炭素のケミカルスパッタリングII（添加物の効果）

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Background

- **Graphite for plasma walls**
- **<u>Chemical sputtering</u>: Reaction of H(D) with C, formation and escape of hydrocarbons, Ts~800K**

*** 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.**

*** 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., IPPJ-AM-41(1985)**

***Related phenomena: Reemission, Retention**

Literatures

Review (mainly undoped graphite)

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
*Doped-graphite : ~10 papers

Aim

* **Data compilation & understanding of chemical sputtering: Dopant effect,**
* **Control of chemical sputtering**

Dopant (10 elements)

B, Be

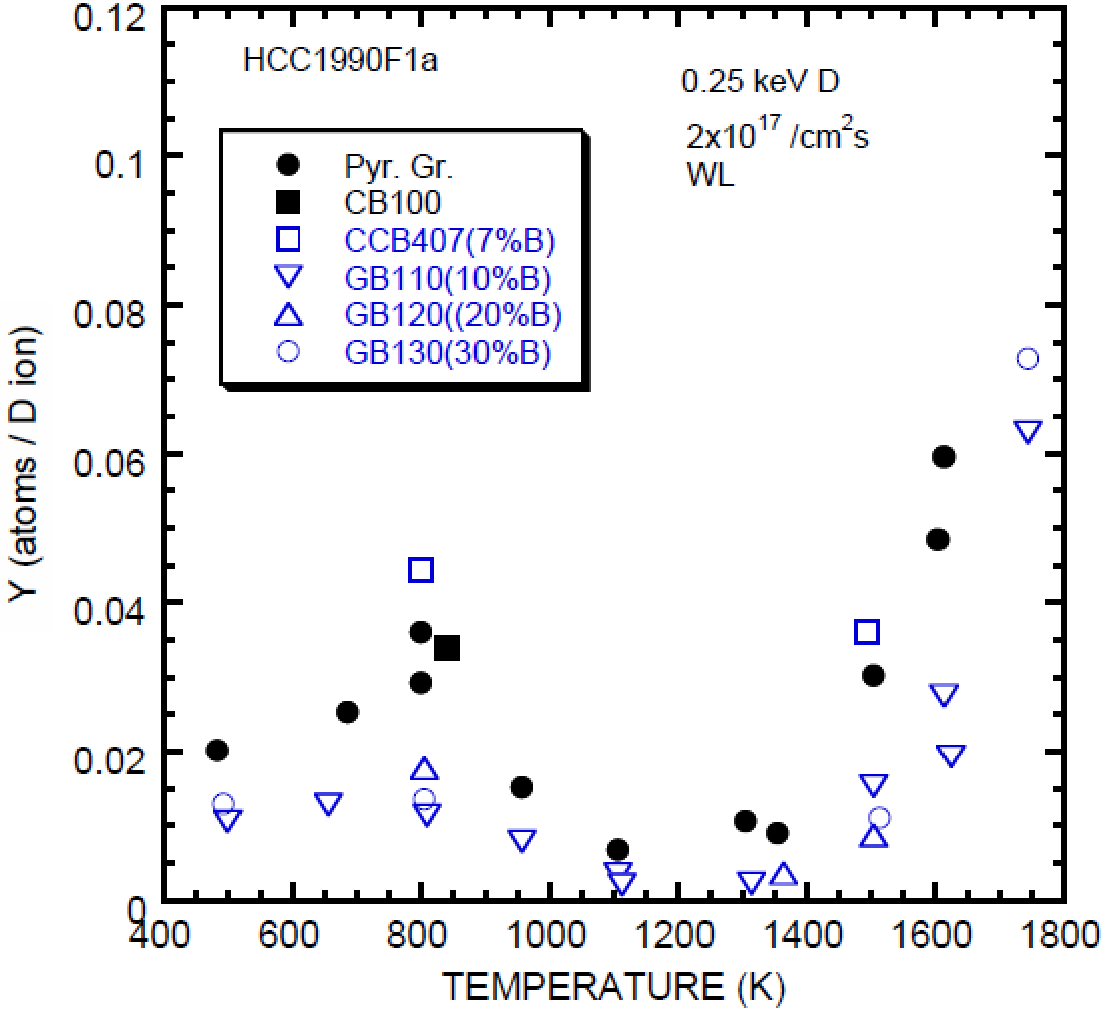
Si, Ti, W, V, Fe, Cr, Li, Zr

Temperature Dependence

Y. Hirooka, R. Conn, R. Causey, D. Croessmann, R. Doerner, D. Holland,M. Khandagle, T. Matsuda, G. Smolik, T. Sogabe, J. Whitley, K. Wilson, J. Nucl. Mater. 176&177(1990)473.

