NIBS 2018

The 6th International symposium on Negative Ions, Beams and Sources (NIBS'18)

3-7 September 2018
Budker INP

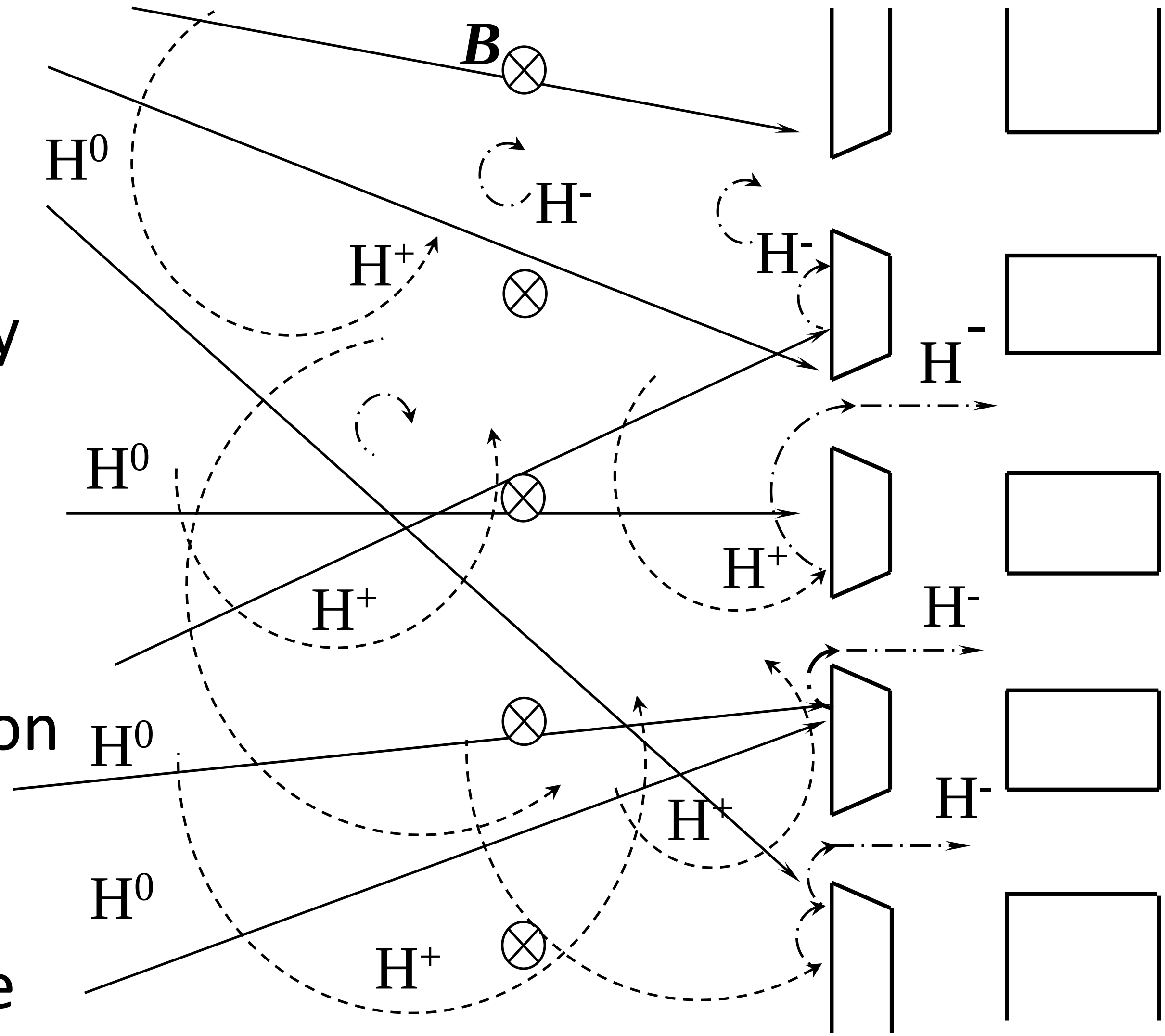
Effects of impurity ions upon Cs recycling in a negative hydrogen ion source

Motoi Wada

Doshisha University, Kyoto, Japan

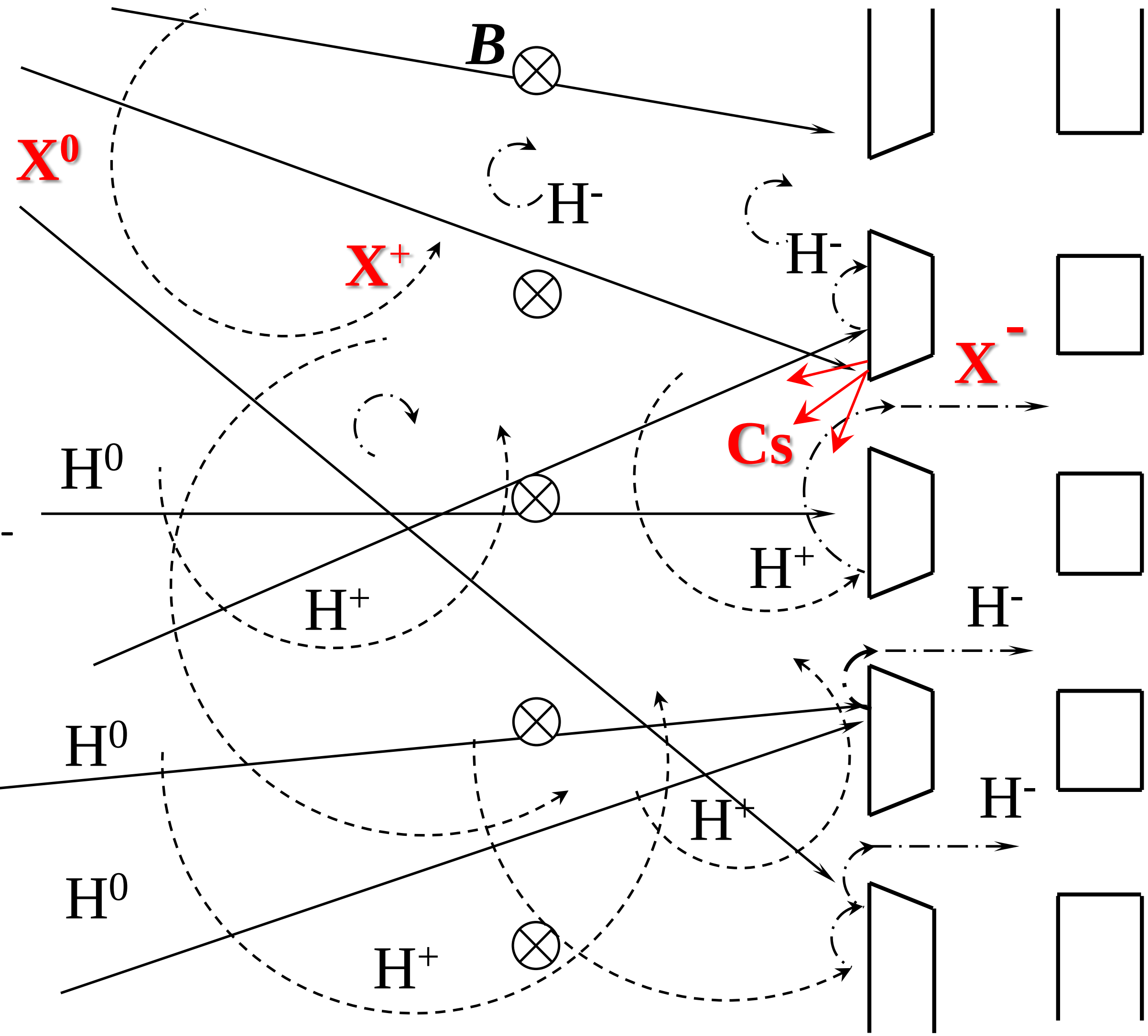
Extraction region of a H^- source

- Surface collision
    - Reflection
    - Desorption
    - Implantation
- Plasma-wall energy exchange
    - Thermalization
    - Collisions
    - Adsorption
    - Electron injection
- Sheath formation
    - Magnetic field
    - Potential profile



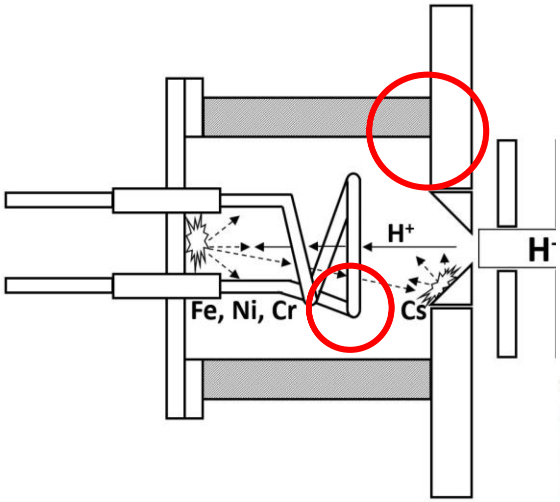
Impurities in a H^- source

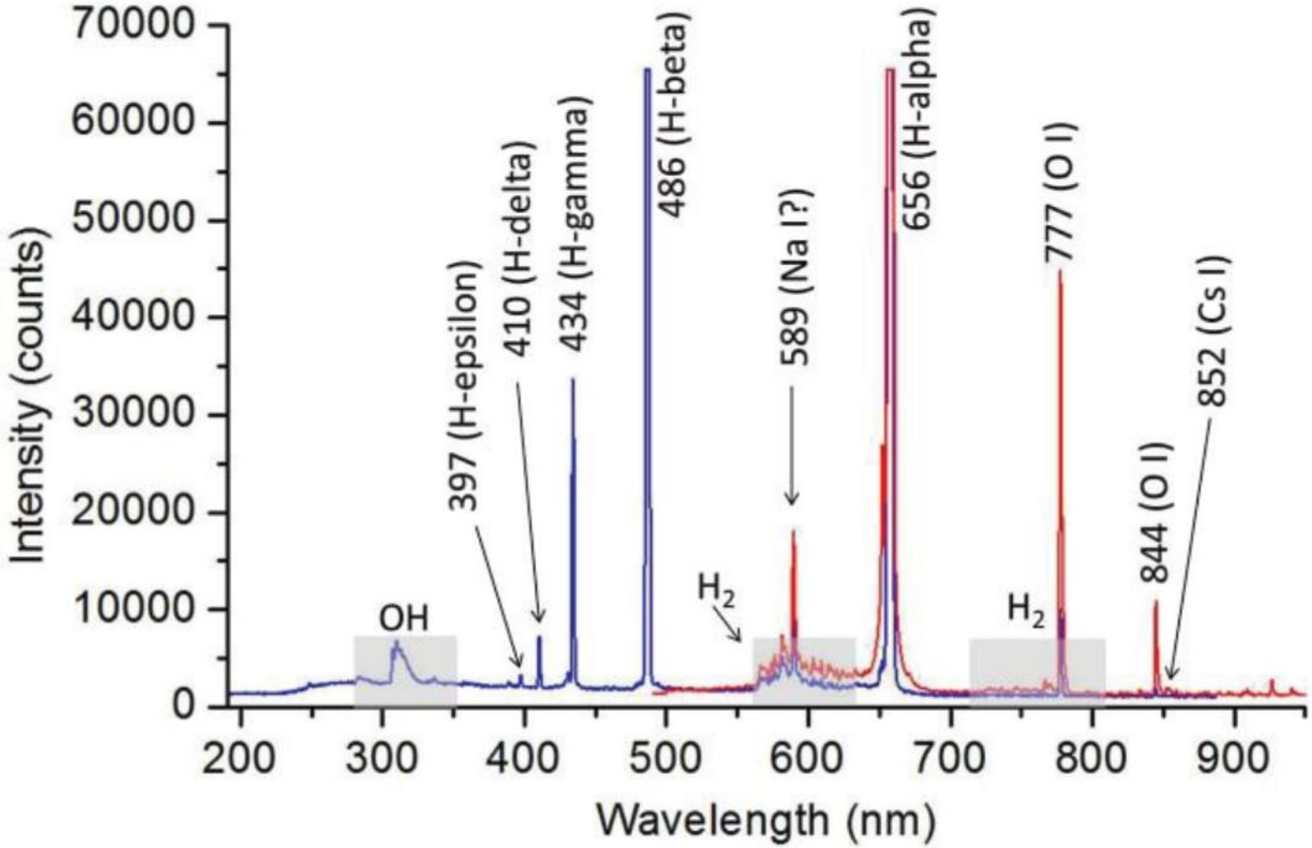
- Surface collision
  - Sputtering PG
  - Desorption of Cs
  - Implantation
- Plasma-wall energy exchange
  - Thermalization
  - Collisions with H^-
  - Adsorption
  - Electron injection
- Sheath formation
  - Magnetic field
  - Potential profile



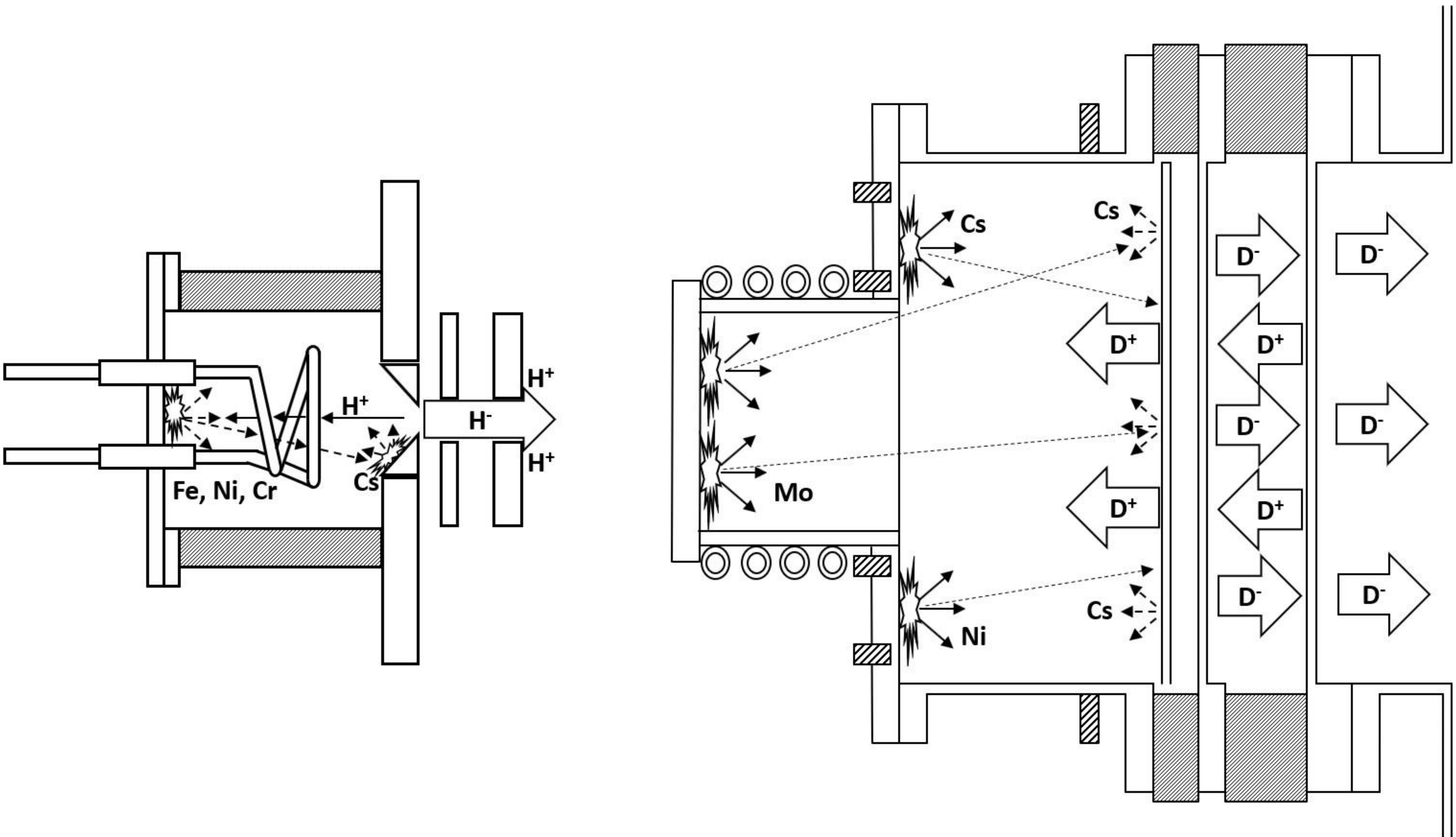
Source of impurities

B.X. Han, R.F. Welton, S.N. Murray Jr., T.R. Pennisi, M. Santana, and M.P. Stockli, "OPTICAL EMISSION SPECTROSCOPY STUDIES OF THE SPALLATION NEUTRON SOURCE (SNS) H^- ION SOURCE", Proceedings of IPAC2012, TUPPD048, New Orleans, Louisiana, USA (2012).

