炭素のケミカルスパッタリングIII（O, N衝撃効果）

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Background : Graphite for fusion-plasma walls

Summary of H(D) on pure-graphite [2007 Report]

- Chemical sputtering: Reaction of H(D) with C, formation and escape of hydrocarbons.

* For H energy > 0.3 keV, yield takes maximum at Ts~800K, CH_4 dominant, larger by an order of magnitude than physical sputtering

e.g. ~0.01 /ion for 1 keV H ,Matsunami et al. ADNDT 31(1984)1., Yamamura et al. ADNDT62(1996)149.

- For low energy, Ts~600K, contribution other than CH_4 becomes larger.

* c.f. Enhanced sublimation, >1200K, Philips et al. JNM 155-157(1988)319.

*NB. Reflection, ~0.1 at 1 keV H on C, Tabata et al. NIM B9(1985)113

*Related phenomena: Reemission, Retention

Summary of H(D) on doped-graphite [2008 Report]

Dopant (10 elements)

B, Be

Si, Ti, W, V, Fe, Cr, Li, Zr

Suppression of chemical sputtering,

~10 % doping is effective.

Literatures

Review

1. J. Roth, “Chemical Sputtering”, in Sputtering by Particle Bombardment II, ed. R. Behrisch, Springer-Verlag, 1983.

2. C. Garcia-Rosales, “Erosion processes in plasma-wall Interactions”, J. Nucl. Mat. 211(1994)202.

3. J. W. Davis, A. A. Haasz, “Impurity release from low-Z materials under light particle bombardment”, J. Nucl. Mat. 241-243(1997)37.

*Chemical sputtering: ~30 papers, 1976~2000: graphite [2007 Report]
*Doped-graphite : ~10 papers [2008 Report]
*** O, N impact on graphite: ~20 papers [2009 Report]**

Aim

*** Data compilation & understanding of chemical sputtering of graphite: O, N impact**

*** Control of chemical sputtering**

Temperature Dependence

2.5 keV O on graphite

*Temp. dependence ~ weak

c.f. H impact: strong temp. dep.

* Enhanced sublimation >1200 K

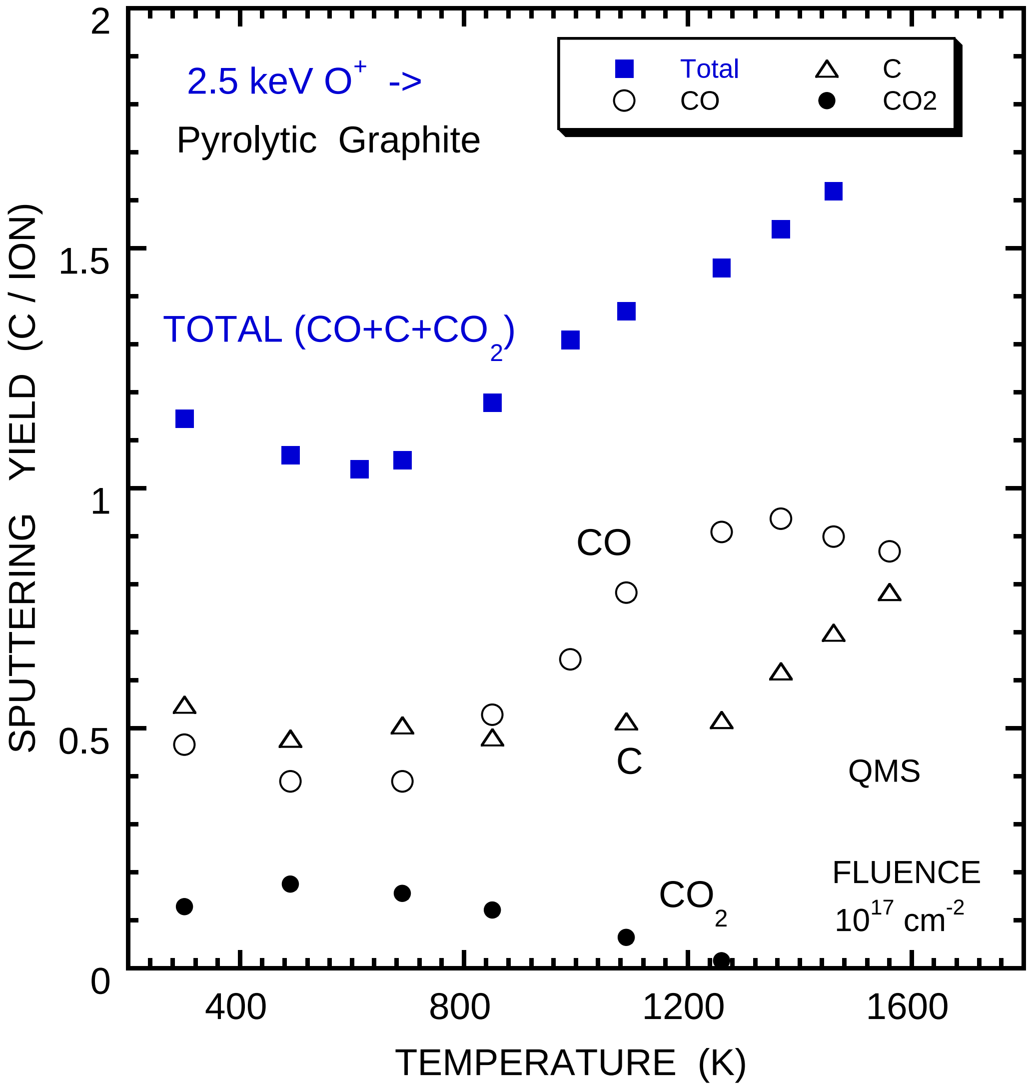
*** CO & CO_2**

CO is dominant .

