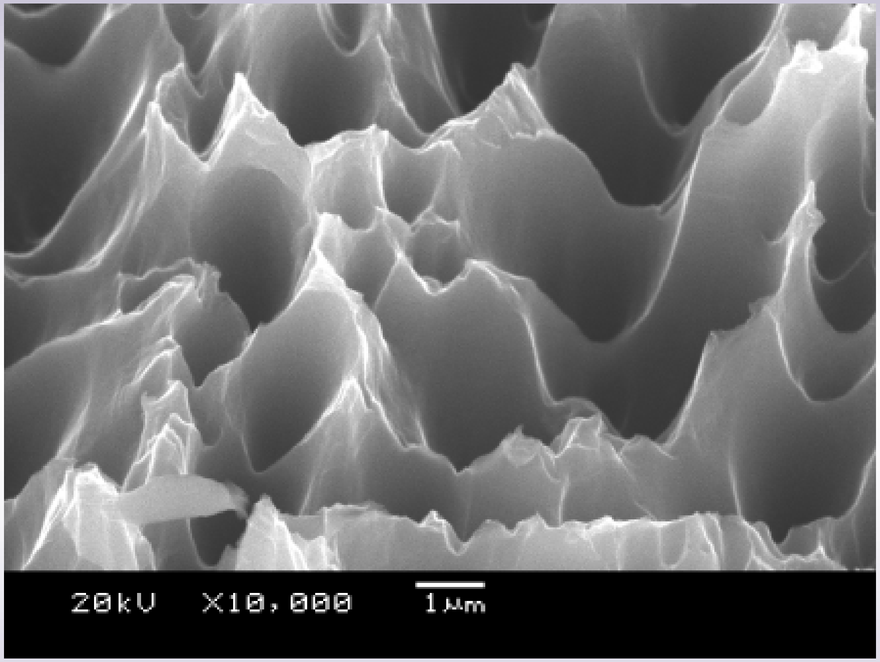
Fluence dependence of chemical erosion

Experiment III

Normalized, background subtracted CD Band intensity



SEM image after exposure



• **No change** (measurable) in CD-band at low temperatures

• „Grass“ starts to evolve but does not reach the height as for high temperatures

Fluence dependence of chemical erosion

"Model"

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Surface non uniformities + Impurities lead to initial surface roughing

↓

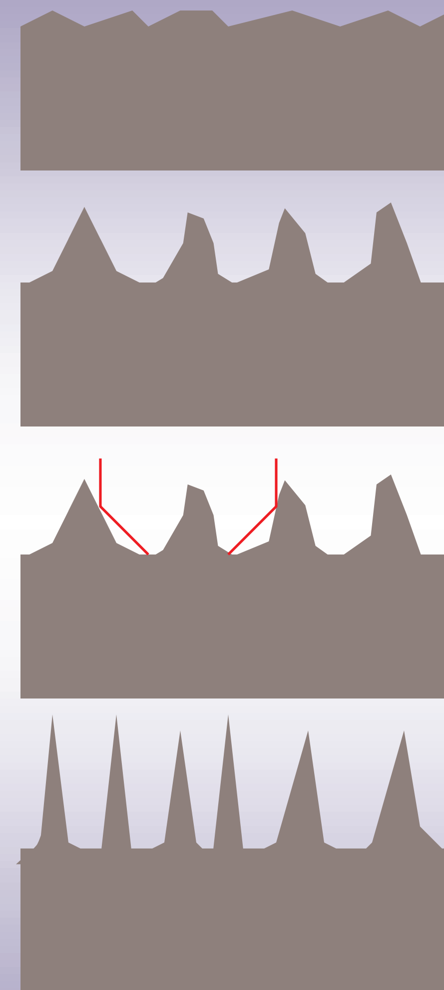
Angular dependence of physical sputtering steepens slopes