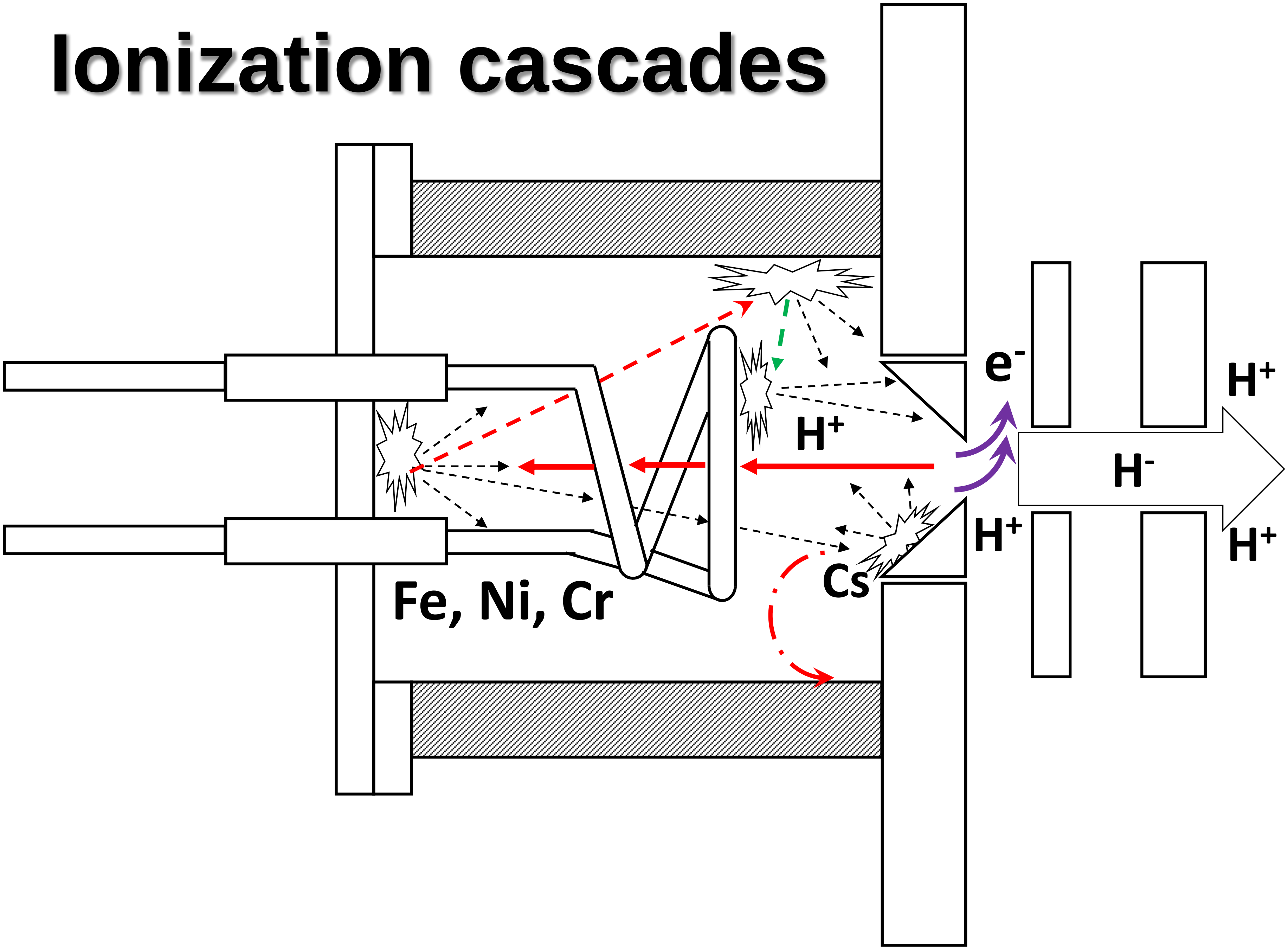




Two configurations

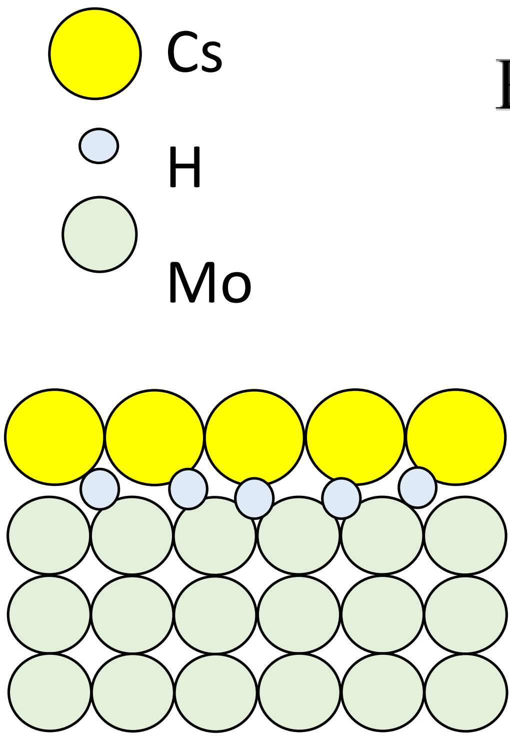


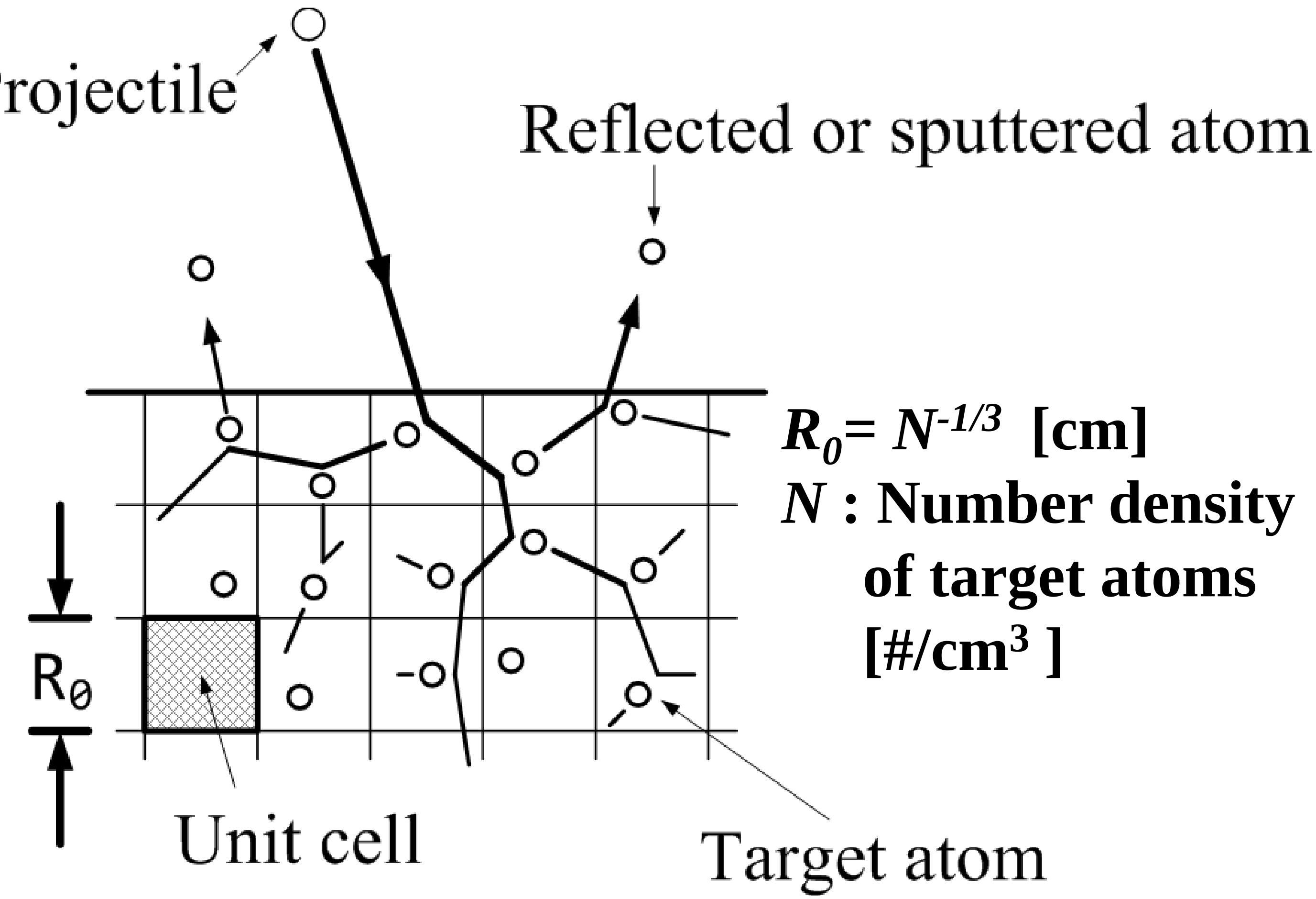
Ionization cascades



Treatment of the adsorbed layer

- **Both adsorption and retention form interlayers.**
- **ACAT configures nucleus location by layers.**
- **Empty site/vacancy are generated by random number.**