Phys. Sputtering ~0.5

c.f. Calc. =0.8 (1984)

VTP1987TF2



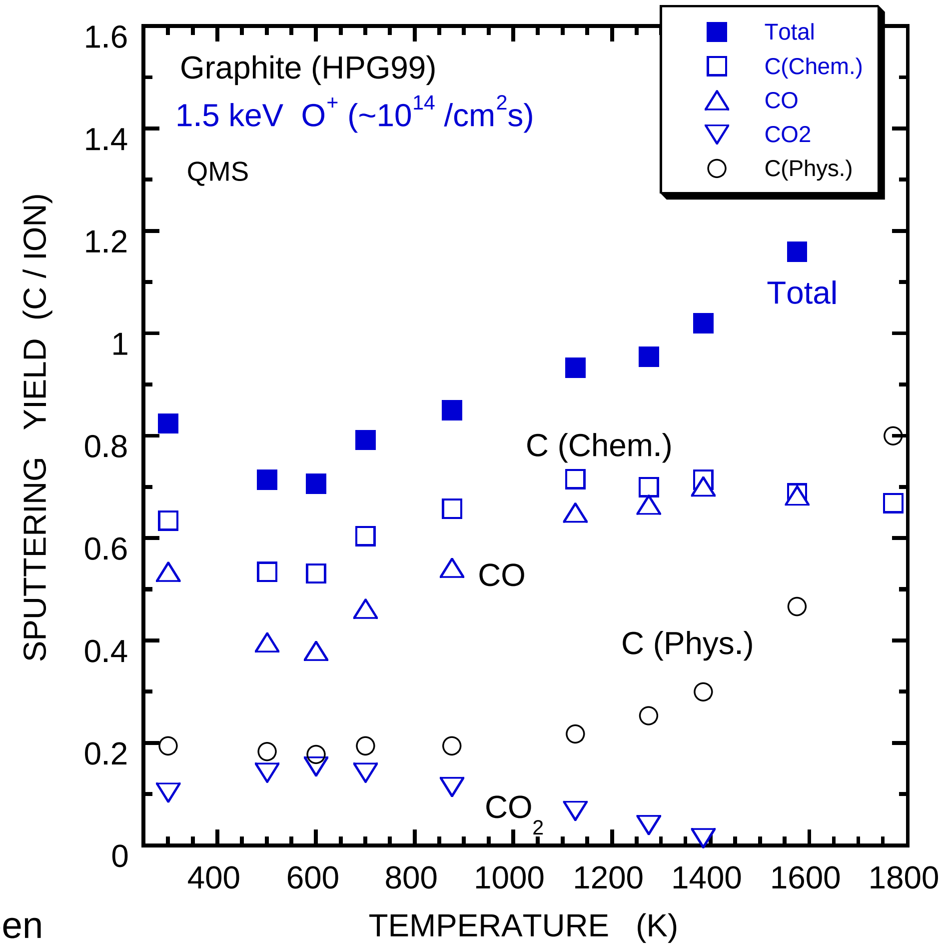
E. Vietzke, T. Tanabe, V. Philipps, M. Erdweg, K. Flaskamp
J. Nucl. Mater. 145-147(1987)425.

Temperature Dependence

*Temp. dependence ~ weak

*Chem. Sp. > Phys. Sp.