B-doping

Suppression of chemical sputtering



B-doping

More suppression

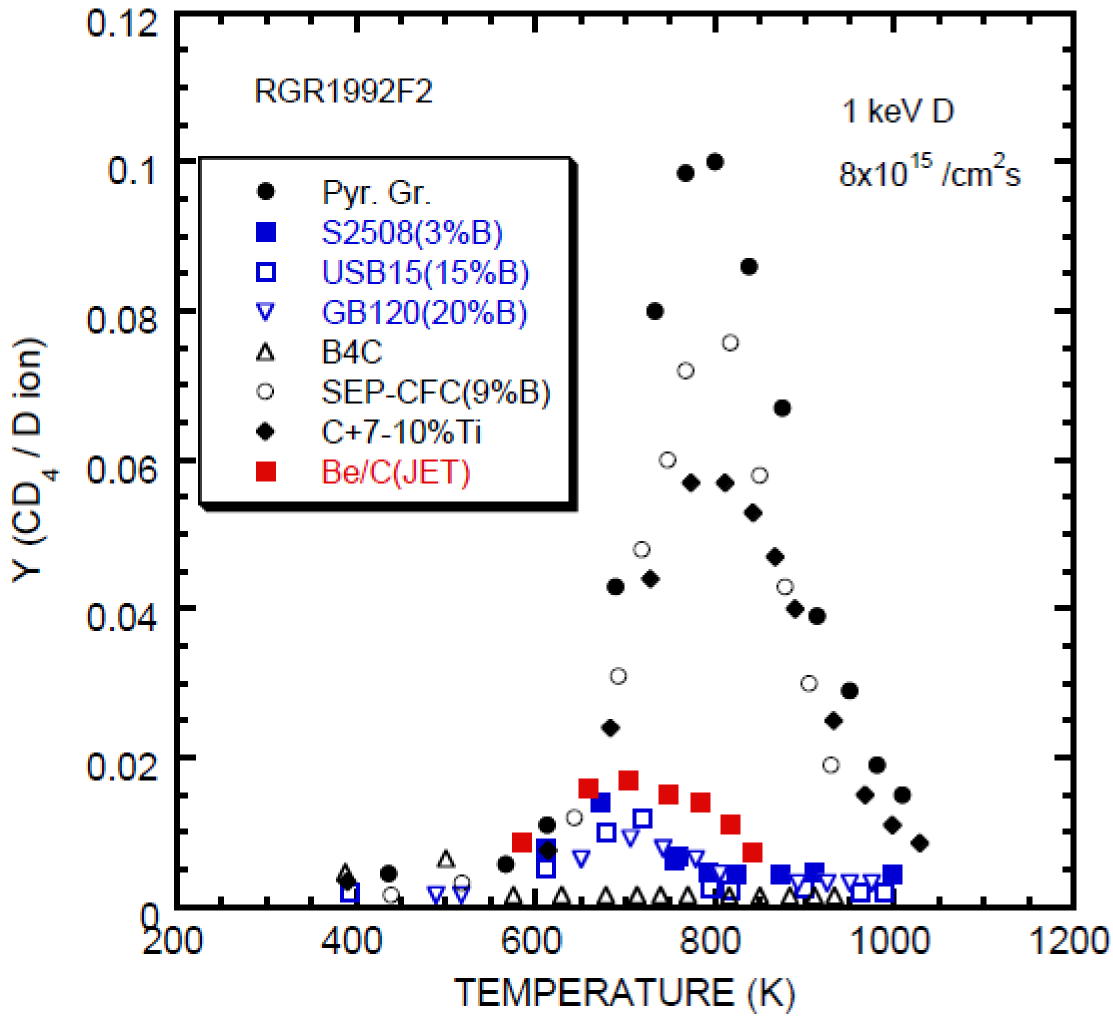
Energy dependence

Be-doping

Similarly to B-doping,