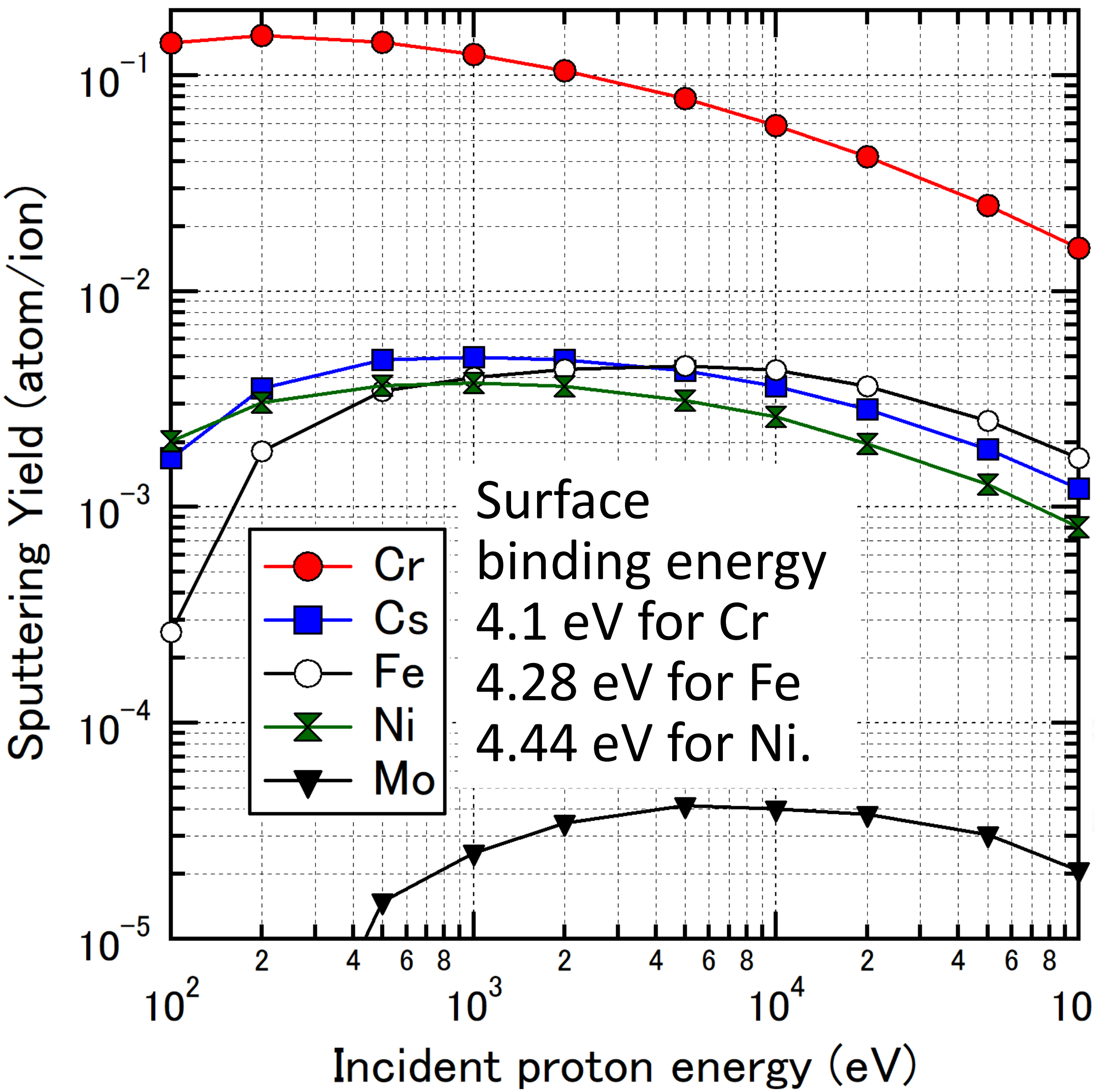


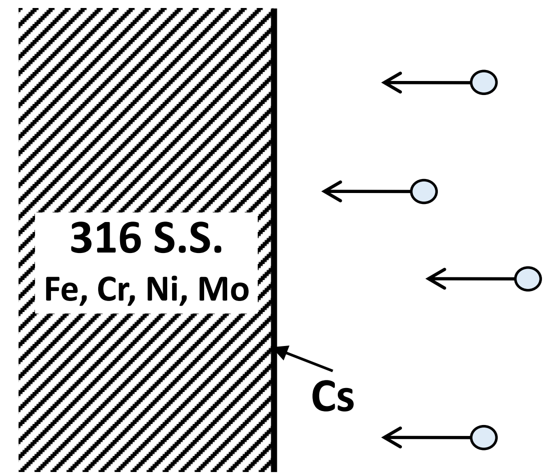


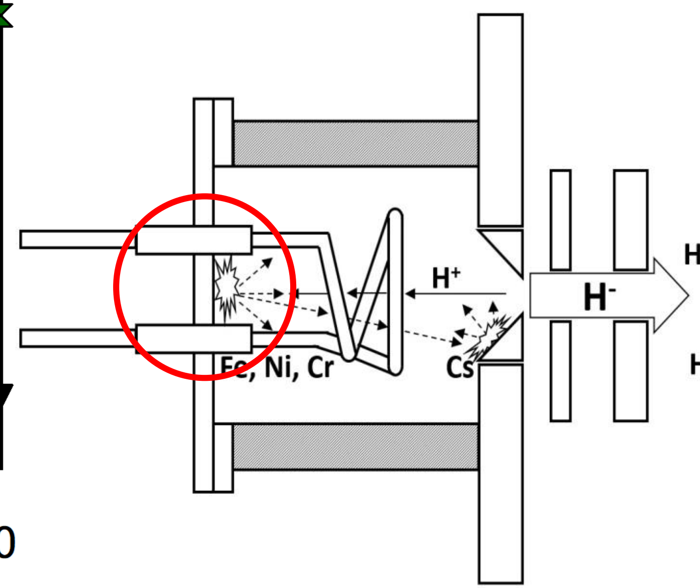
$R_0 = N^{-1/3}$ **[cm]**

N **: Number density of target atoms [#/cm^3]**

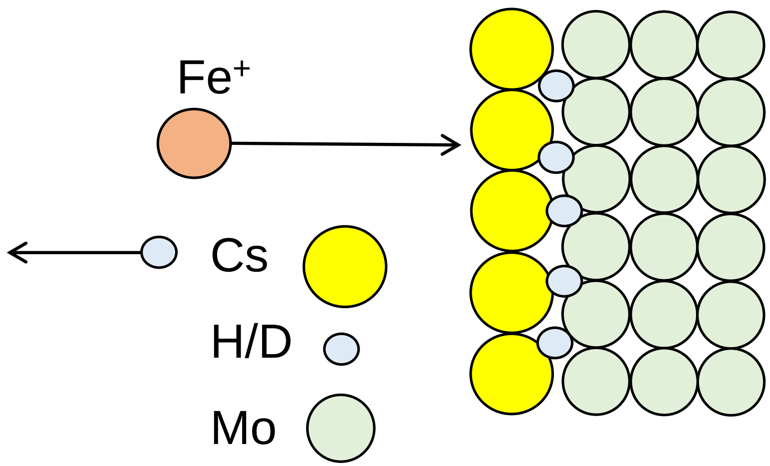
72% Fe, 10% Ni, 16% Cr and 2% Mo



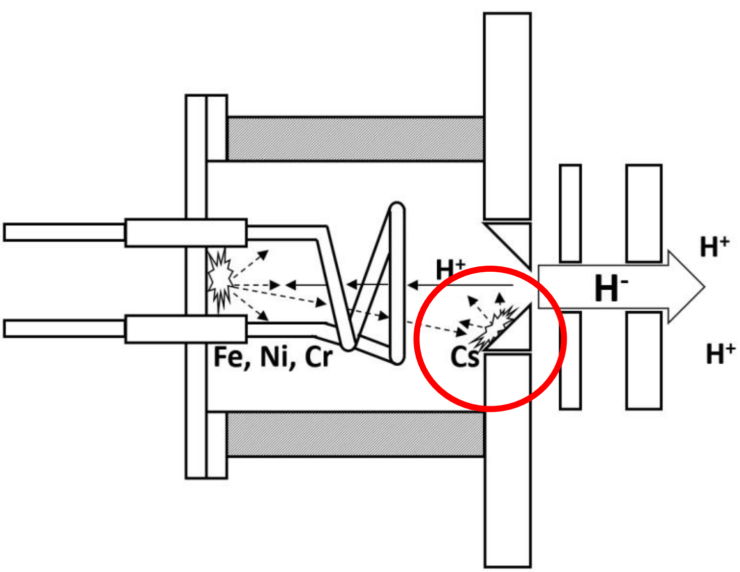




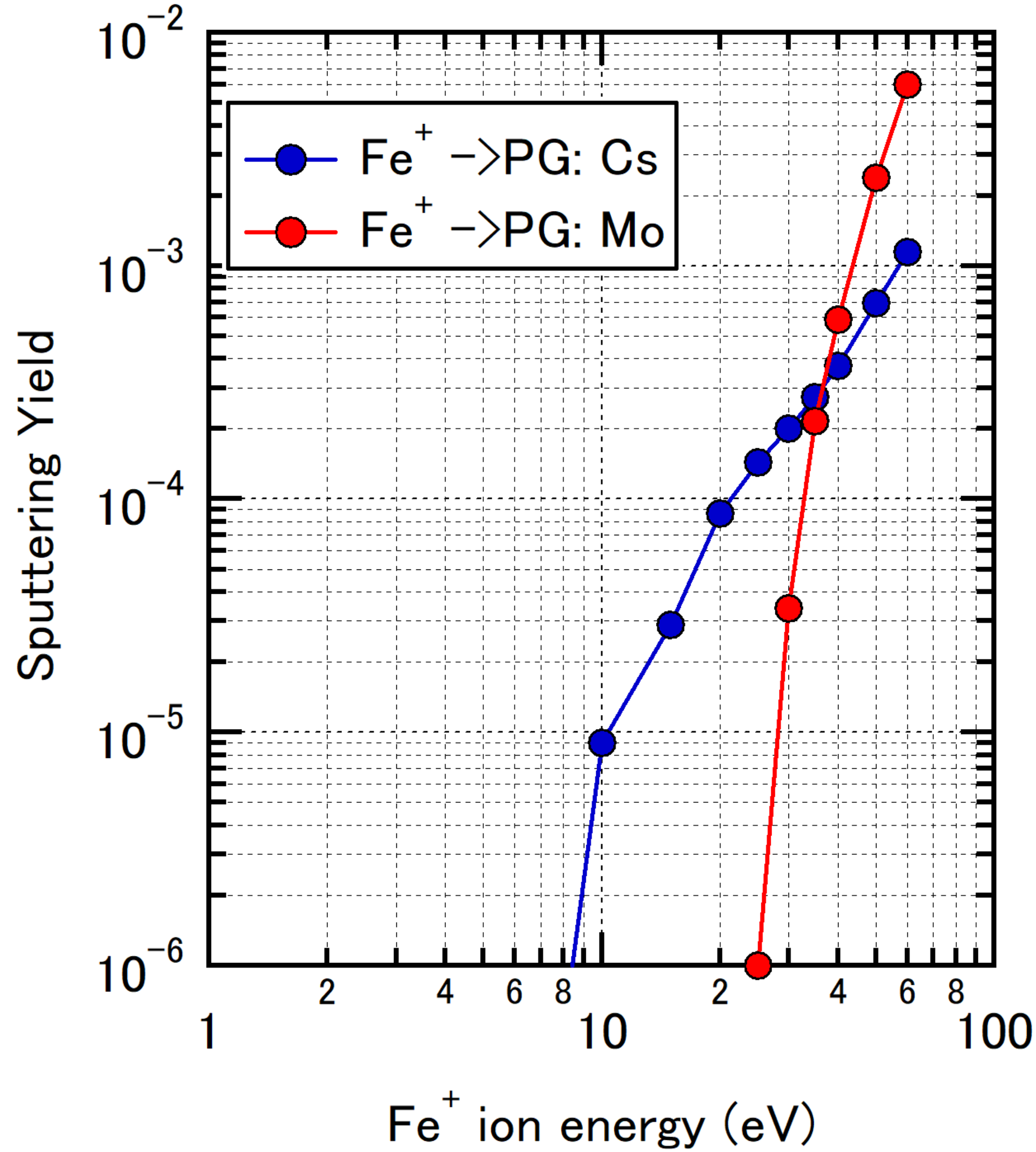
Cs removal



Fe+
Cs
H/D
Mo

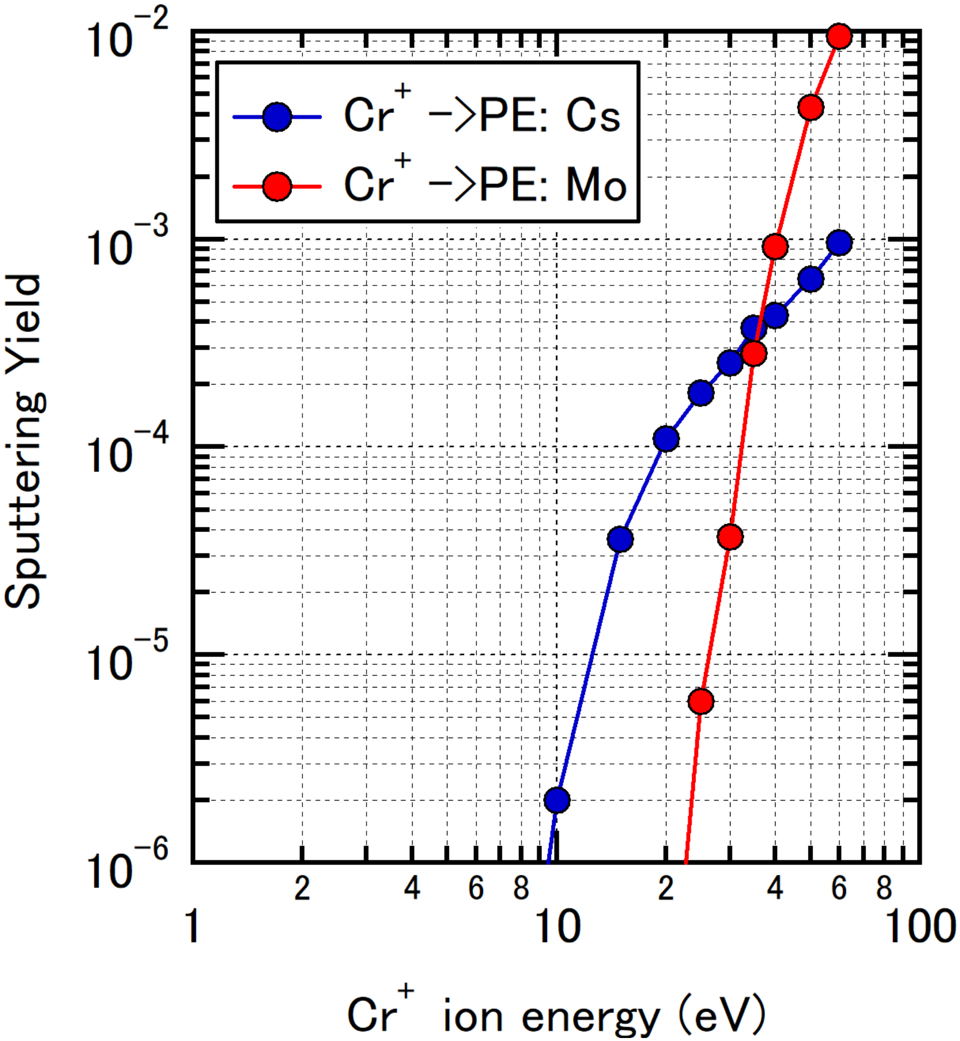


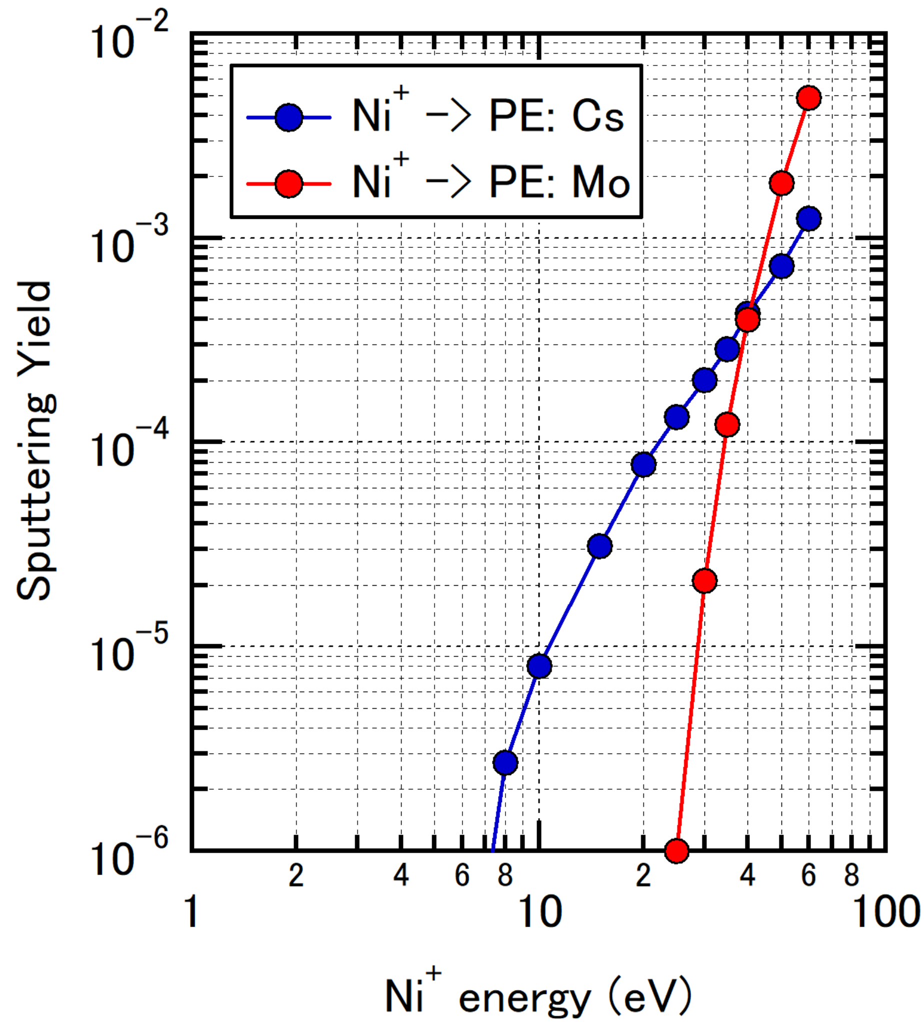
H+
H-
H+
H+
Fe, Ni, Cr
Cs



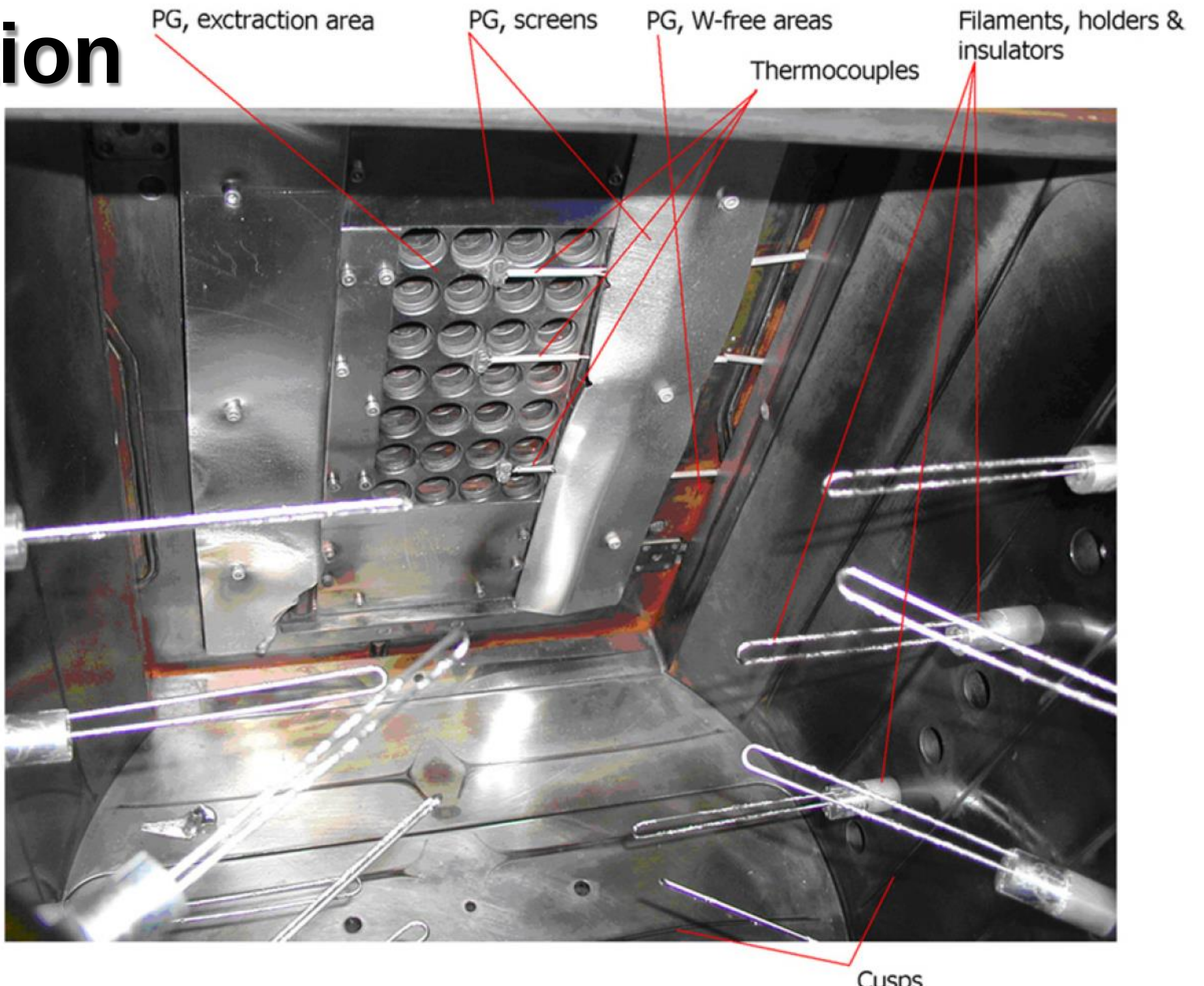
Fe+ ->PG: Cs
Fe+ ->PG: Mo
Sputtering Yield
Fe+ ion energy (eV)
10−2
10−3
10−4
10−5
10−6
1
2
4
6
8
10
2
4
6
8
100

Small difference





Motivation



A. Krylov, D. Boilson, U. Fantz, R.S. Hemsworth,O. Provitina, S. Pontremoli and B. Zaniol, "Caesium and tungsten behaviour in the filamented arc driven Kamaboko-III negative ion source", Nucl. Fusion 46, S324(2006).

Cu found in the source

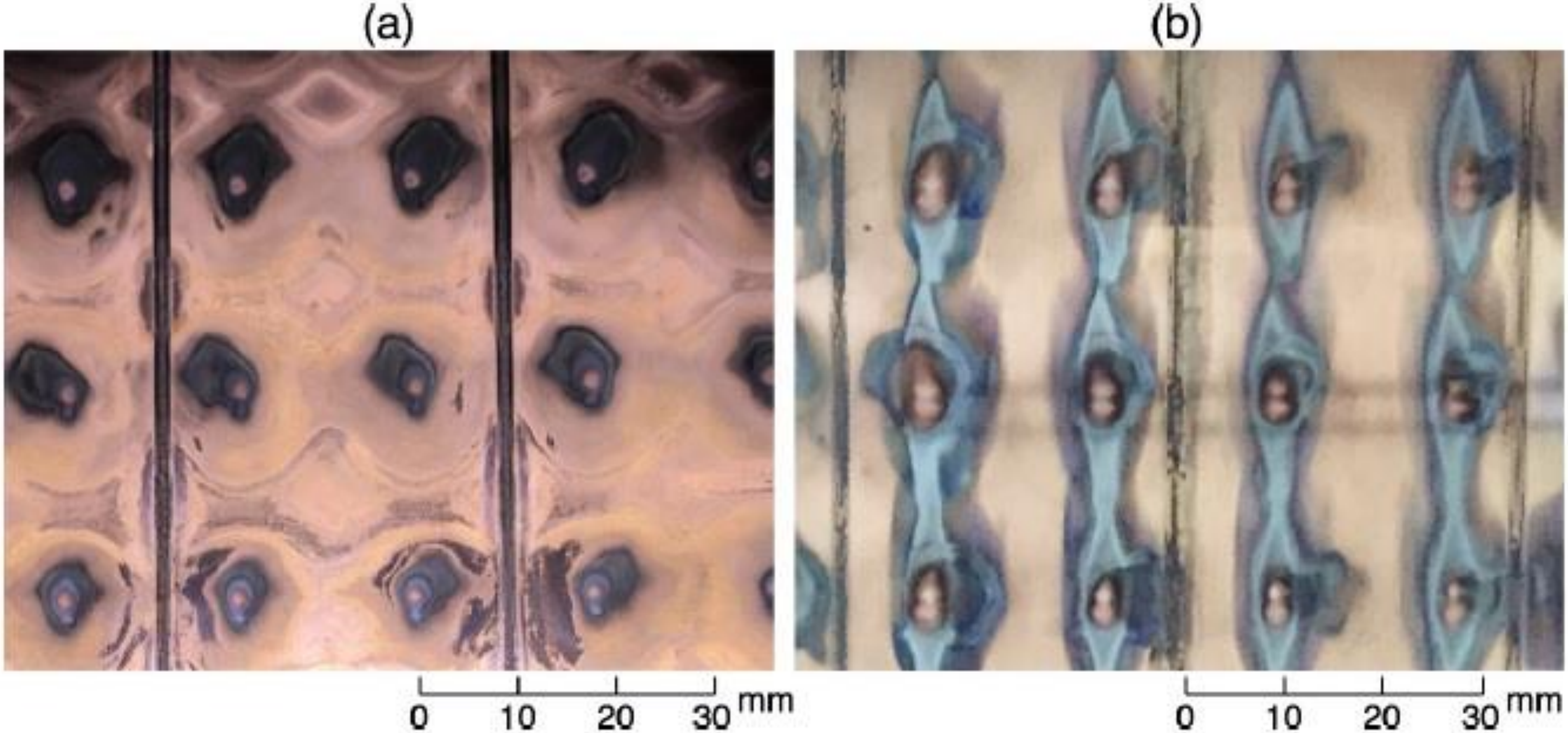
Table 1. Surface coverage in the Kamaboko III ion source.