RPV1997TF6



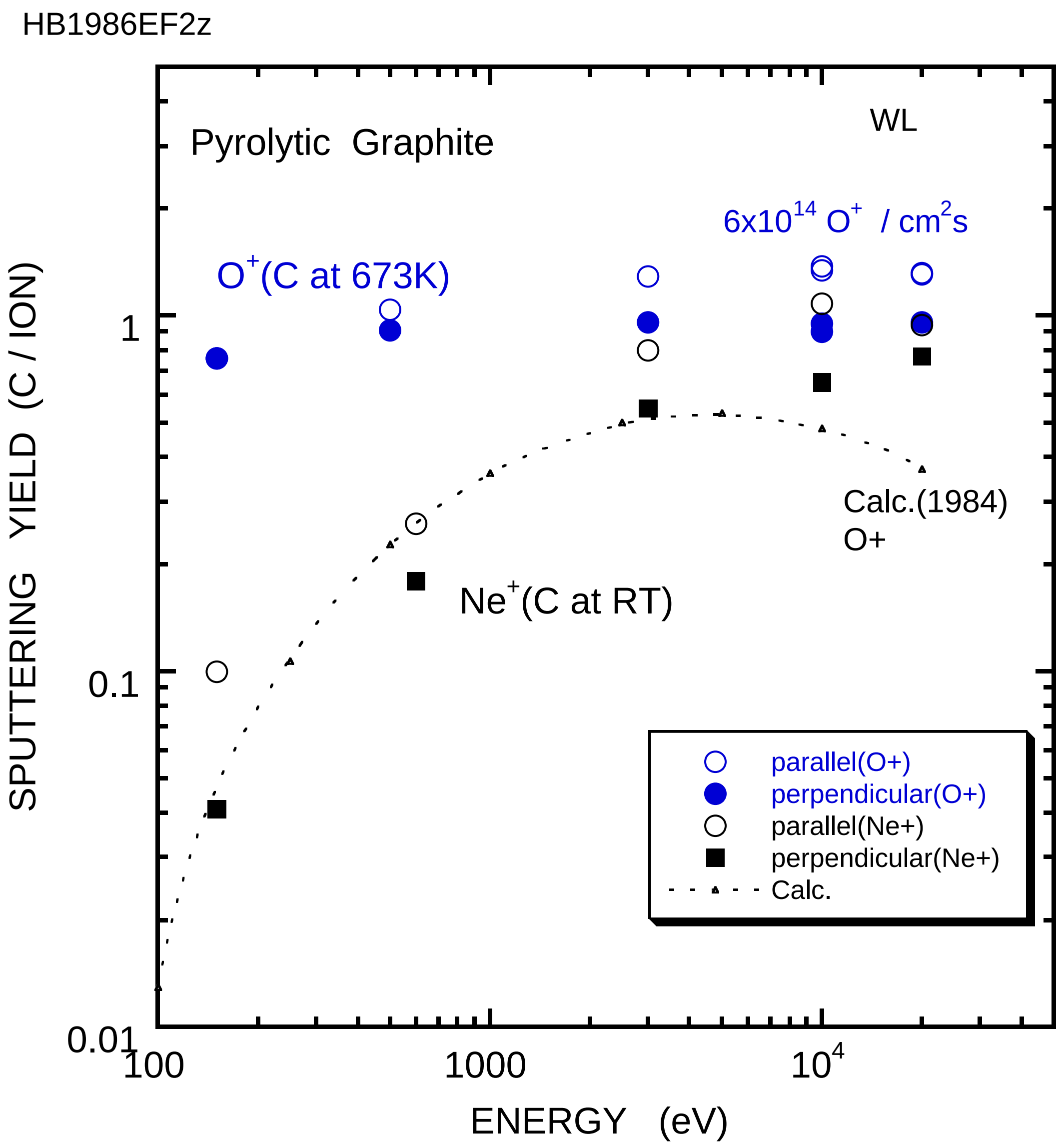
A. Refke, V. Philipps, E. Vietzke, J. Nucl. Mater. 250(1997)13.

Normal incidence. QMS-LOS and TOF have been used and the energy distribution has been considered. C (Chem.) : chemical sputtering yield, C (Phys.): physical sputtering yield and enhanced sublimation starts at ~1300 K.

Energy Dependence

***Weak**

***Chem. Sp. ≥ Phys. Sp.**



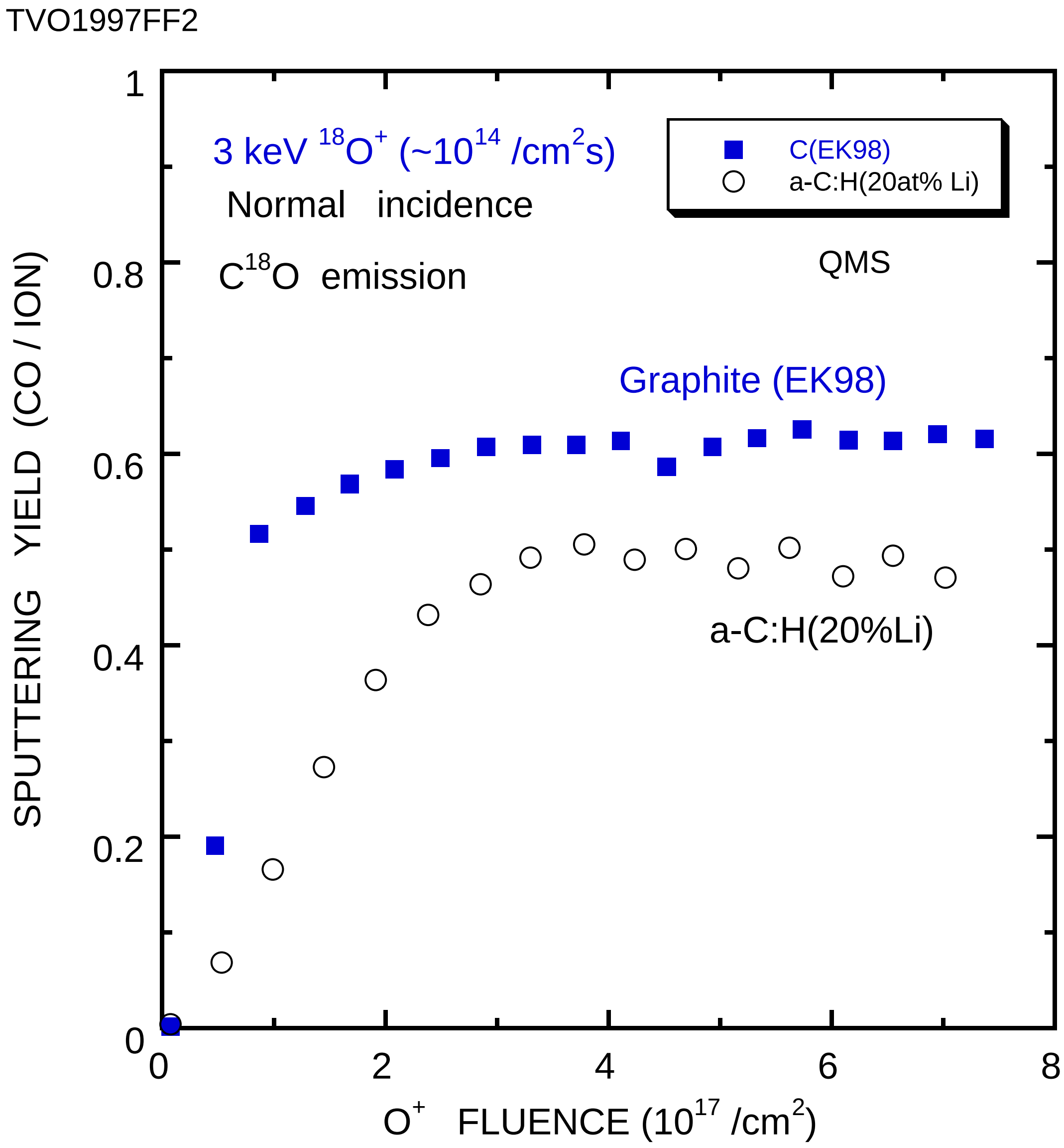
E. Hechtl, J. Bohdansky,
J. Nucl. Mater. 141-143(1986)139.