Strong reduction of chemical sputtering

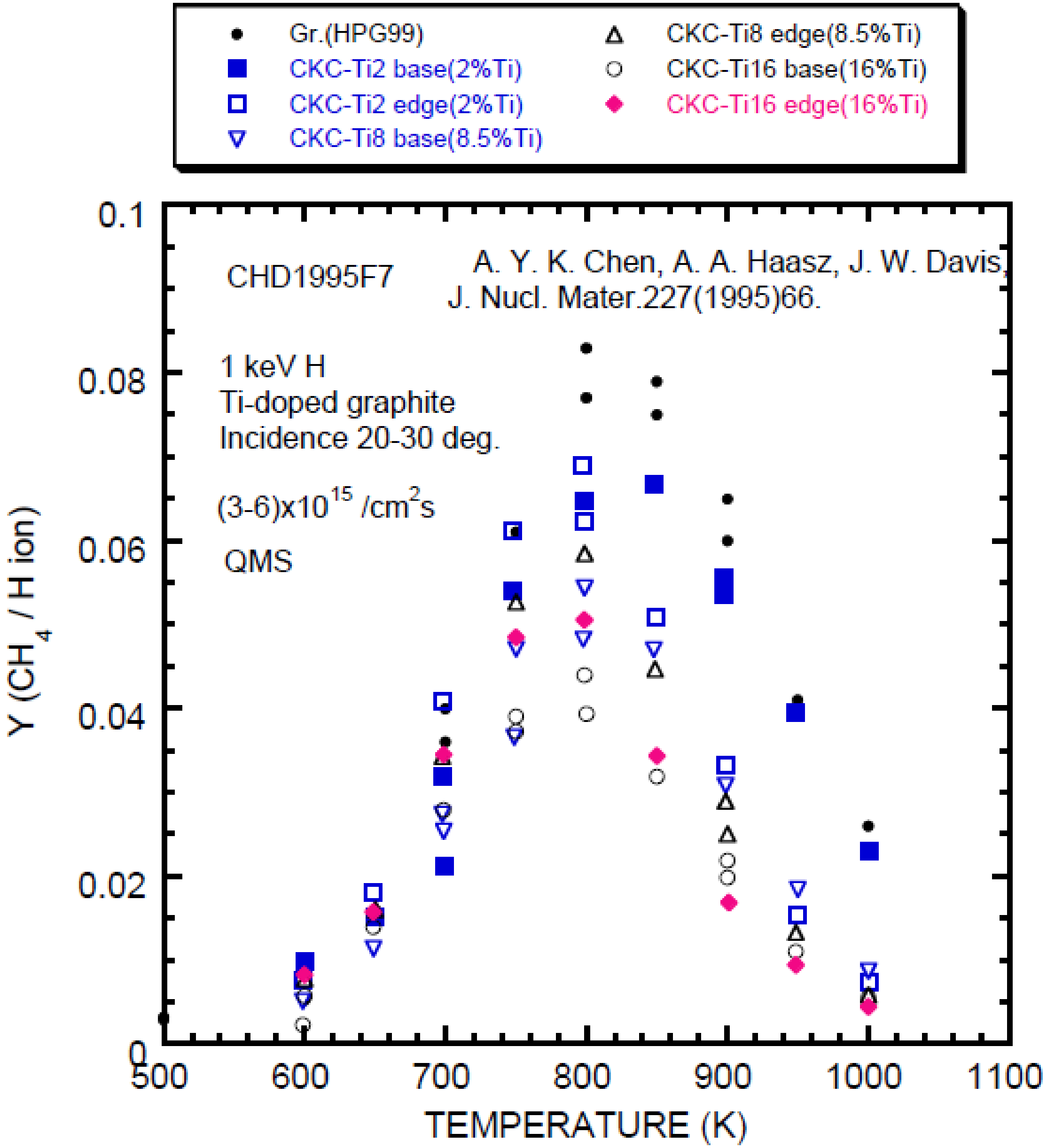
C. G.-Rosales, E. Gauthier, J. Roth,
R. Schworer, W. Eckstein
J. Nucl. Mater.1893(1992)1.