	Cs	W	Cu	Ca	Mo	Fe
Mass (mg) in the area indicated. First row is from the solution, the second from the sediment						
PG extraction area	150	58.5	1.2	6.3	2.7	—
	2.84	76.9	12	3.06	0.189	0.473
PG periphery (frame)[b]	2400	310	3	21	8	—
	7.58	15.6	32.5	1.86	0.031	0.162
Arc chamber walls	6000	1250	8	7	30	—
	13.8	46.6	18.2	2.82	0.123	0.159
Total (g)	8.6	1.8	0.07	0.04	0.04	0.001
Surface density in the area indicated (atom/cm^2)						
PG extraction	2.5E + 18	1.6E + 18	4.5E + 17	5.1E + 17	6.6E + 16	1.8E + 16
PG periphery	1.3E + 19	1.3E + 18	4.0E + 17	4.1E + 17	5.9E + 16	2.1E + 15
Arc chamber	4.9E + 18	7.5E + 17	4.4E + 16	2.6E + 16	3.3E + 16	3.0E + 14

[a] Traces of Cr, Na, Mg and Si were also found.

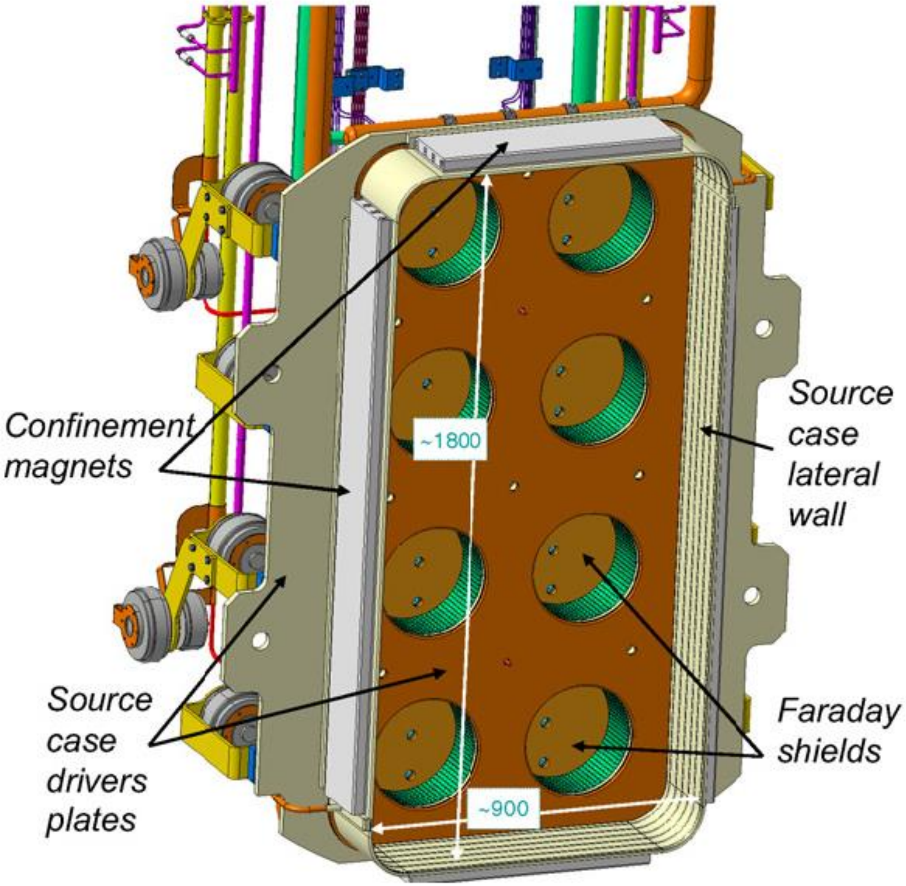
[b] For this campaign there were no side masks on the PG. (The side masks are shown in figure 1).

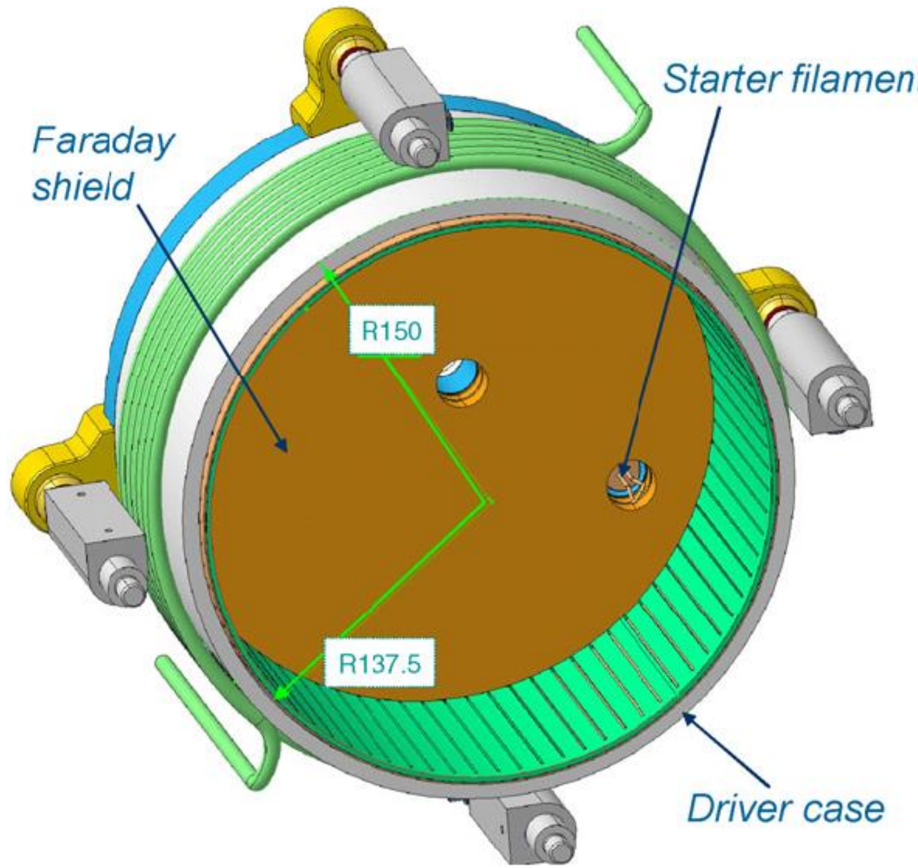
Back streaming ion foot print: NIFS source



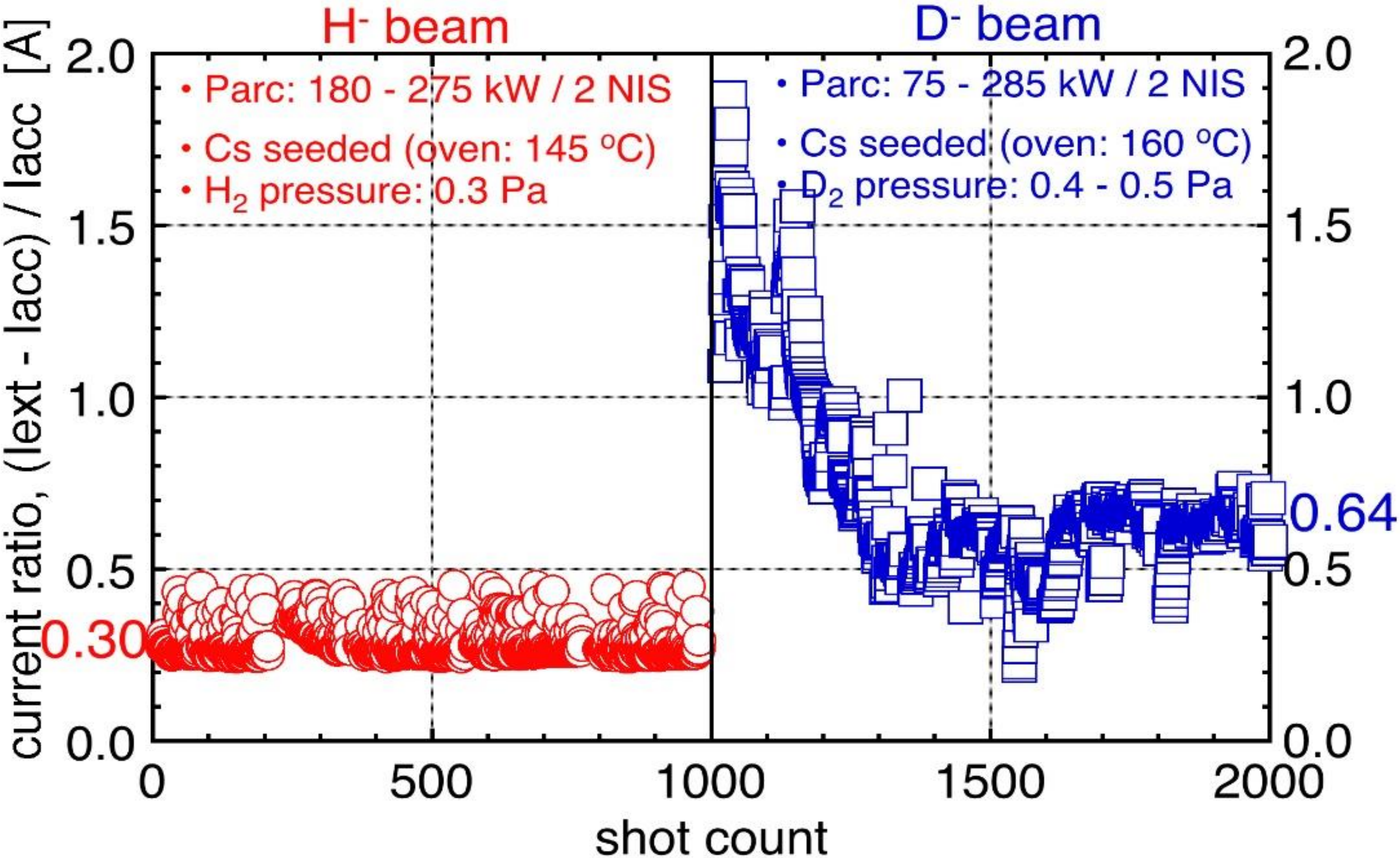
K. Ikeda, M. Kisaki, H. Nakano, K. Nagaoka, M. Osakabe, S. Kamio, K. Tsumori, S. Geng, Y. Takeiri, AIP Conference Proceedings 1869, 050004 (2017).

Mo/Ni coatings to reduce sputtering yields

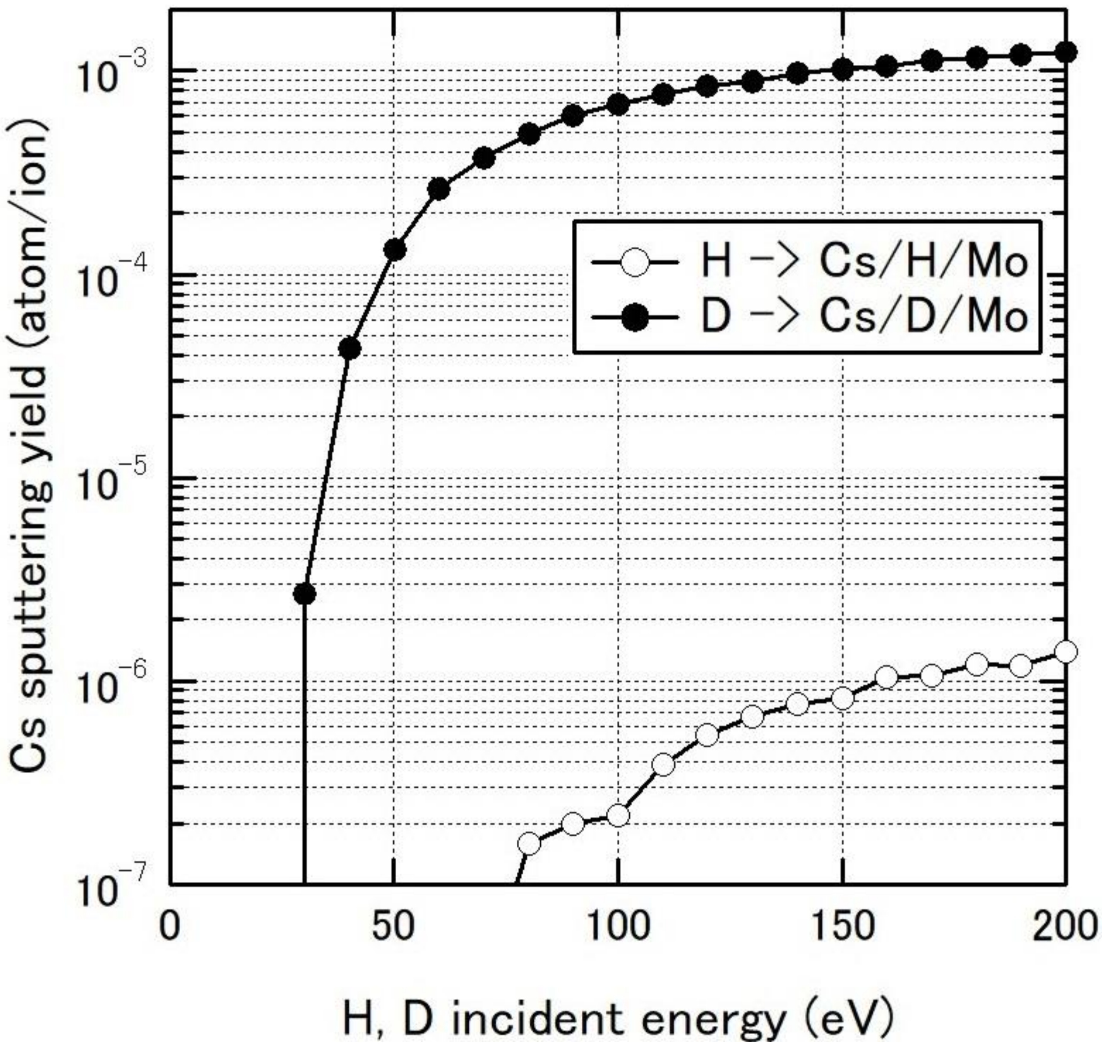


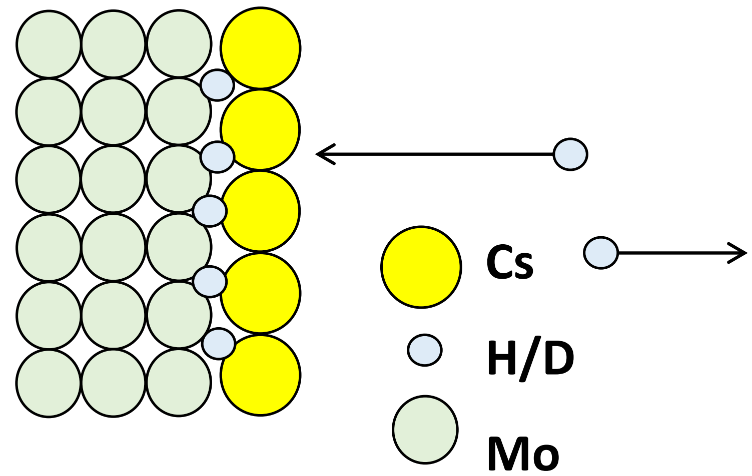


Observation of higher Cs consumption rate



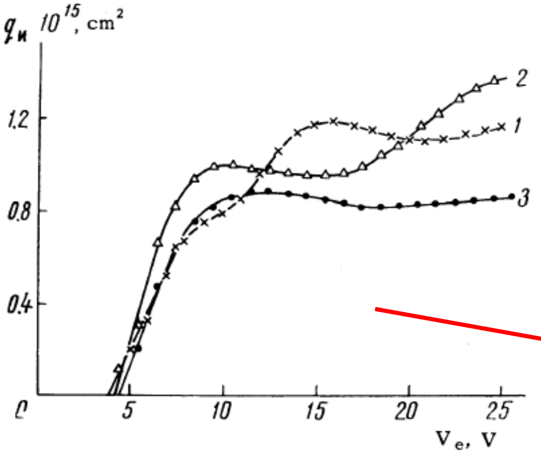
Mass effect is serious!