Fluence Dependence

Sp. Yield is very small for $<0.5\times10^{17}\ \mathrm{cm}^{-2}$,

Accumulation effect, ?

Li-doping: Little effect



J.-U. Thiele, E. Vietzke, P. Oelhafen,
J. Nucl. Mater. 241-243(1997)1127.

Energy Distribution of CO at RT

Vietzke et al JNM220-222(19995)249.

Two component

Maxwell-Bolzman (MB) : Eexp(-E/kT)

&

Thompson (Collision-cascade sputtering) :

$E/(E+U)^3$, $U=0.25$ eV

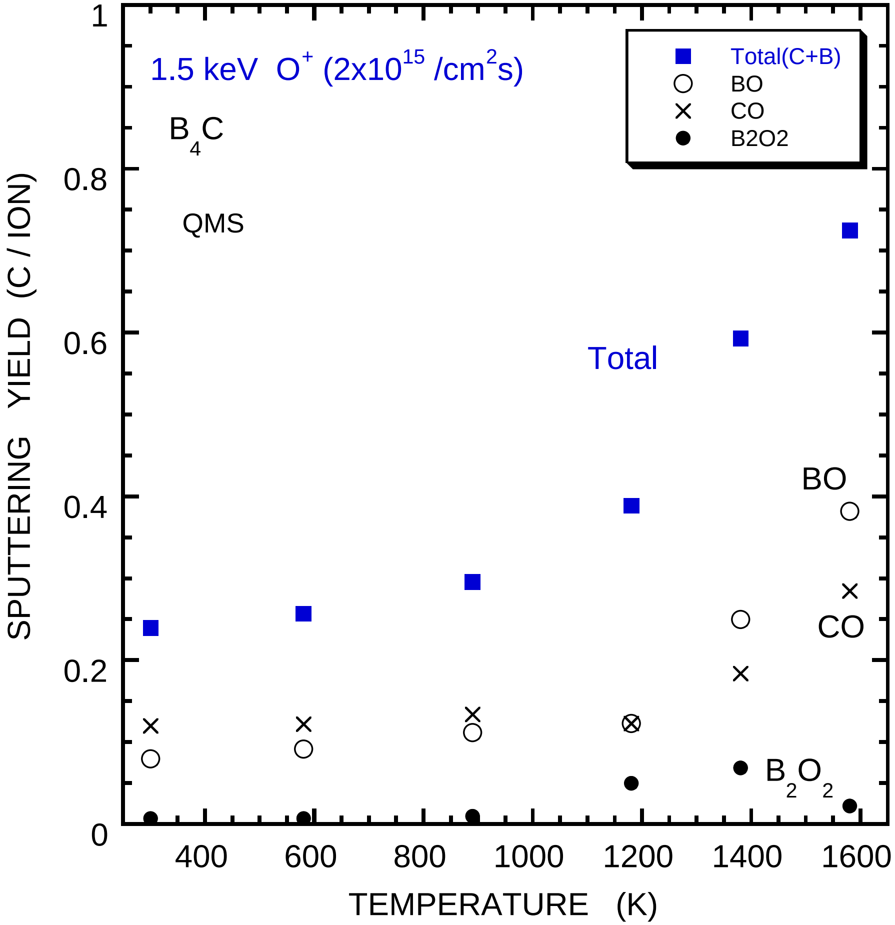
Temperature Dependence (Compound)

B_4C

Non-negligible chem. Sp.