↓

Reflection of particles increases flux/erosion in between structures

↓

Ongoing erosion between structures leads to formation of deep canyons



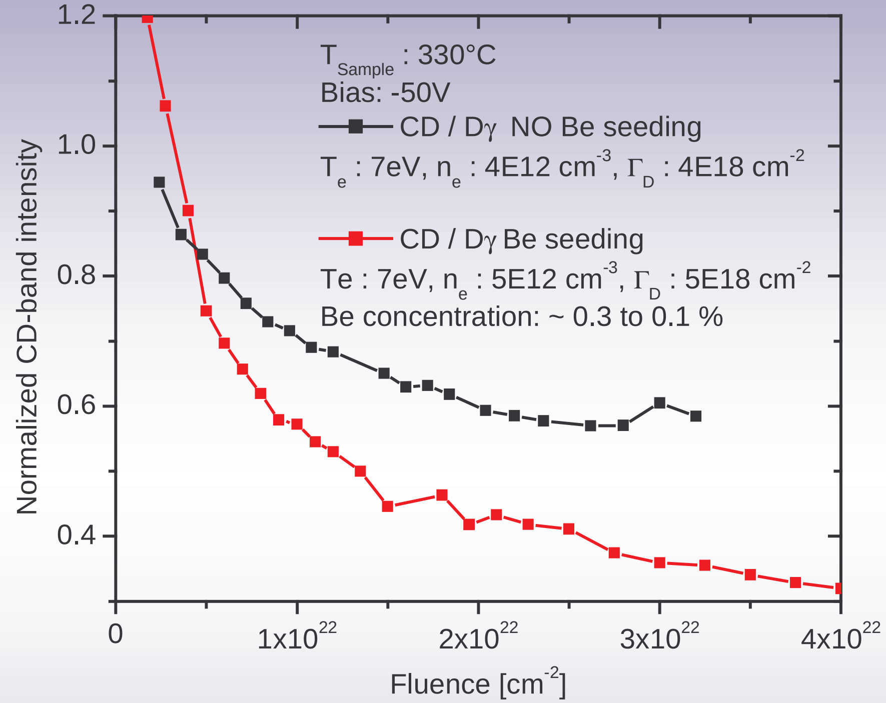
Eroded species can only partially escape from canyons (redeposition) → Reduction in net erosion

Schmid Klaus, 2002

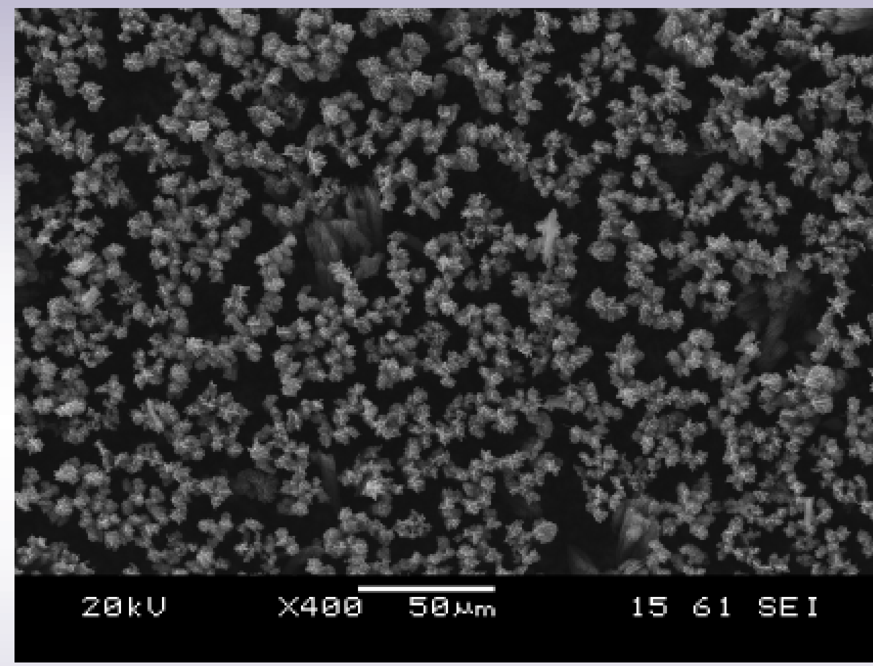
Influence of Be seeding on chemical erosion

Fluence dependence & Be seeding

Normalized, background subtracted CD intensity



SEM image after exposure (330° C sample temp., Be seeding)