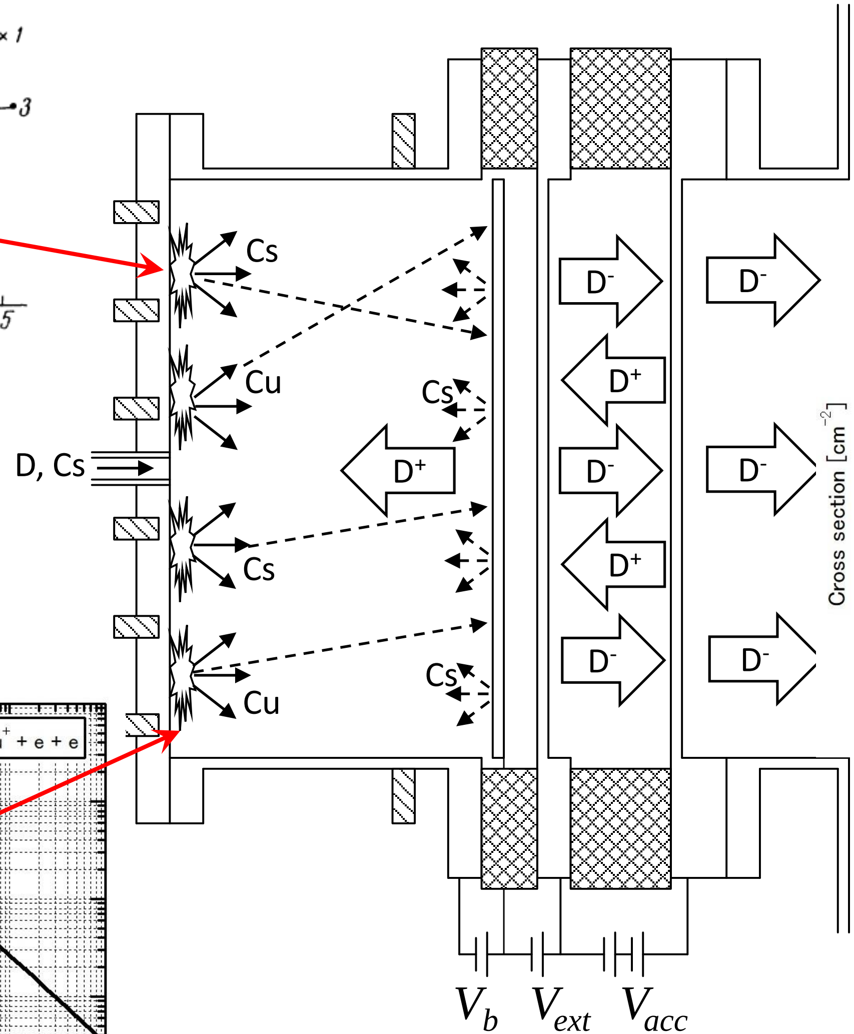




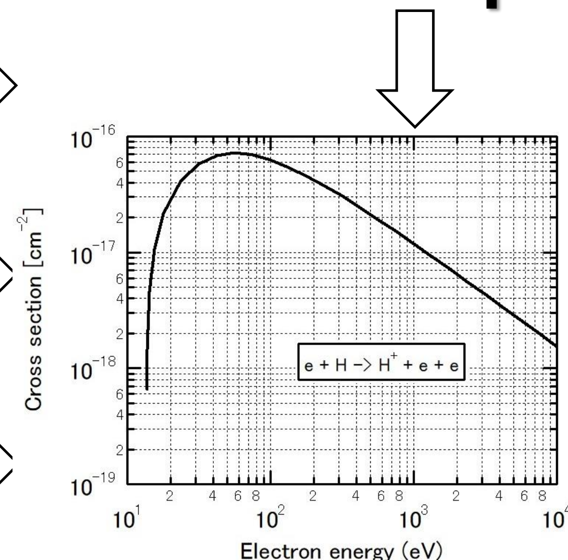
- ACAT (Atomic Collision in Amorphous Target) computed collision cascades for both the both back end-plate and the PG.
- Deuterium atoms occupying the layer in between Cs and Mo (bulk PG) enhances collision cascade in the subsurface layer.
- The collision cascade in the subsurface layer enlarges Cs sputtering yields; more Cs is lost in deuterium discharge.