CO, BO, B_2O_2

VRP1995TF5b



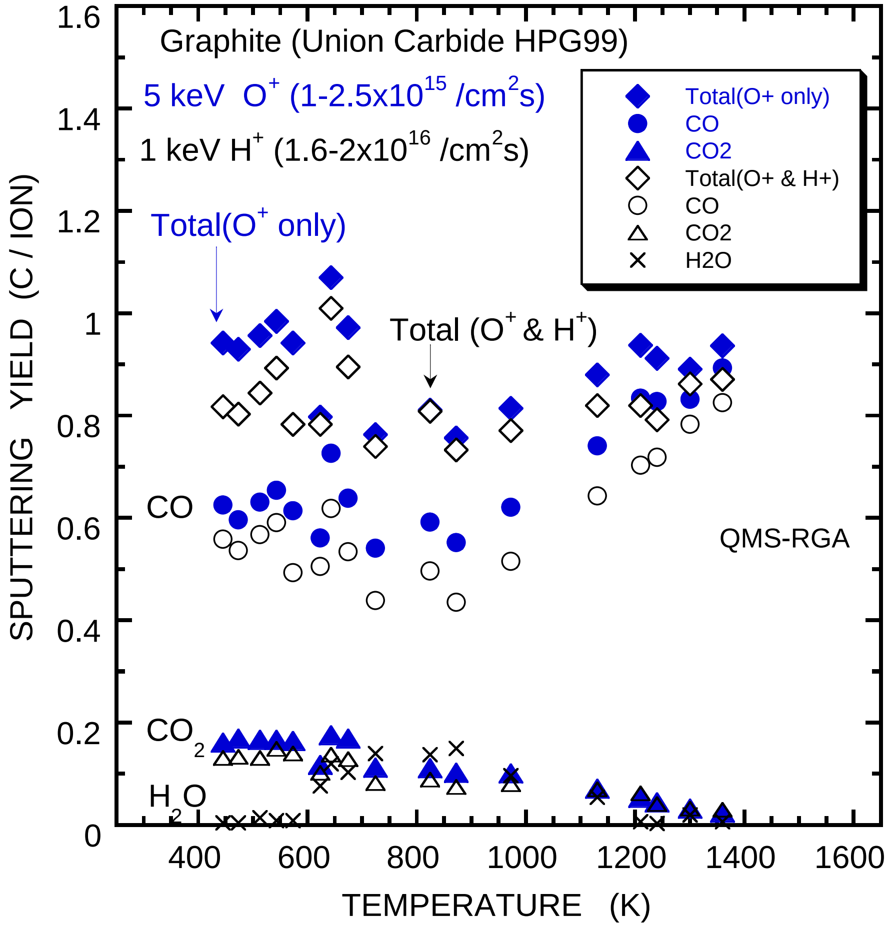
E. Vietzke, A. Refke, V. Philipps, M. Hennes,
J. Nucl. Mater. 220-222(1995)249.

Mix ion impact

5 keV O & 1 keV H

Little difference between O and O & H impacts

HCD1997TF5



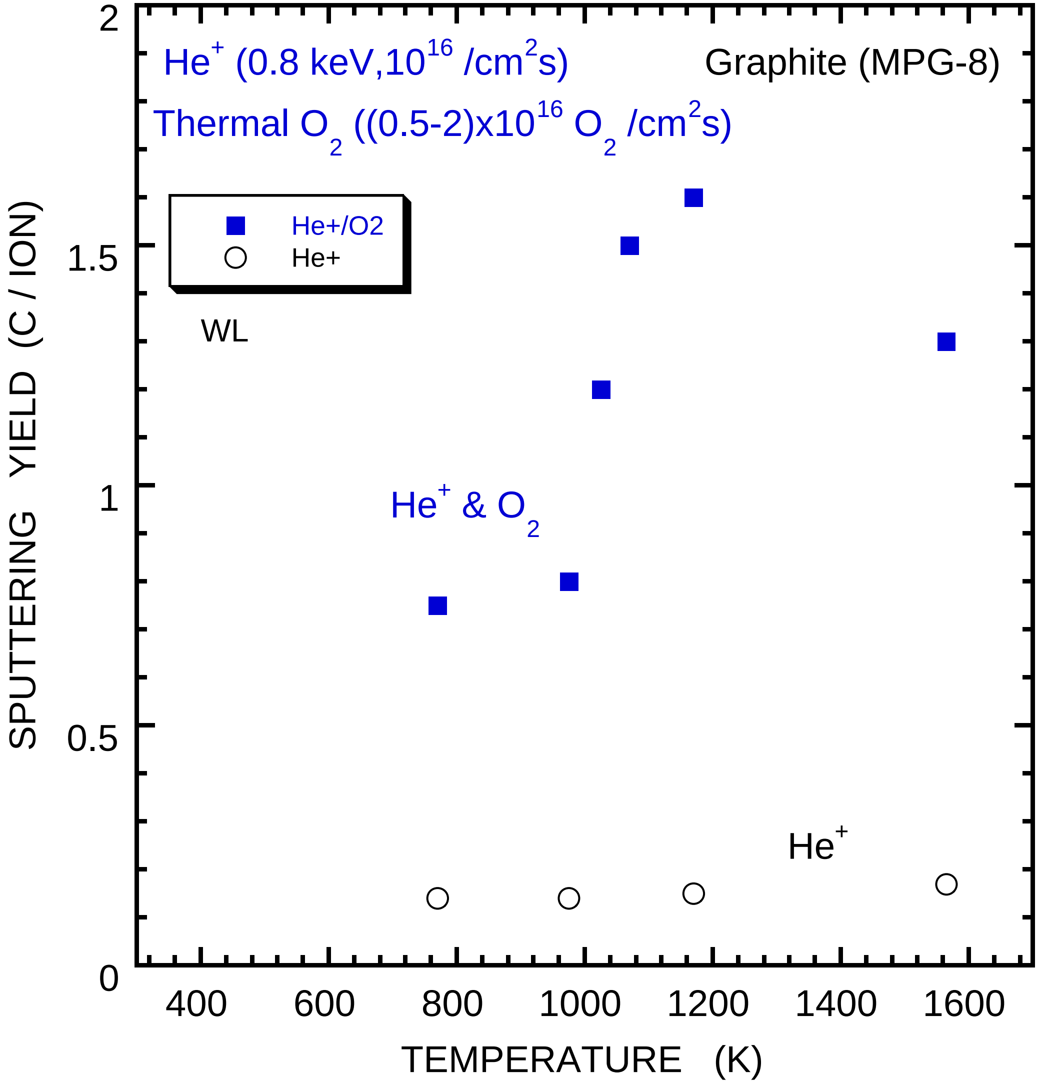
A. A. Haasz, A. Y. K. Chen, J. W. Davis, E. Vietzke, J. Nucl. Mater. 248(1997)19.