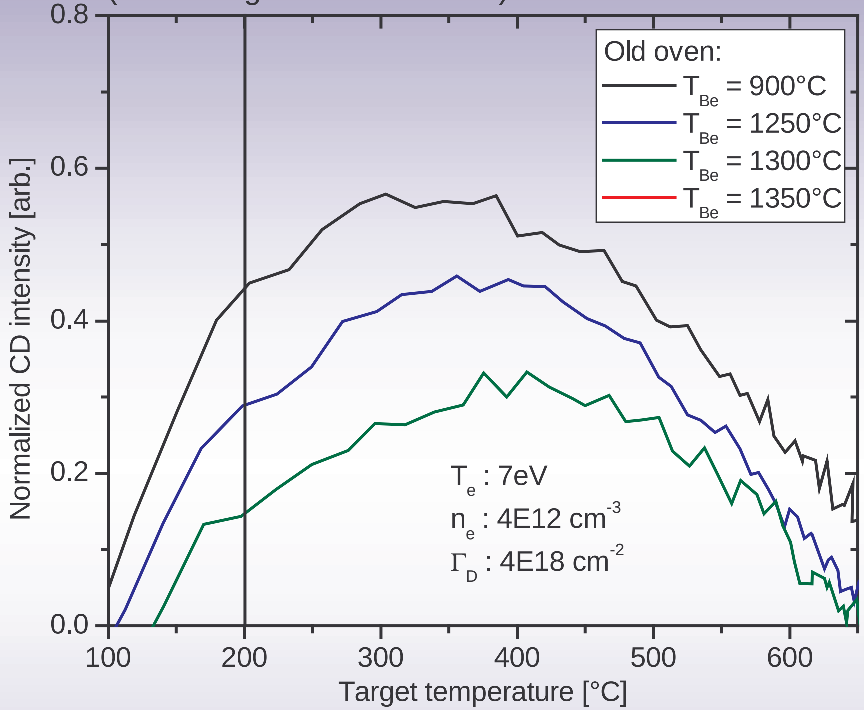
- 40% drop without Be in CD band
- 60% drop with Be in CD band
- Final Be surface concentration: 15 % (AES)
- Surface is covered with „tree trunks“
- Top of trunks contain Mo & Be

Schmid Klaus, 2002

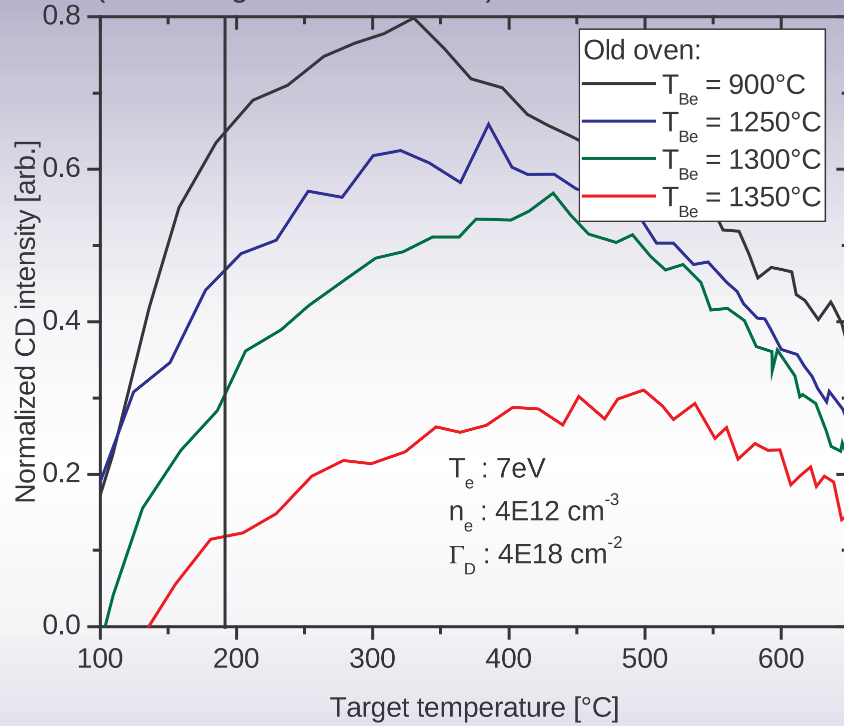
Influence of Be seeding on chemical erosion

Temperature ramps

Temperature Ramp, Bias -35V
(CD-Background subtracted)



Temperature Ramp, Bias -50V
(CD-Background subtracted)



- **Clear dependence of CD-band intensity on Be oven temperature / Be plasma concentration**
- **Increased Be sputtering at 50 V bias reduces Be sample concentration**