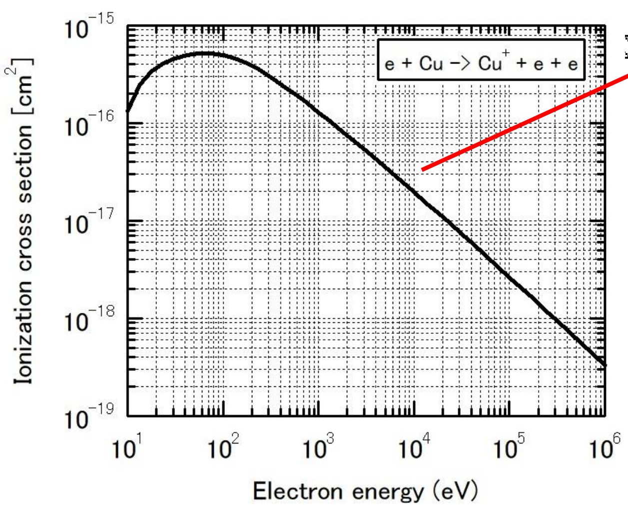
Complicated process



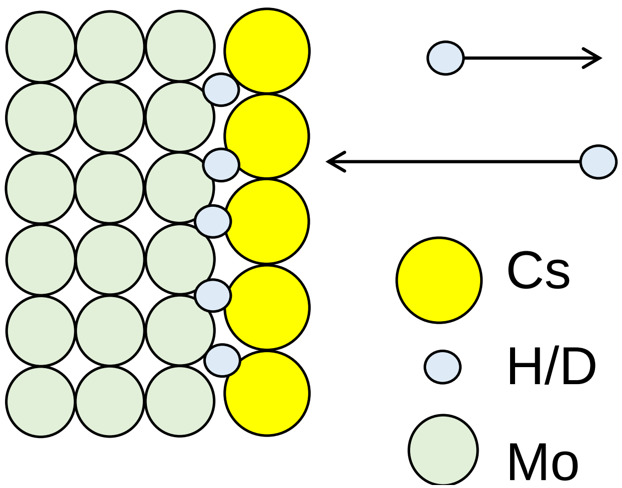


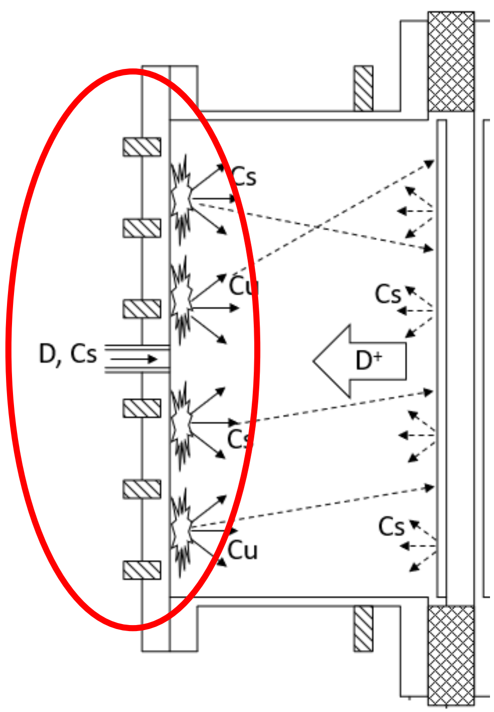
100 kV p

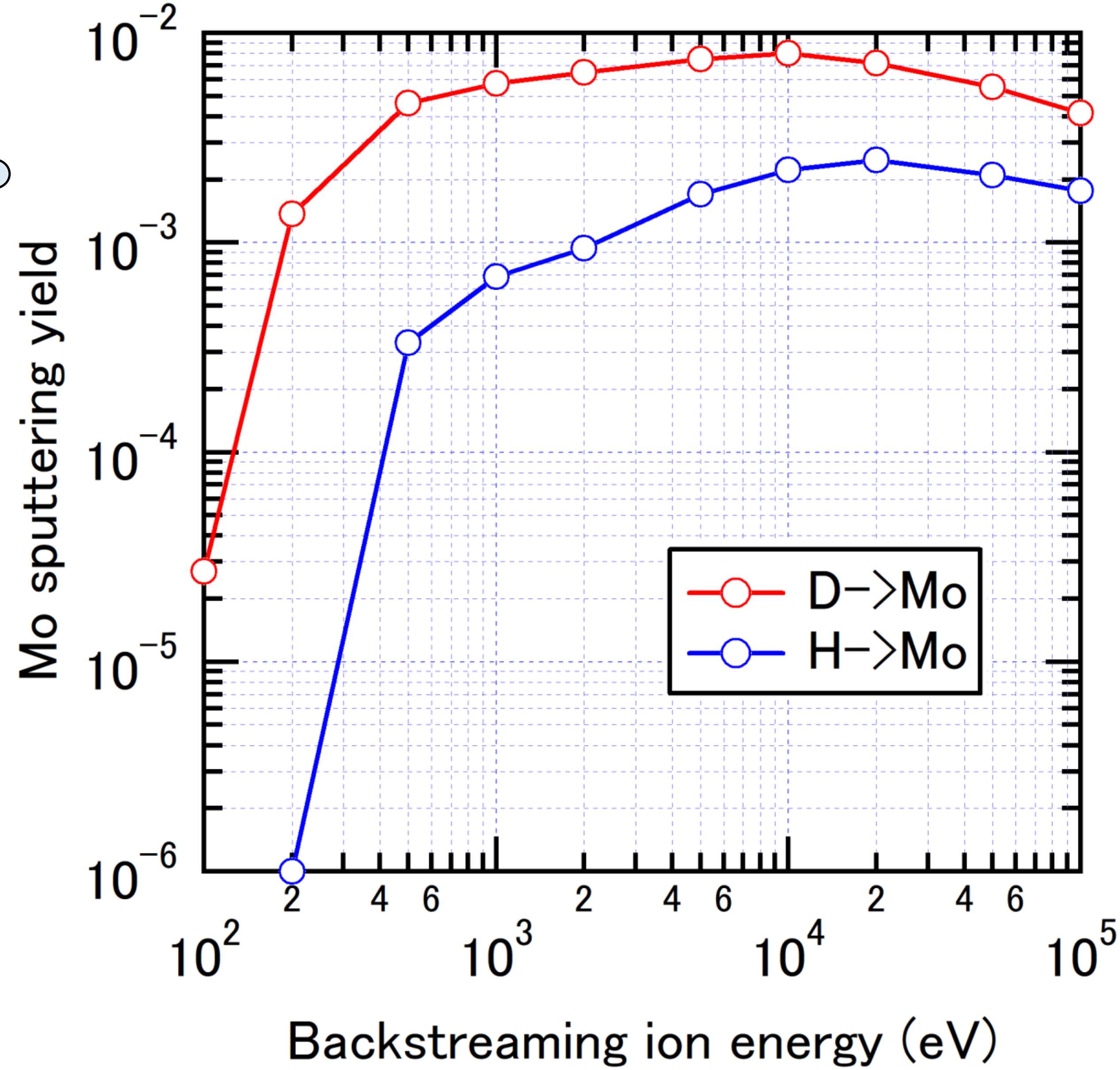




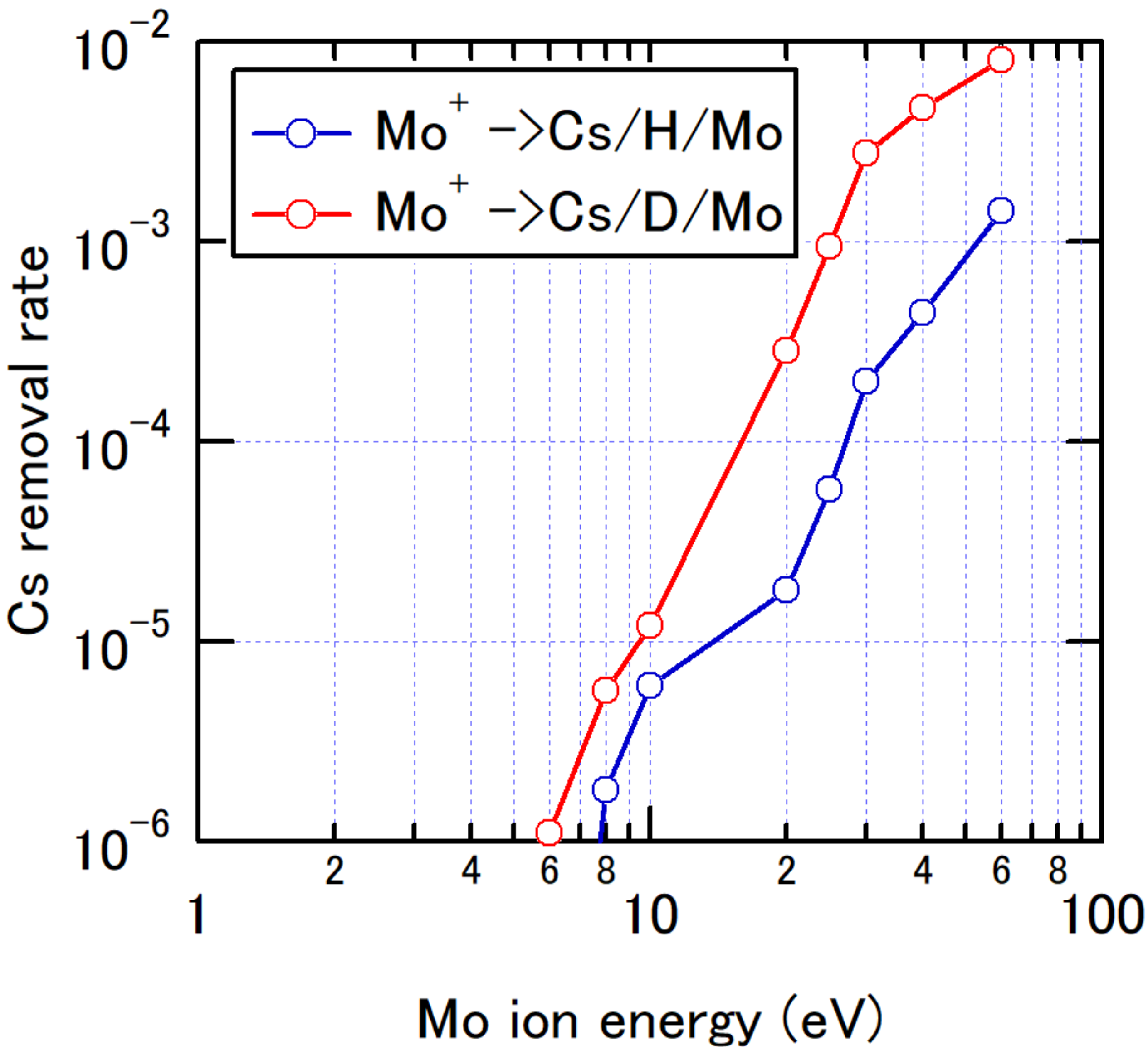
Lower threshold/larger yields

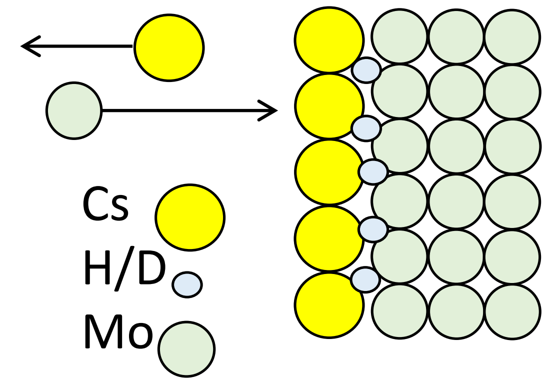


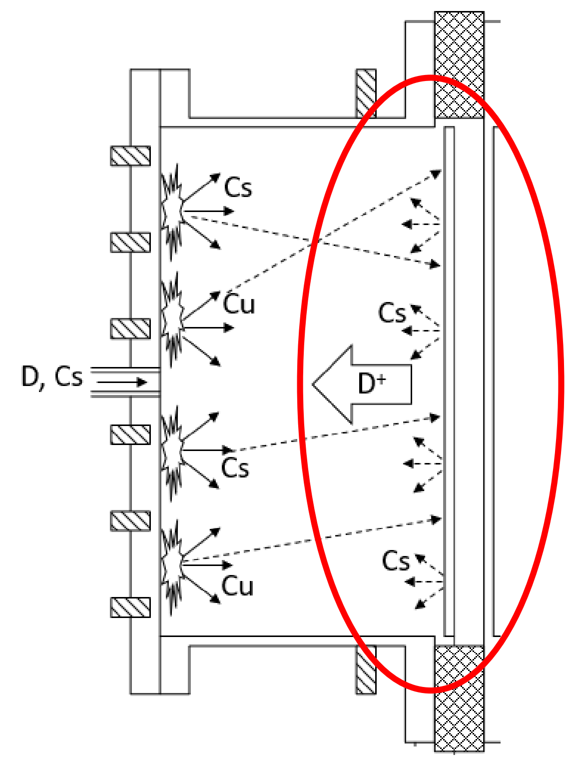


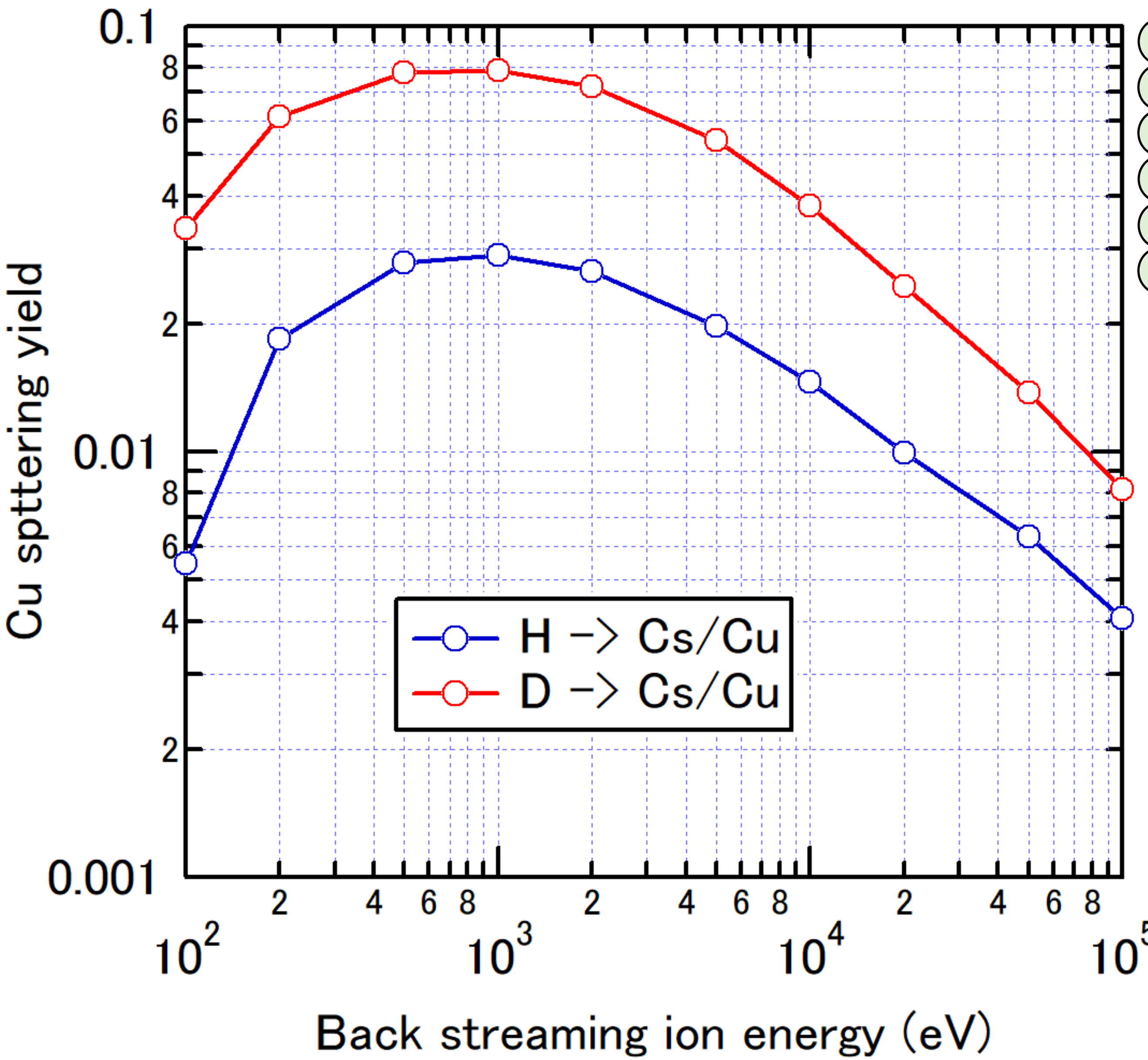


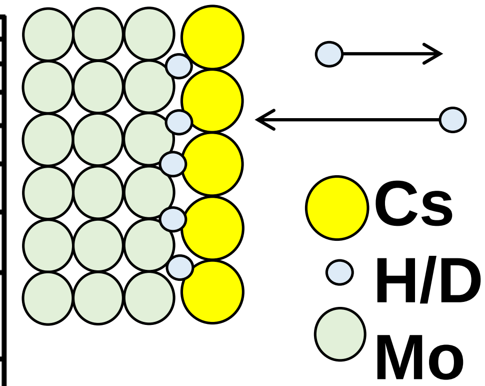
Faster removal

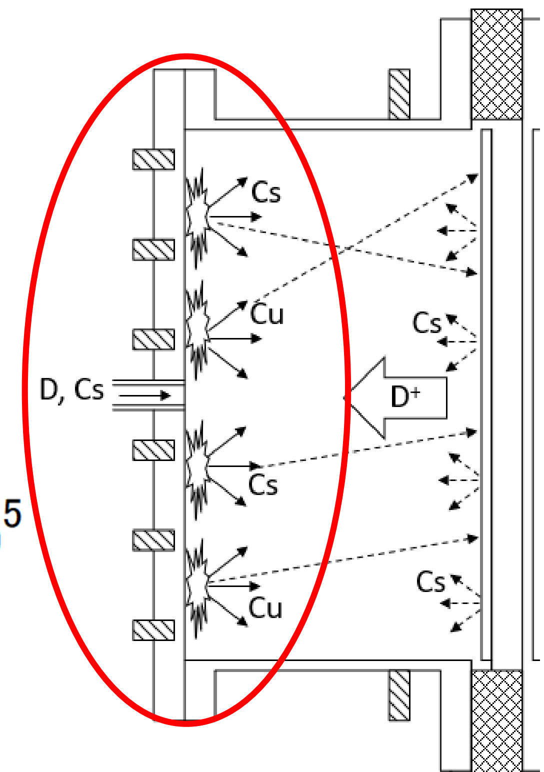


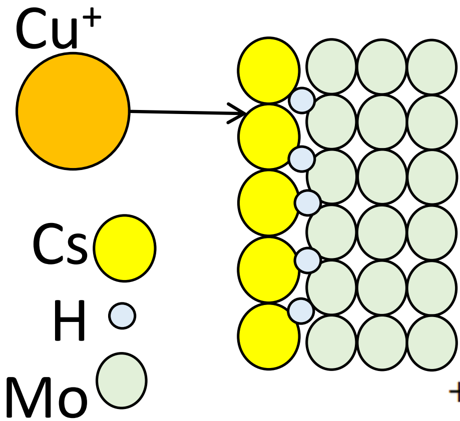


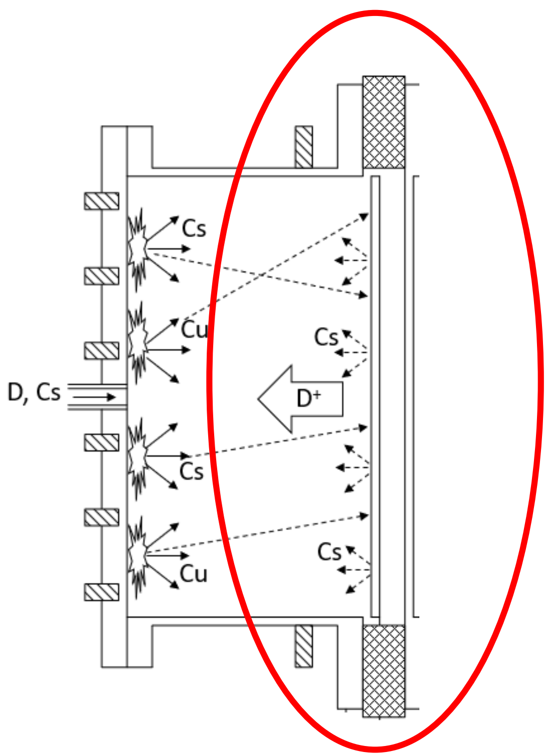


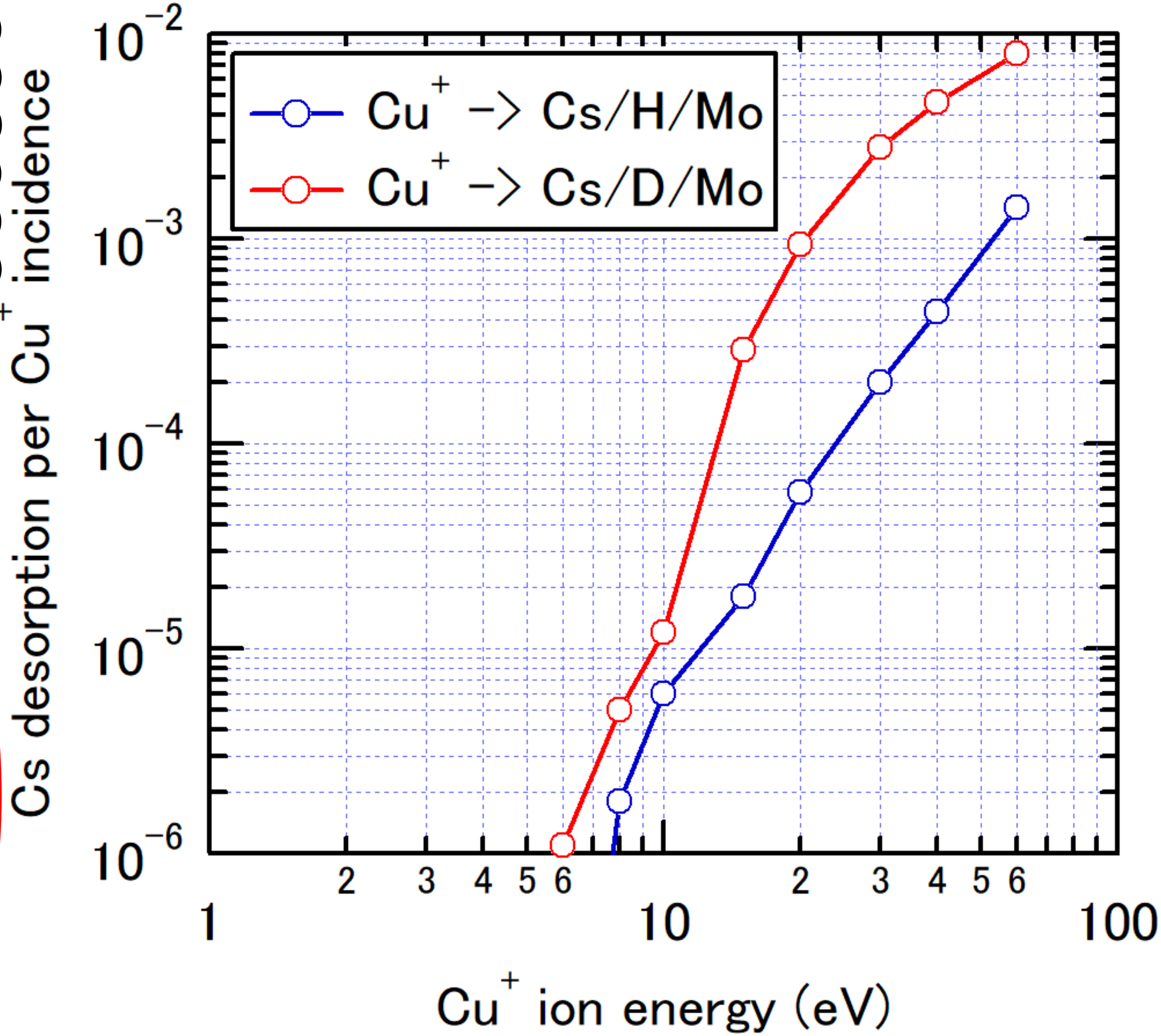

0.1
0.01
0.001
8
6
4
2
10^2
10^3
10^4
10^5
Cu sptttering yield
Back streaming ion energy (eV)
H -> Cs/Cu
D -> Cs/Cu