Mix ion impact

Thermal O_2 & He^+ impact:

Chem. Sp. appreciable

BBV1990TF2



L. B. Begrambekov, O. I. Buzhinsky, S. V. Vergasov, A. M. Zakharov, V. G. Otroschenko, V. G. Telkovsky,J. Nucl. Mater. 176-177(1990)864.

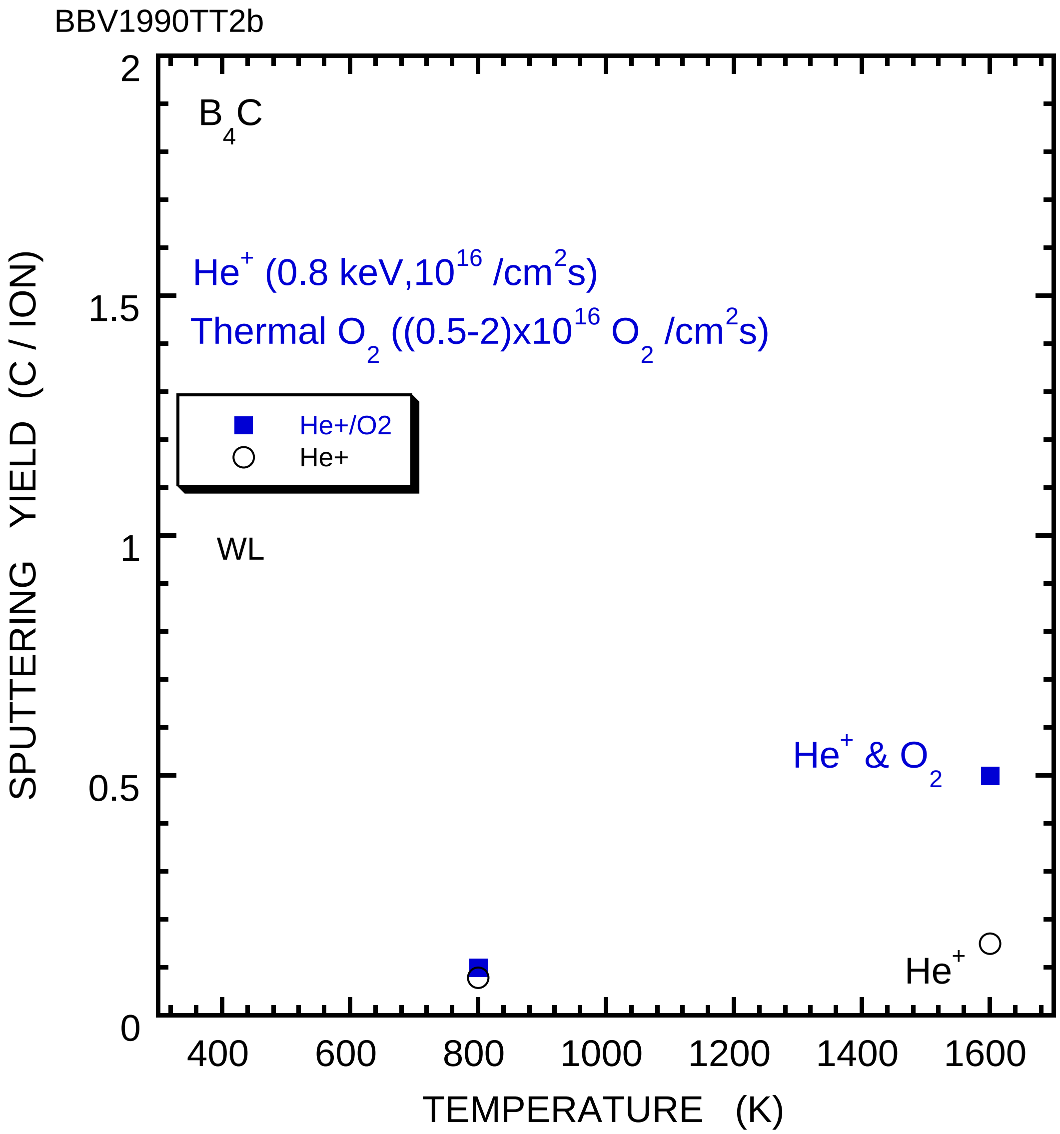
Mix ion impact

B_4C

No appreciable chem. Sp.

B_4C+5at%TiC

Appreciable chem. Sp.



L. B. Begrambekov, O. I. Buzhinsky, S. V. Vergasov, A. M. Zakharov, V. G. Otroschenko, V. G. Telkovsky,J. Nucl. Mater. 176-177(1990)864.