→ **yields less reduction in chemical erosion**

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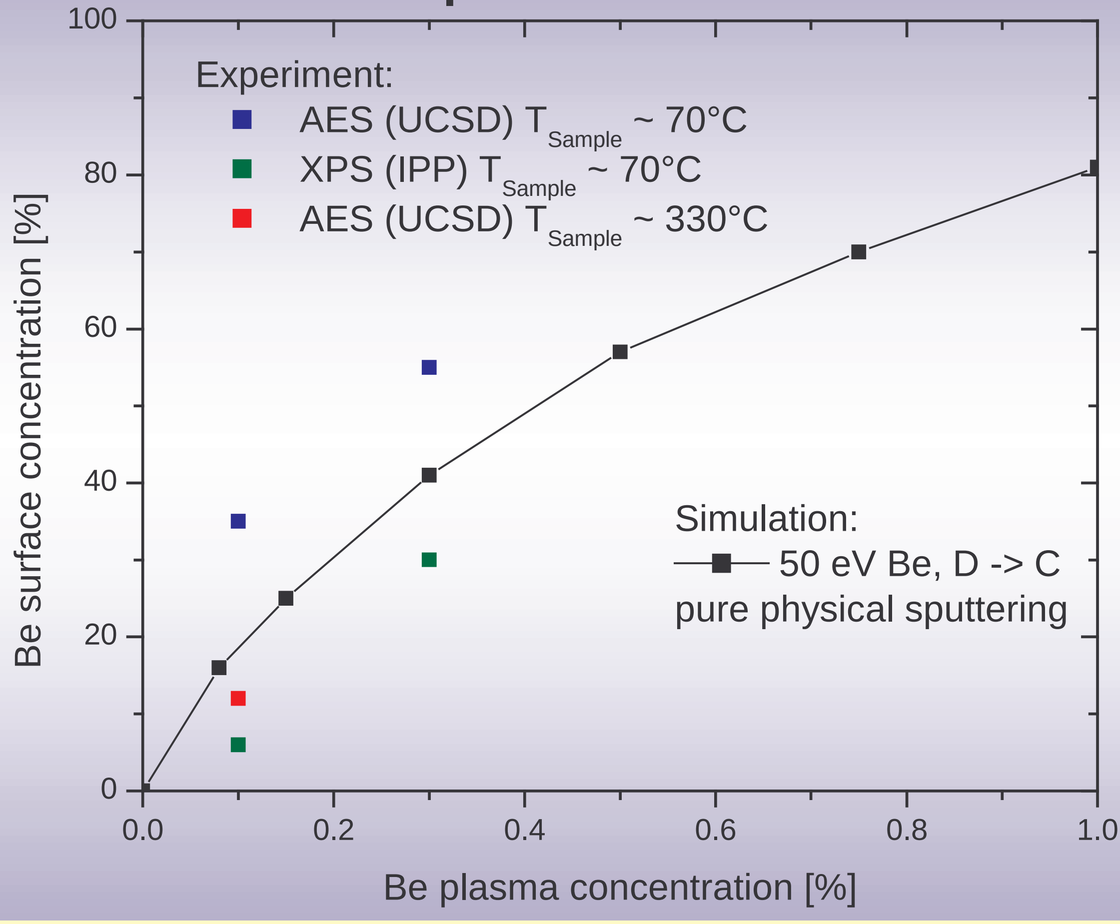
Influence of Be seeding on chemical erosion