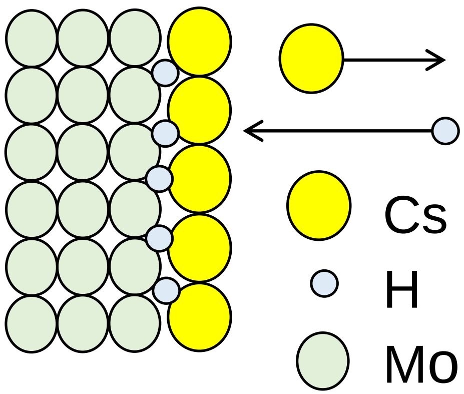

Cs
H/D
Mo

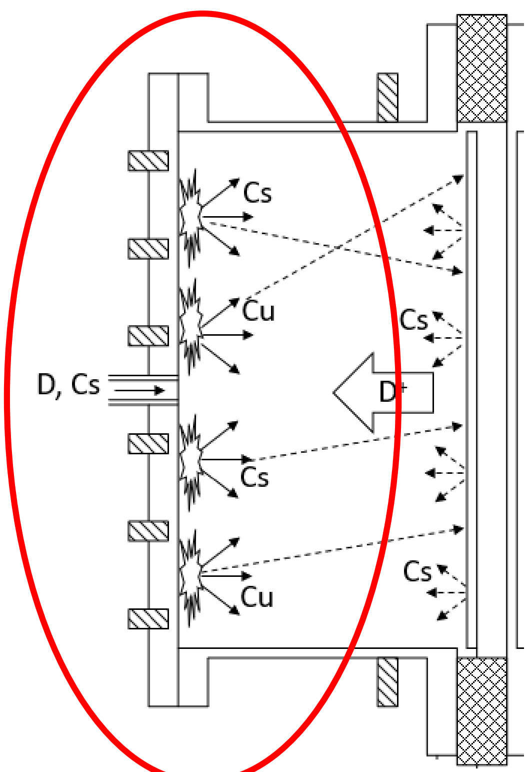

Cs
Cu
Cs
Cu
D, Cs
D+
Cs
Cs

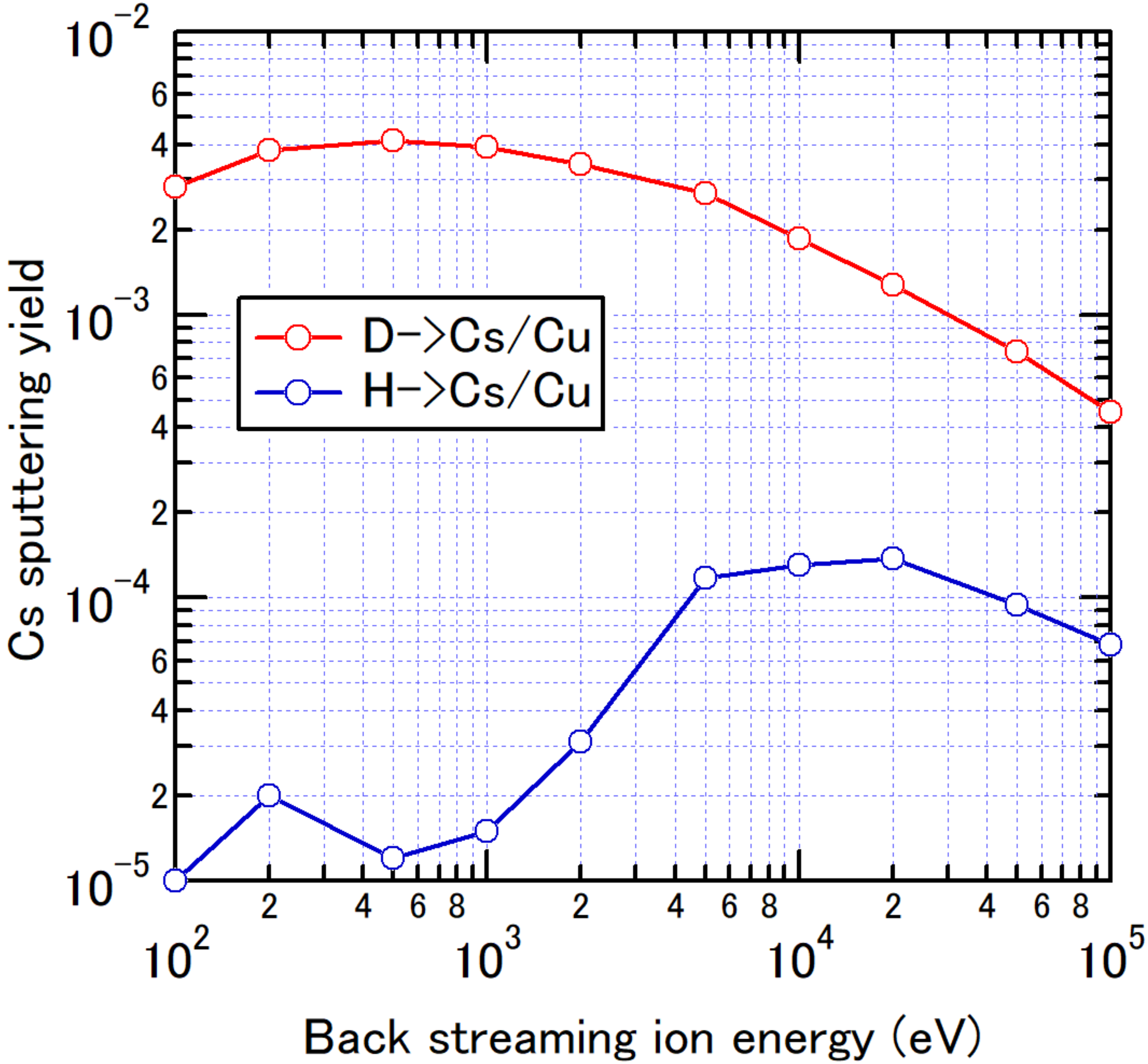

Cu+
Cs
H
Mo


Cs
Cu
Cs
Cu
Cs
Cs
D, Cs
D+

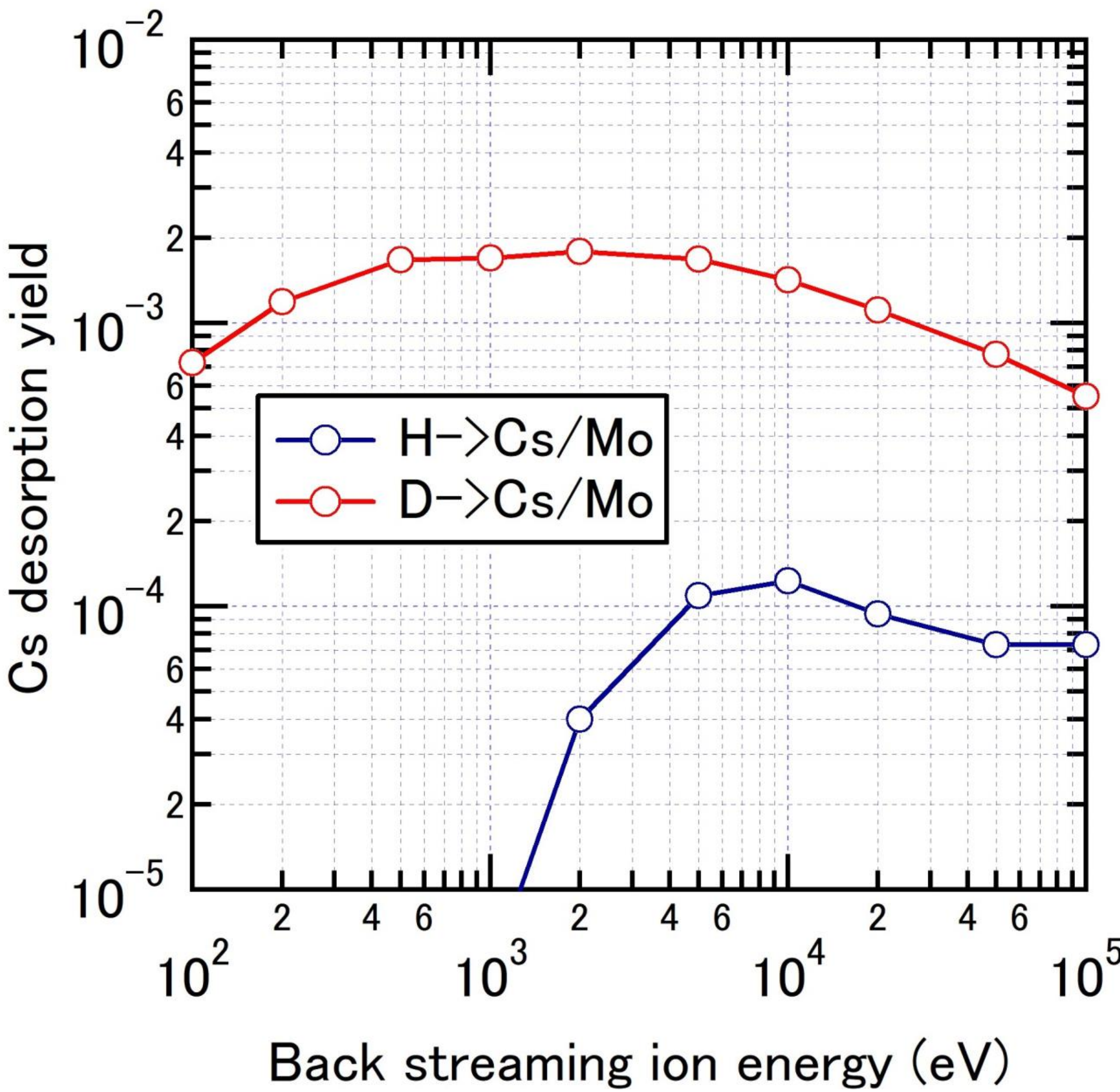

Cu+ -> Cs/H/Mo
Cu+ -> Cs/D/Mo
Cs desorption per Cu+ incidence
Cu+ ion energy (eV)
10−2
10−3
10−4
10−5
10−6
1
10
100
2
3
4
5
6


Cs
H
Mo

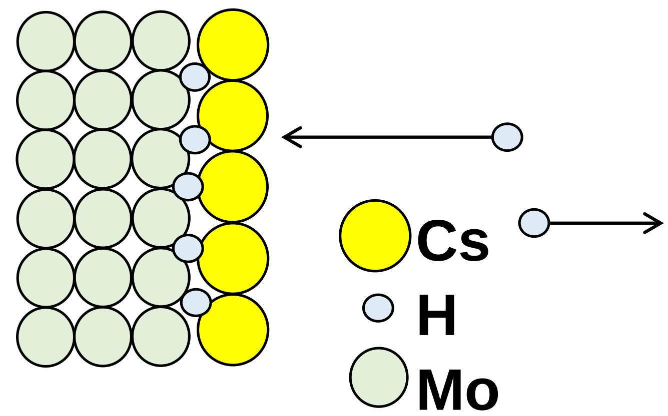

Cs
Cu
Cs
D, Cs
D+
Cs
Cs
Cu


Cs sputtering yield
Back streaming ion energy (eV)
D->Cs/Cu
H->Cs/Cu
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{2}
10^{3}
10^{4}
10^{5}

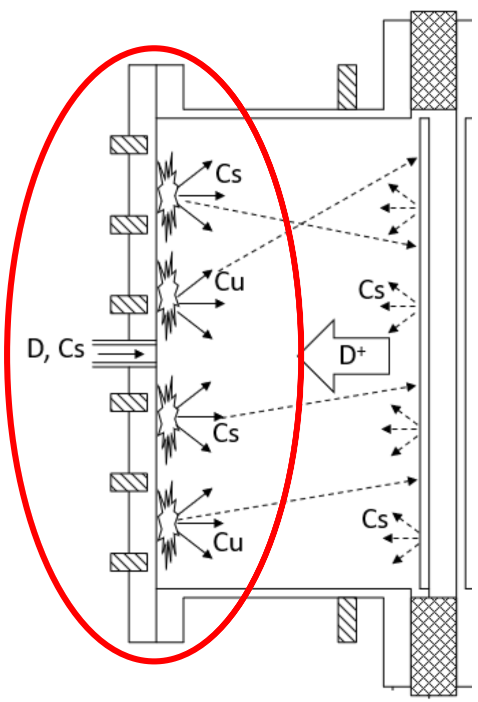
Source of Cs?