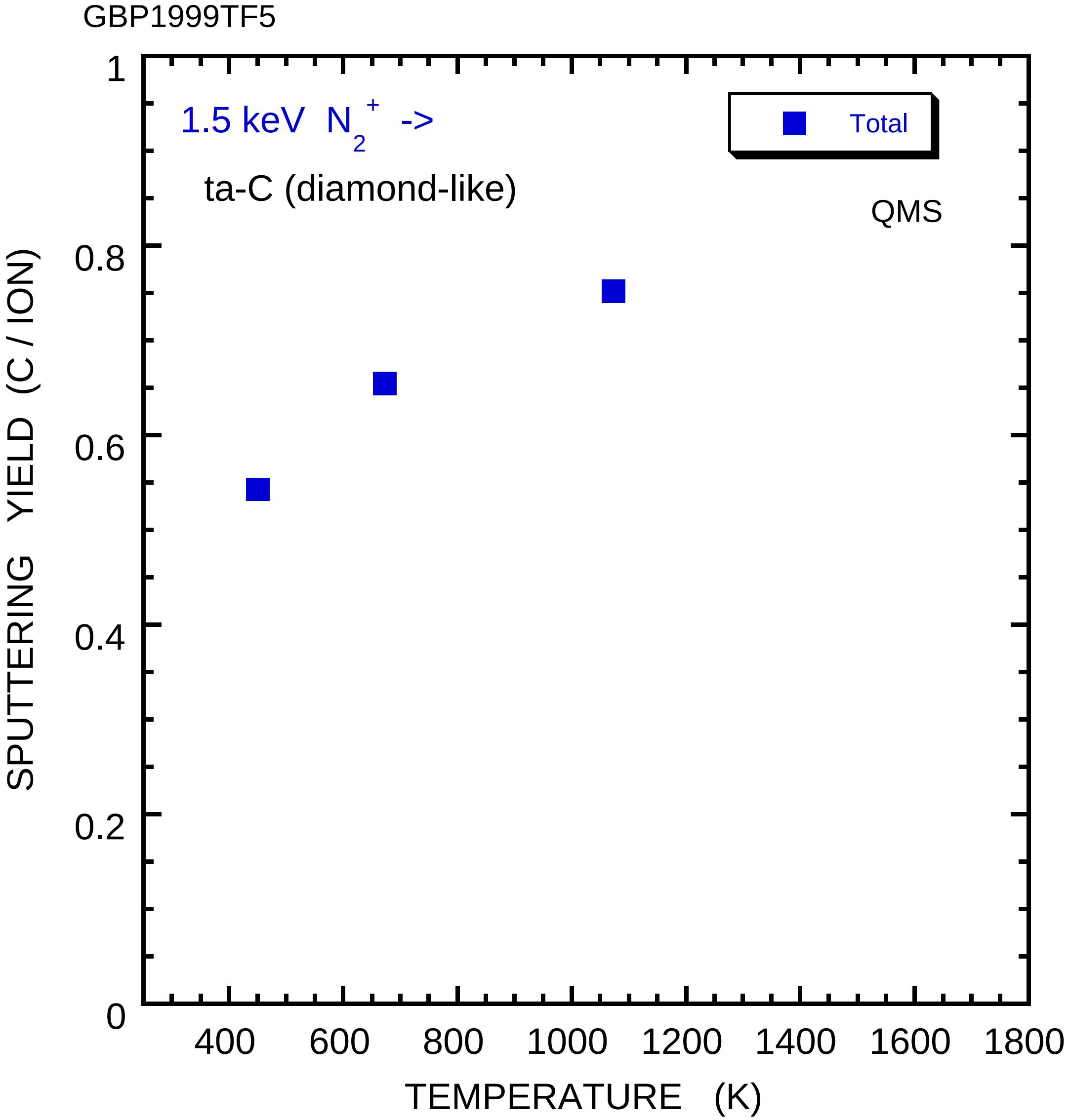
Temperature dependence

N ion impact

Chem. Sp. appreciable

Phys. Sp. = 0.29
(1984 version, Q=1.9)