Ti-doping

Orientation-dependence

Edge > Base

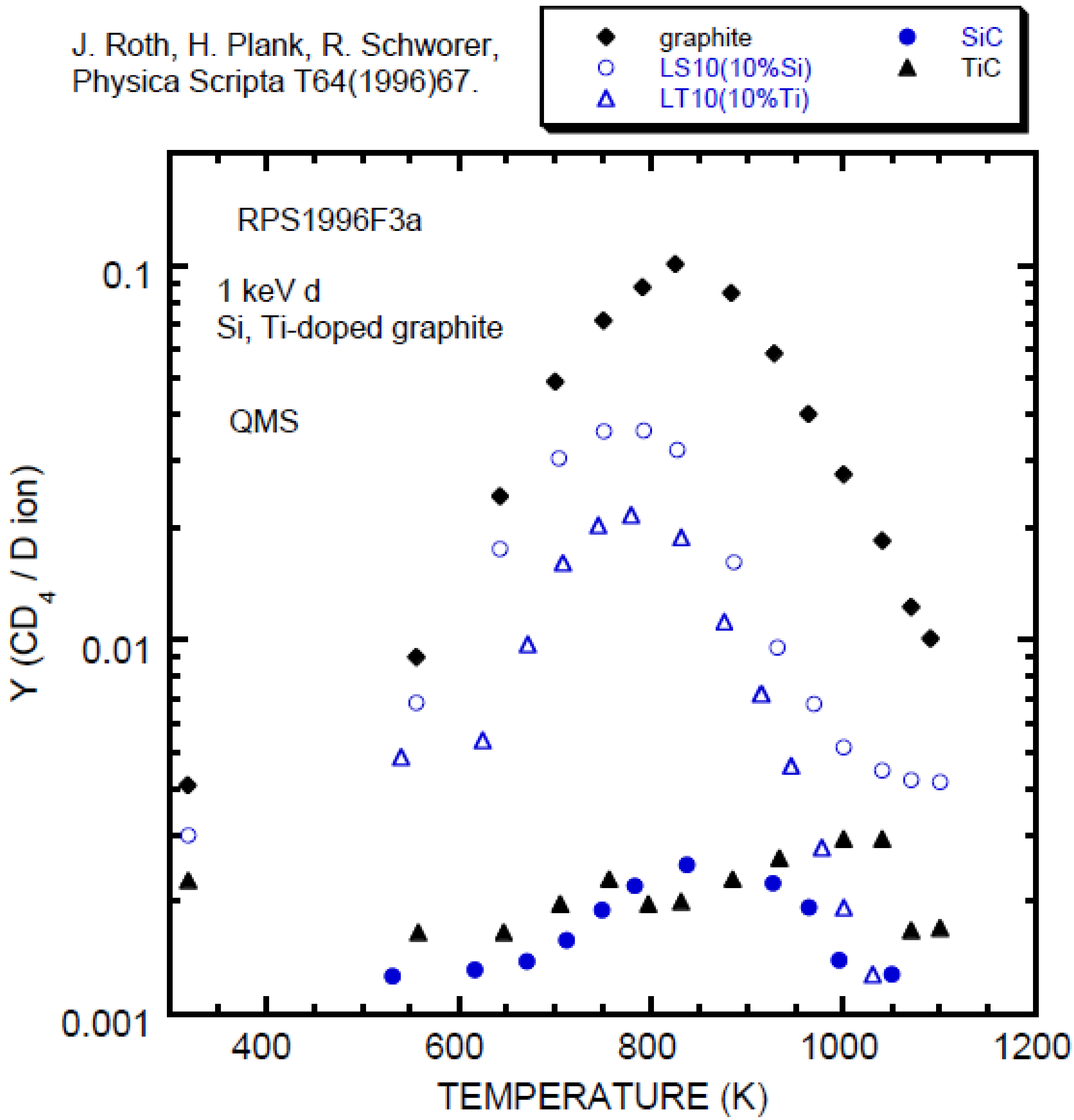


Si, Ti-doping

Chemical sputtering

SiC, TiC

J. Roth, H. Plank, R. Schworer, Physica Scripta T64(1996)67.