Be surfaces vs. Plasma concentration

Simulated Be surface concentration in equilibrium vs. Be plasma concentration



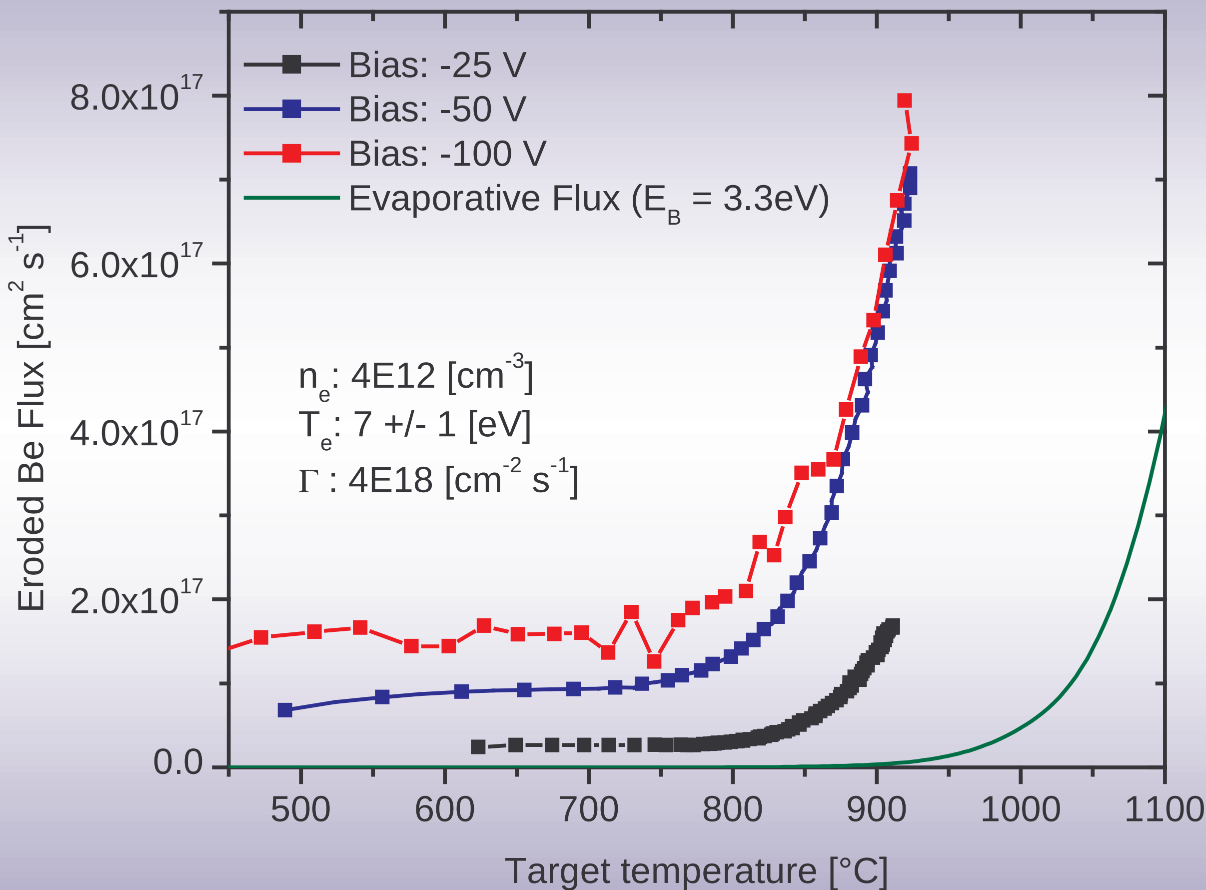
- **Despite the observed morphology changes, simulation still gives correct order of magnitude**

- **Plasma concentrations ~ 2% should result in a fully Be covered surface**

Temperature dependence of Be sputtering

Experimental observations

Increase in Be flux / erosion yield



- Strong increase of Be erosion yield above 800 °C
- Can not be explained by normal evaporation

Temperature dependence of Be sputtering

Possible explanations

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• Thermal spike due to near surface energy deposition ?

✖ Would be independent of surface temperature

• Be diffuses thru BeO surface layer à Be with lower surface binding energy and enhanced sputtering ?

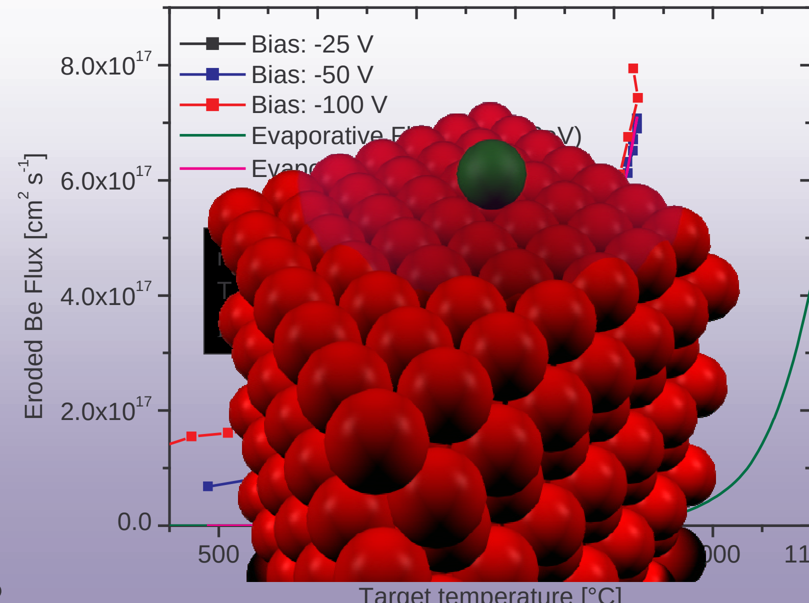
✖ Decrease in surface binding energy cannot explain increase by factor of three or more

• Evaporation of weakly bonded surface atoms created by the bombardment ?