C_2N_2

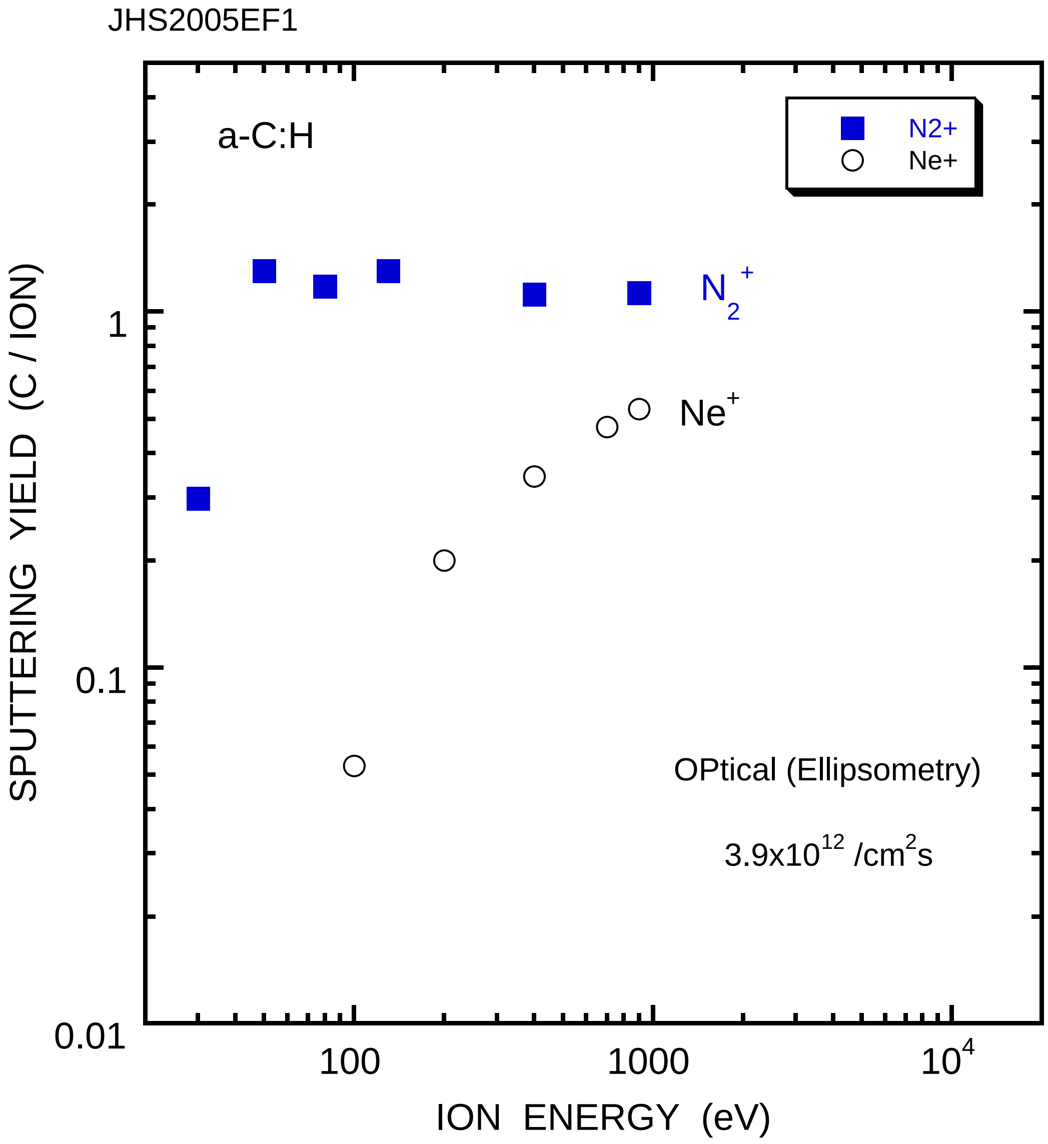


S. Grigull, R. Behrisch, S. Parascandola,J. Nucl. Mater. 275(1999)158.

Energy Dependence

N ion impact

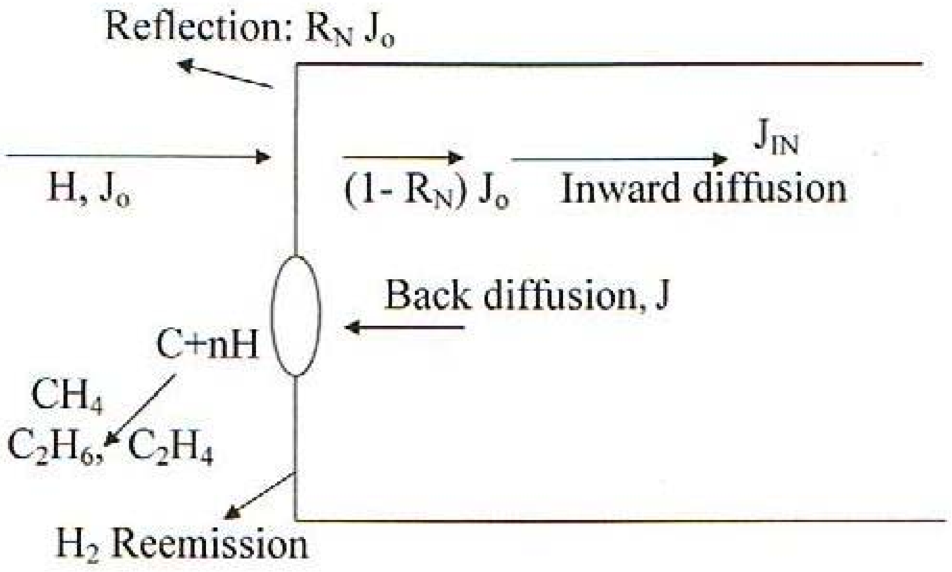
Chem. Sp. appreciable



W. Jacob, C. Hopf, M. Schluter, Appl. Phys. Lett. 86(2005)204103.

Model: pure graphite

S.K.Erents, C.M.Braganza, G.M.McCracken, J. Nucl. Mat.63(1976)399.



H -> O

Hydrocarbon ->

CO, CO_2

$Y_{chem}=n_H*cnst*\exp(-Q_1/RT)$,

n_H:H conc. at surfce, $dn_H/dt = J - Jo\sigma n_H - n_H/(\tau_0 \exp(Q_2/RT))$

ion-induced desorption thermal desorption

Q_1: 159kJ/mol, activation energy (heat of CH_4 formation?)

Q_2: 228kJ/mol

R_N: Reflection coefficient

Summary

- **Survey of chemical sputtering data: O, N impact effects**
- **Appreciable chemical sputtering**
- **CO is dominant for O impact**
- **Mechanism, similar to H impact??**

Future problems

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- **A simple analytical formula?**
- **Reemission, Retention**
- **Isotope effect**