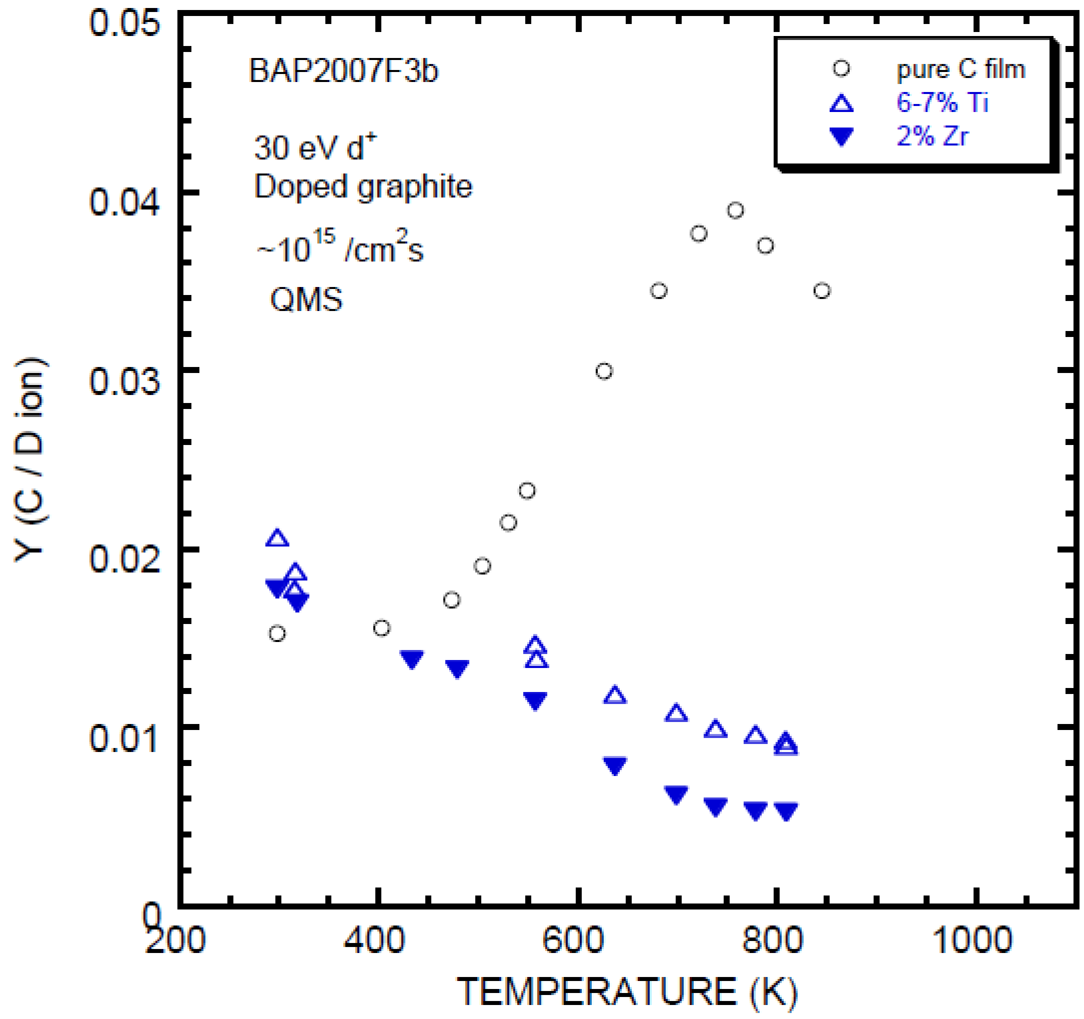


T-dependence

Monotonous decrease

NB very low energy

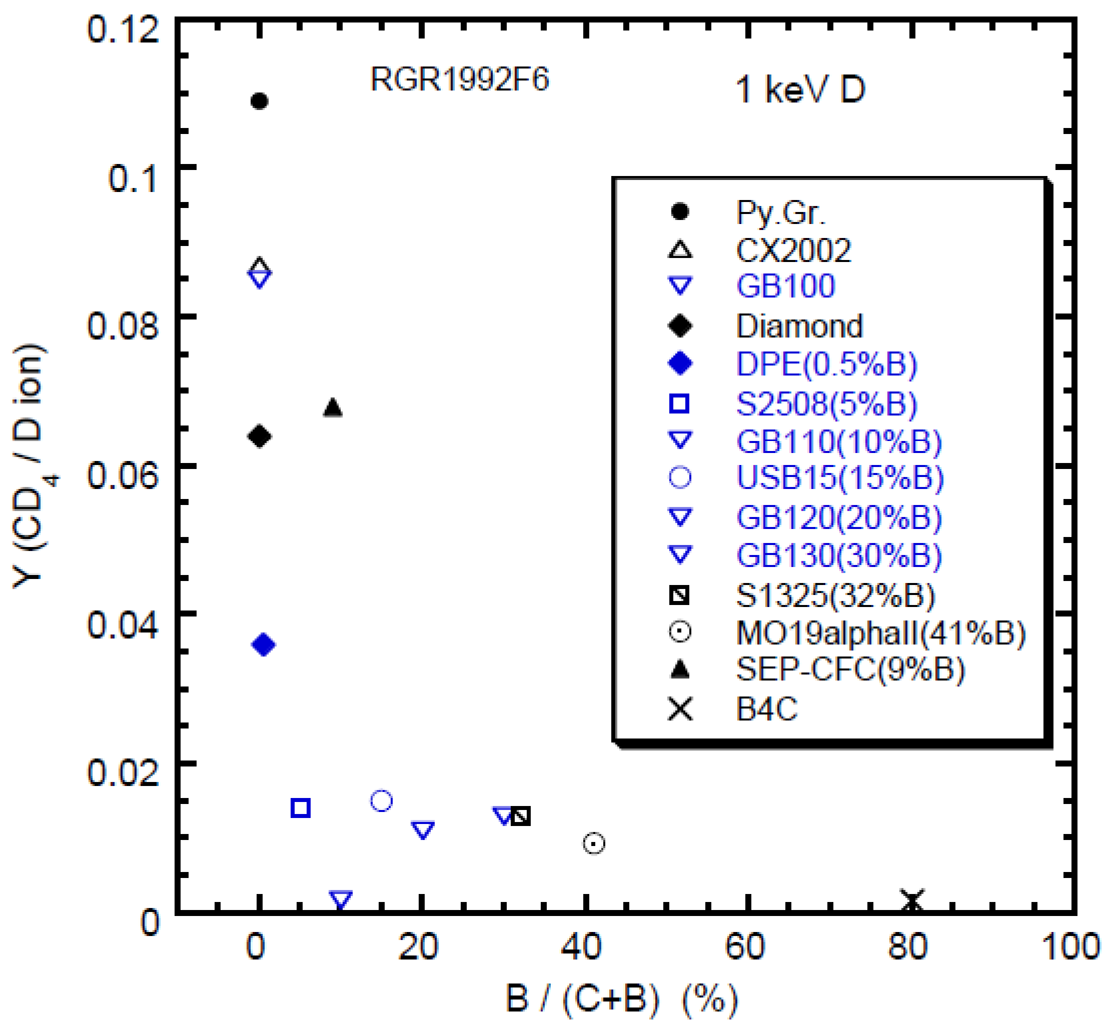
M. Balden, C. Adelhelm, E. de. J. Pardo, J. Roth, J. Nucl. Mater. 363-365(2007)1173.