ü Binding energy of Be surface atoms 1 to 2 eV

ü Fit to Be flux vs. Temperature yields an activation energy of 1.7 eV

✖ Lifetime of created surface atoms



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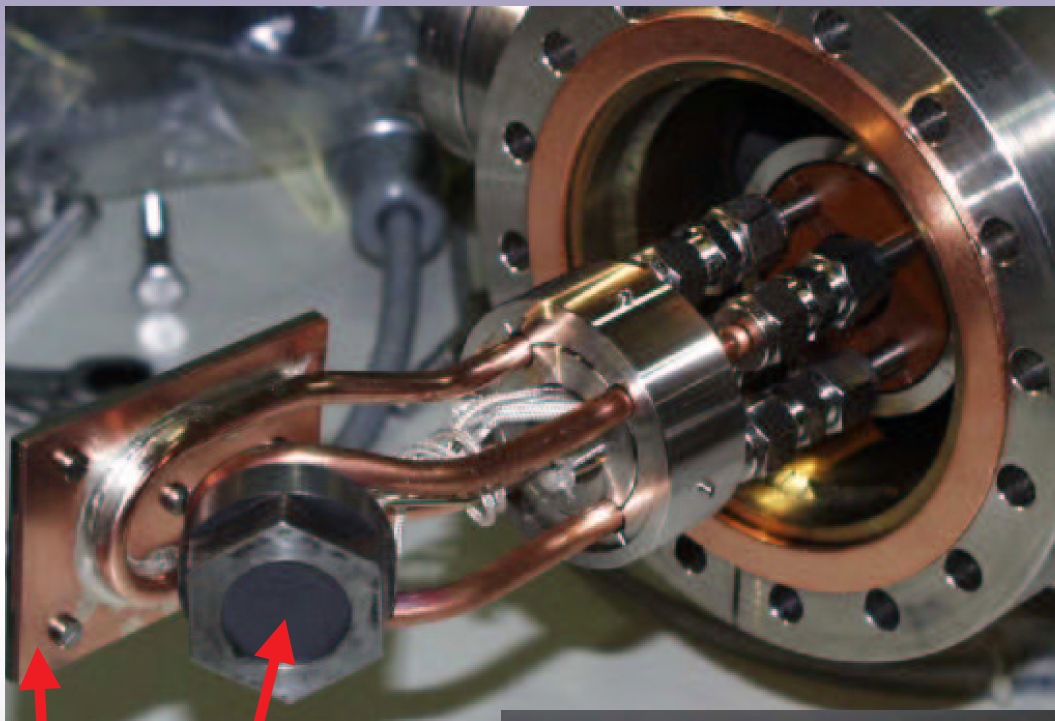
Catcher probe manipulator



- Manipulator has been manufactured at IPP and delivered to UCSD
- Will be installed and tested in January

Sample

Beam dump

Sample lock

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Summary

• CD band intensity / chemical erosion drops with fluence, probably due to changes in the surface morphology

• Be plasma seeding reduces CD band intensity / chemical erosion

? Chemical effect
? Surface coverage / shielding
? Surface morphology

} Yet to be determined

• Be surface concentration quickly increases with Be plasma concentration

• Be erosion exhibits a strong temperature dependence above 800 °C

$\rightarrow$ Most probably due to evaporation of weakly bonded surface atoms created by bombardment

Outlook

Carbon/Beryllium:

- Repeat experiment with different type of carbon (POKO)
- Measure quantitatively the reduction of chemical erosion as function of Be plasma concentration
- Measure a possible reduction of physical sputtering
- Measure H retention as function of Be plasma concentration
- Influence of heavy impurities (Xe, Ne) on reduction of chemical erosion
- Investigate morphology changes during high fluence He bombardment
- Codeposition experiments with catcher probe

Experimental:

- Setup new spectroscopy system: Camera + ADC
- Install catcher probe

Simulation:

- Perform MD calculation of Be sputtering by D to explain temperature dependence