Cs desorption yield
Back streaming ion energy (eV)
H->Cs/Mo
D->Cs/Mo

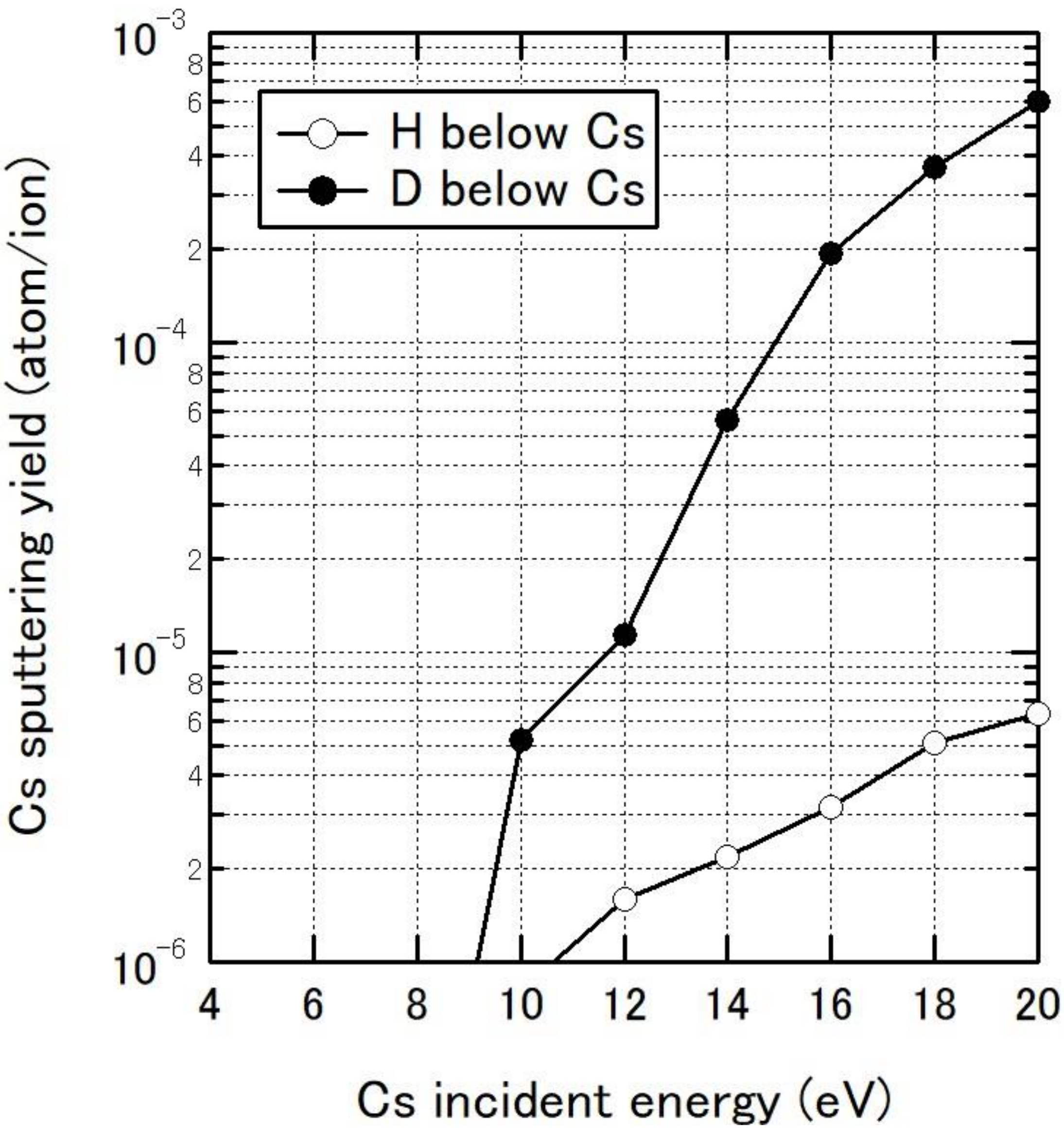


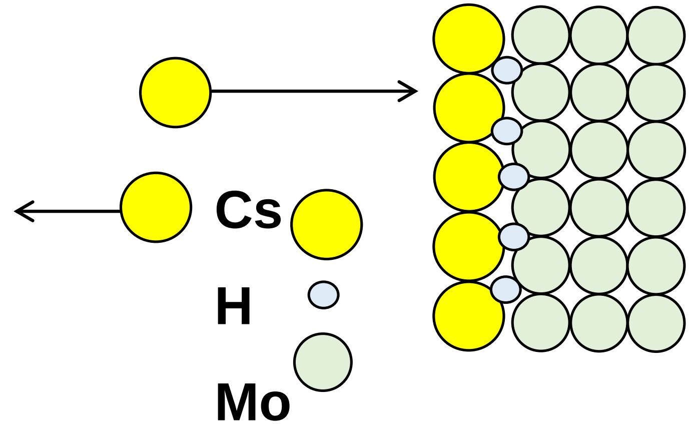
Cs
H
Mo

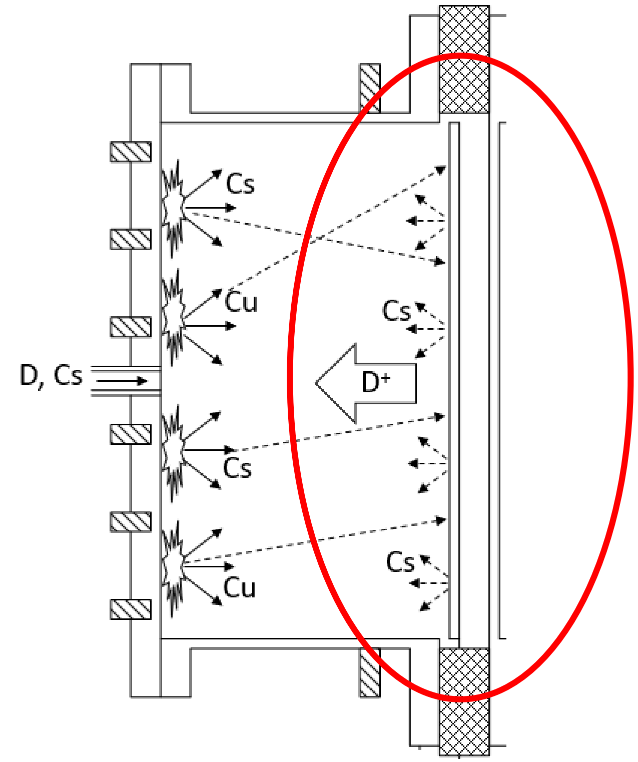


Cs
Cu
D, Cs
D+
Cs
Cu
Cs
Cs

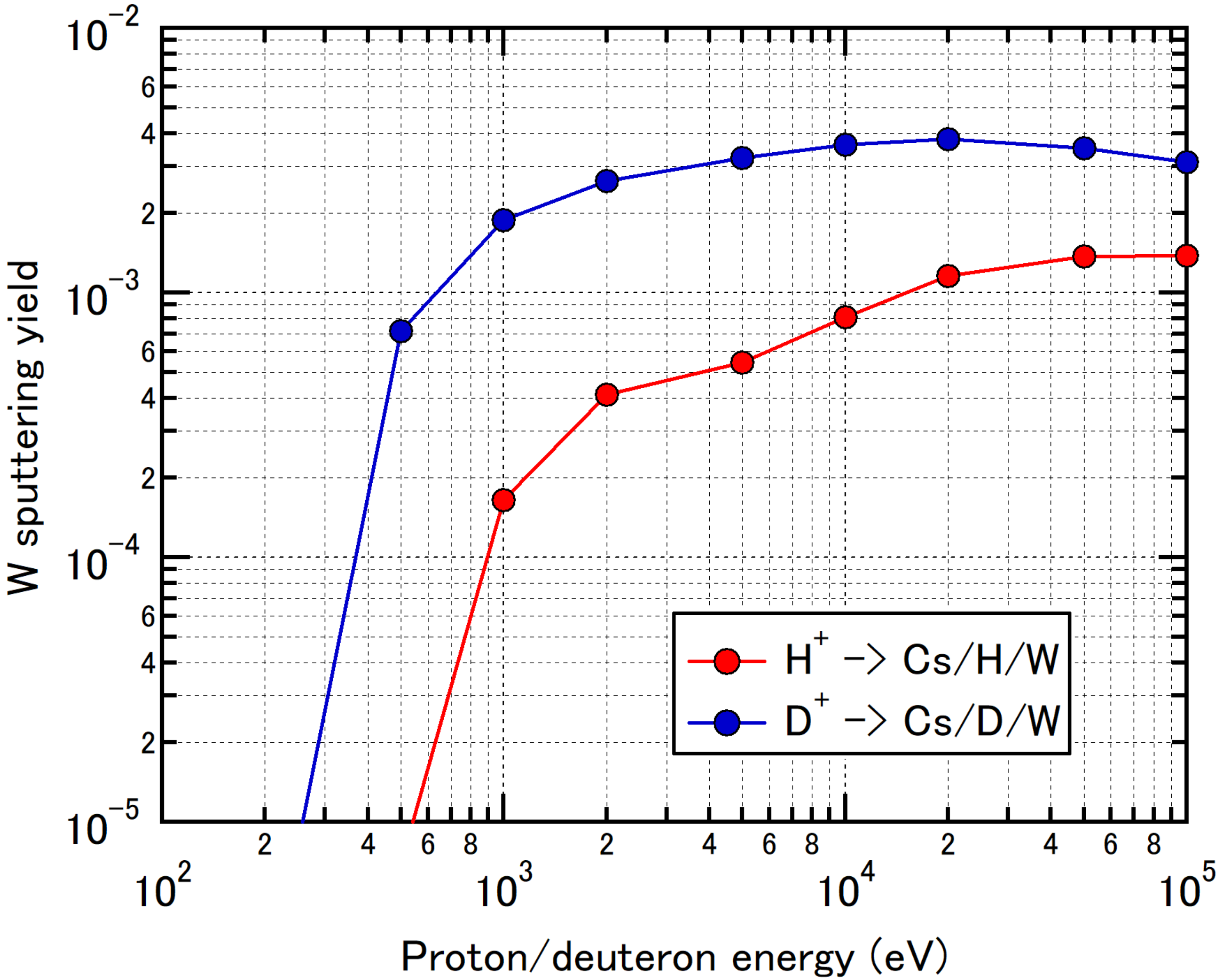
Cs self-sputtering effect

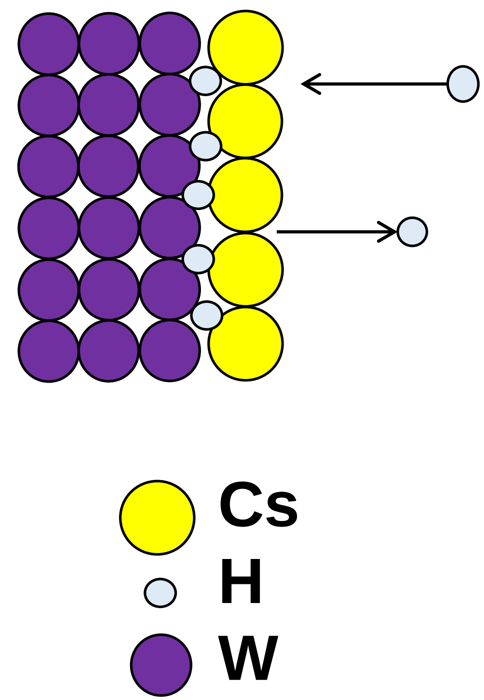




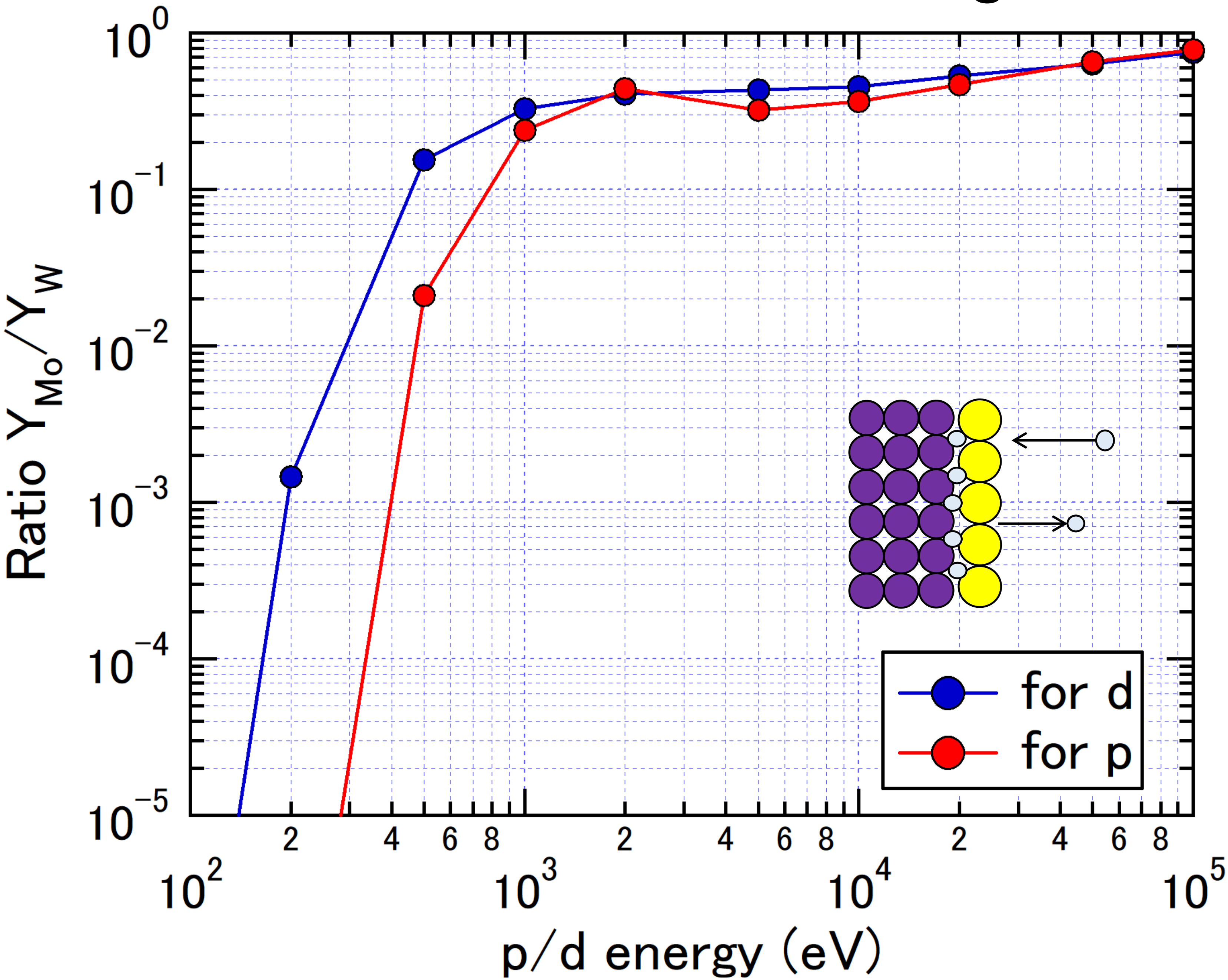


W Coatings on source components



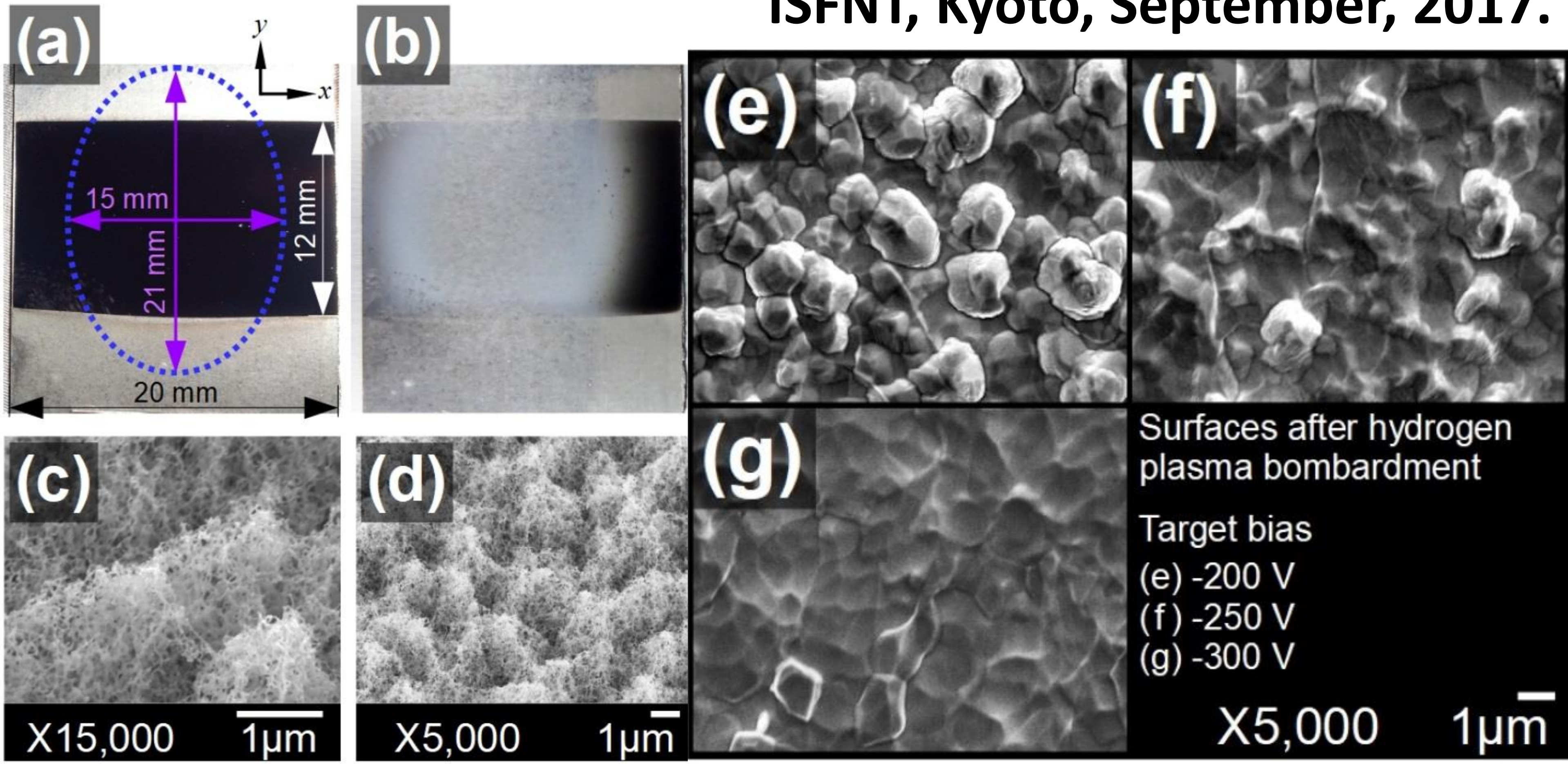


Effectiveness of W coating

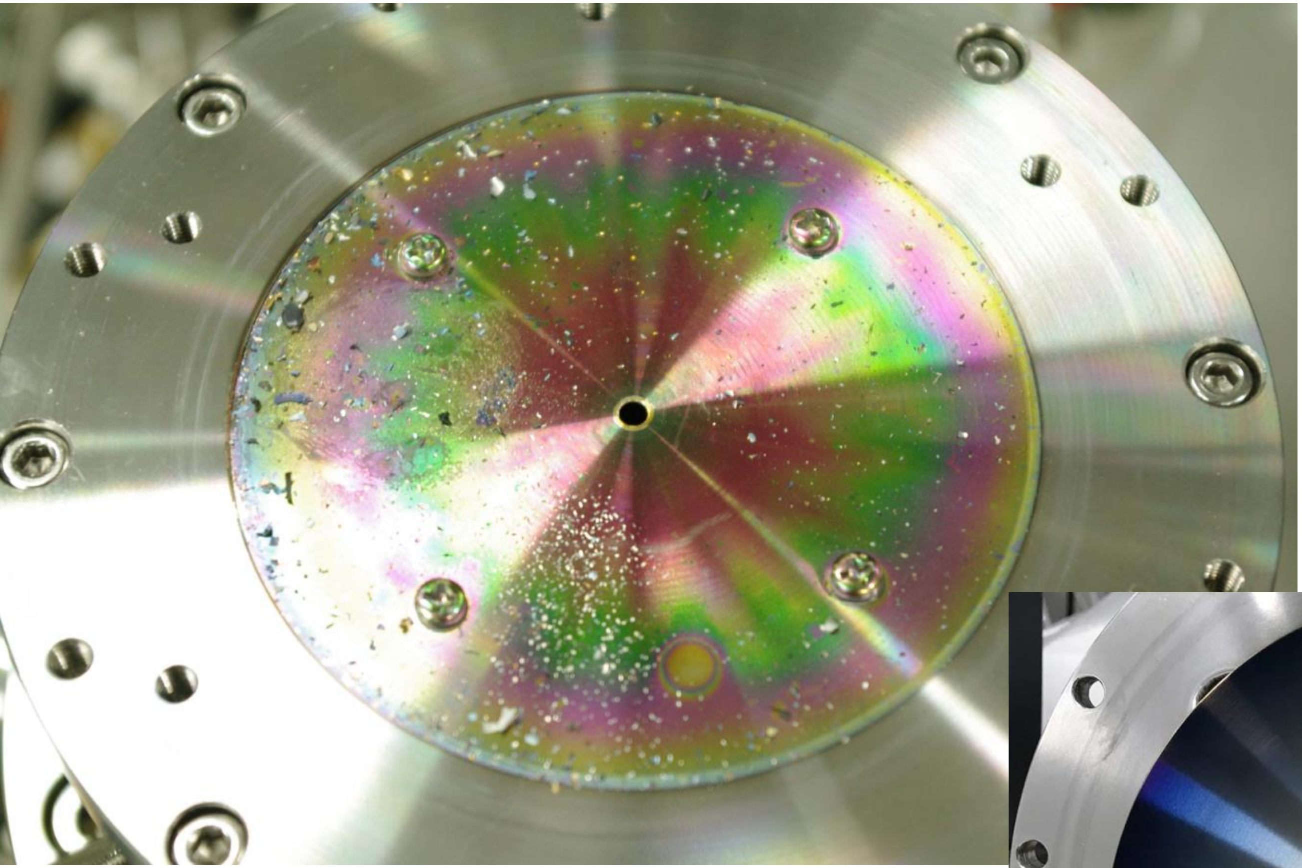


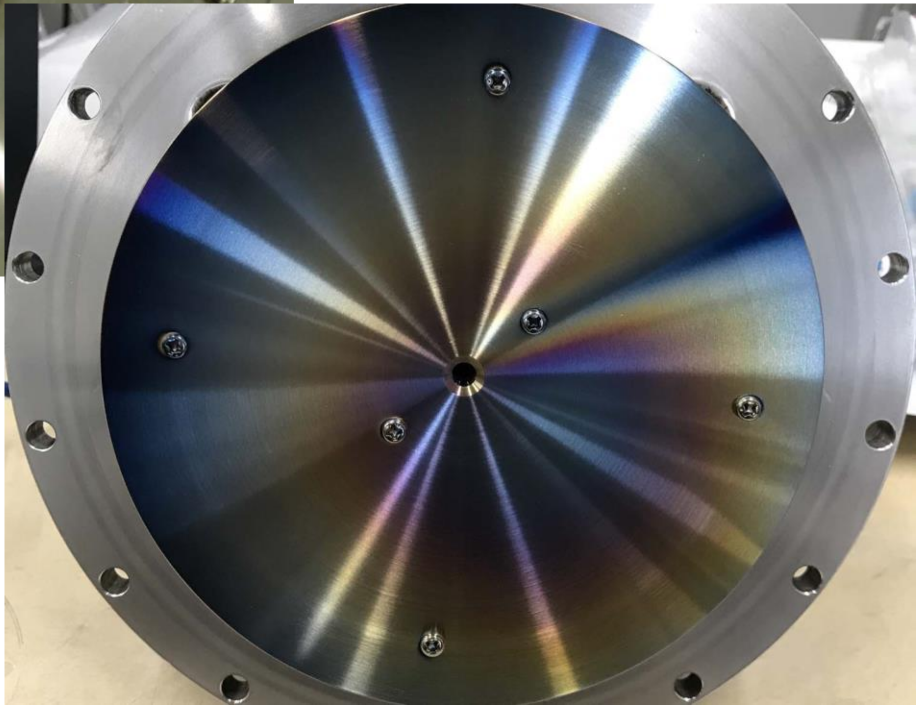
Fuzzy diverter surface

Kenta Doi et al., presented at 13th ISFNT, Kyoto, September, 2017.



Dusts and deposits on the wall





Summary

- Austenitic stainless steel preferentially emits Cr under a bombardment of energetic protons.
- Impurity ions released from stainless-steel wall can remove Cs with 10 eV incident energy. Any potential difference between the plasma electrode and the plasma potential above 10 V can cause sputtering.
- Magnitude of back-streaming positive ion current should be properly evaluated to estimate the effect upon impurity emission.
- Copper exhibits high sputtering yields against protons and deuterons above 100 eV incident energy. Coating the Faraday shield surface with Mo will reduce impurity emission.
- Coating the Faraday shield with W may reduce the impurity emission even smaller.


Спасибо
danke
arigatô
dankie
merci
grazie
hvala
shukran
tak
gràcies
gracias
takk
obrigado
thank you
kiitos
xièxiè
mh'gōi
mahalo
terima kasih
dĕkuji
спасибо
благодаря
благодарам
dank u
faleminderit
köszönöm
diolch
хвала
ačiū
choukrane
nandri
tänan
paldies
kop khun
a dank
tack
dziękuję
ďakujem
дякую
teşekkür ederim
multumesc
dhanyavād
ngiyabonga