Dopant concentration dependence

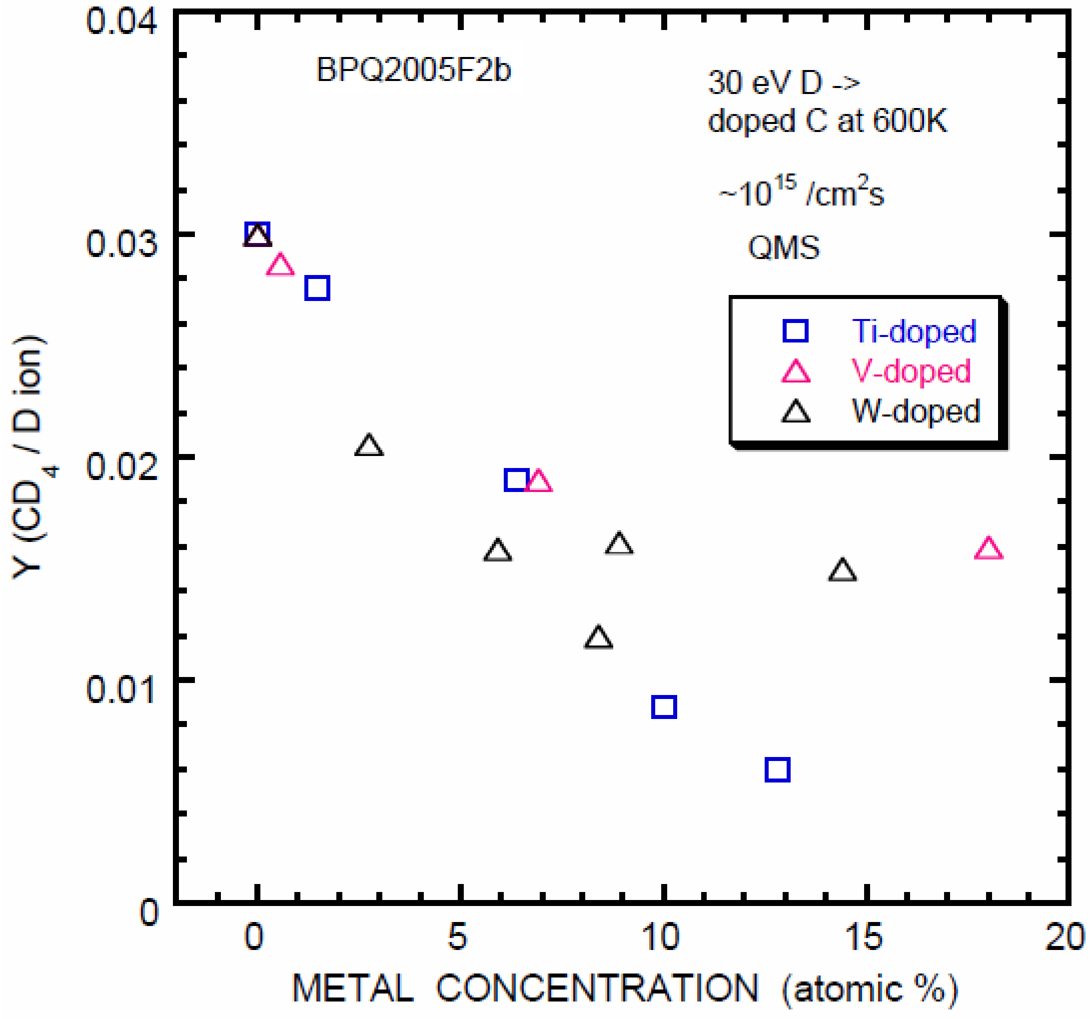
C. G.-Rosales, E. Gauthier, J. Roth, R. Schworer, W. Eckstein J. Nucl. Mater.1893(1992)1.

~10% B is effective for suppression

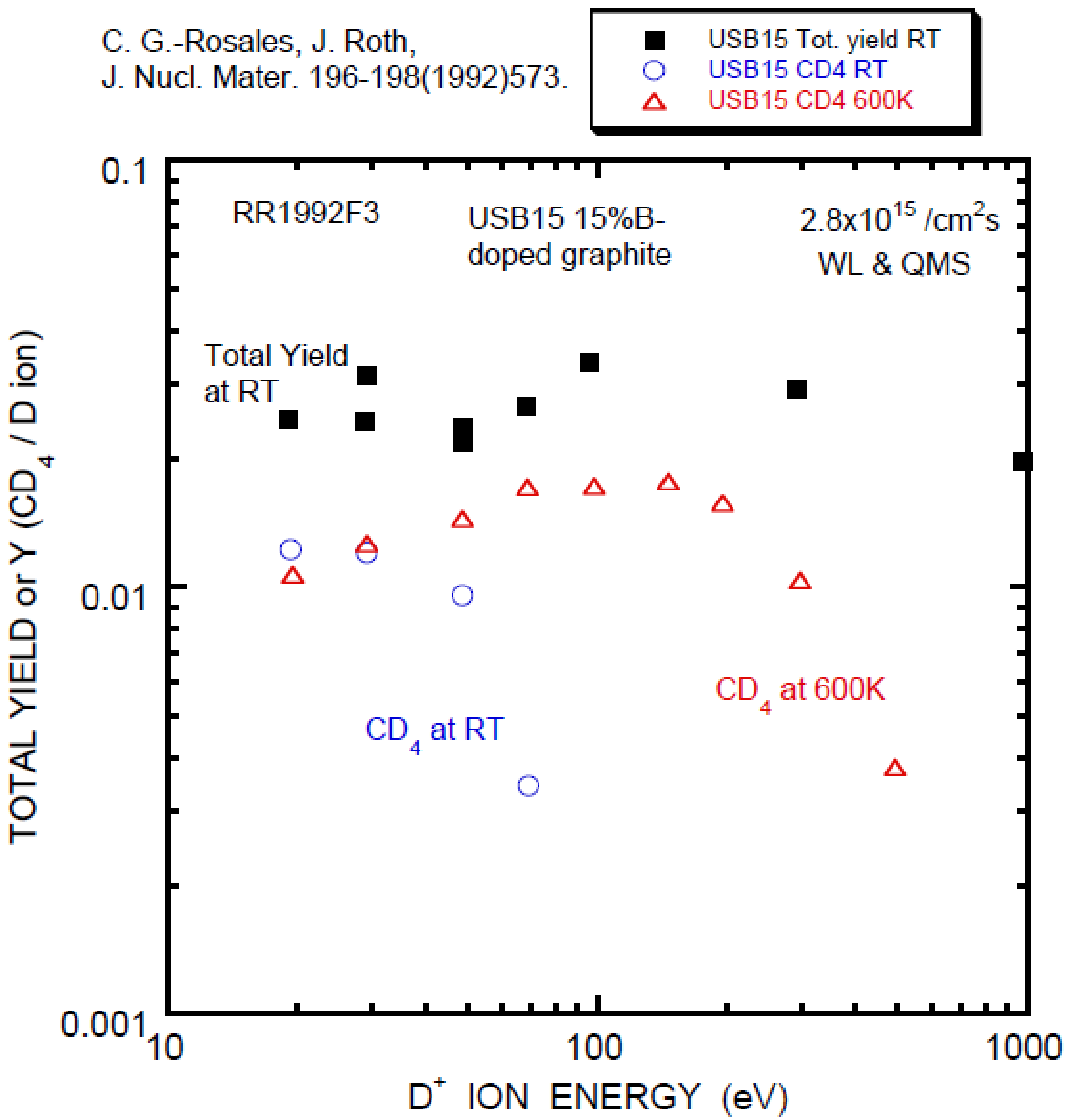


Ti, V, W-doping

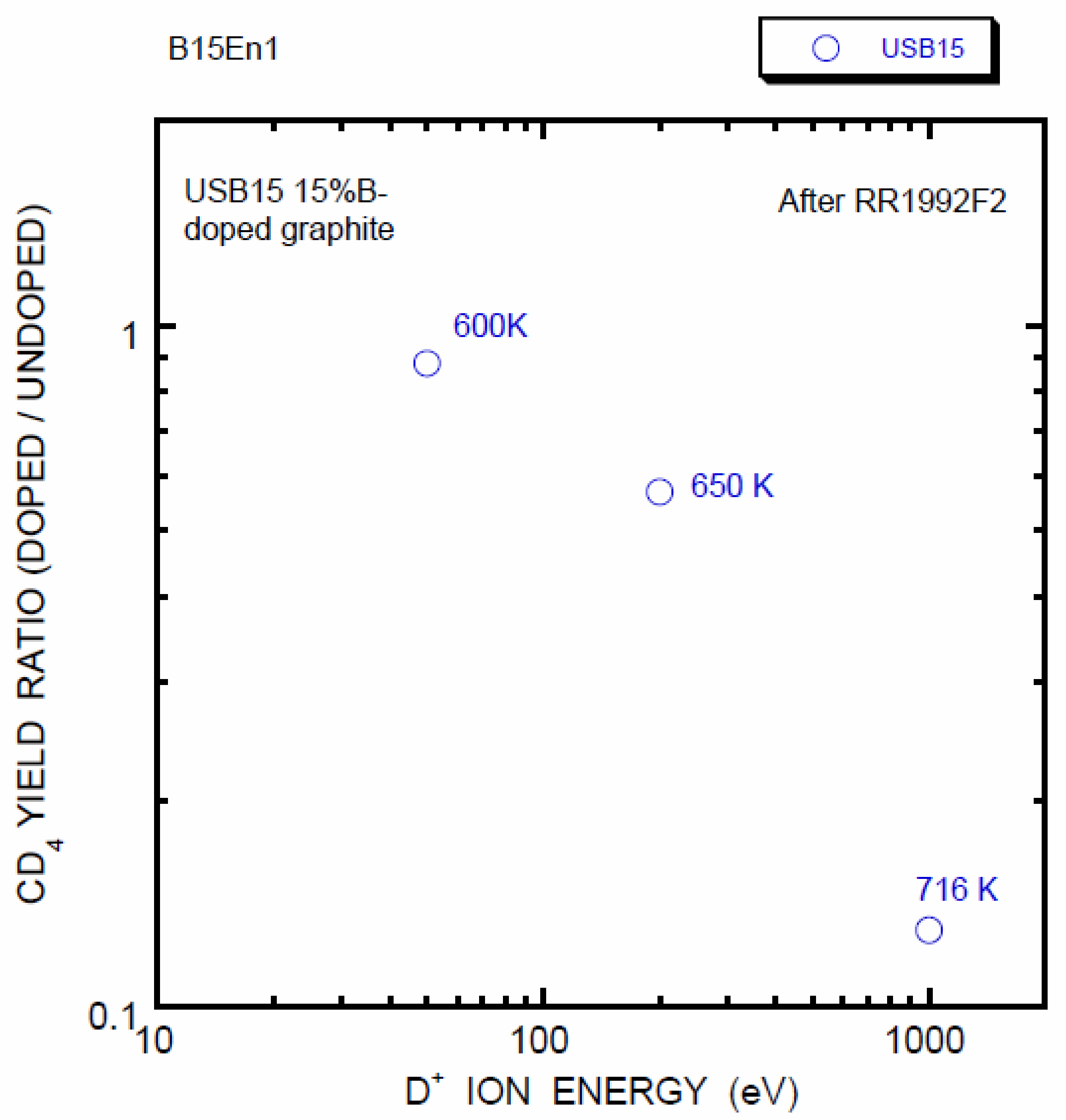
M. Balden, E. de. J. Pardo, I. Quintana, B. Cieciwa, J. Roth,
J. Nucl. Mater. 337-339(2005)980.



Energy dependence

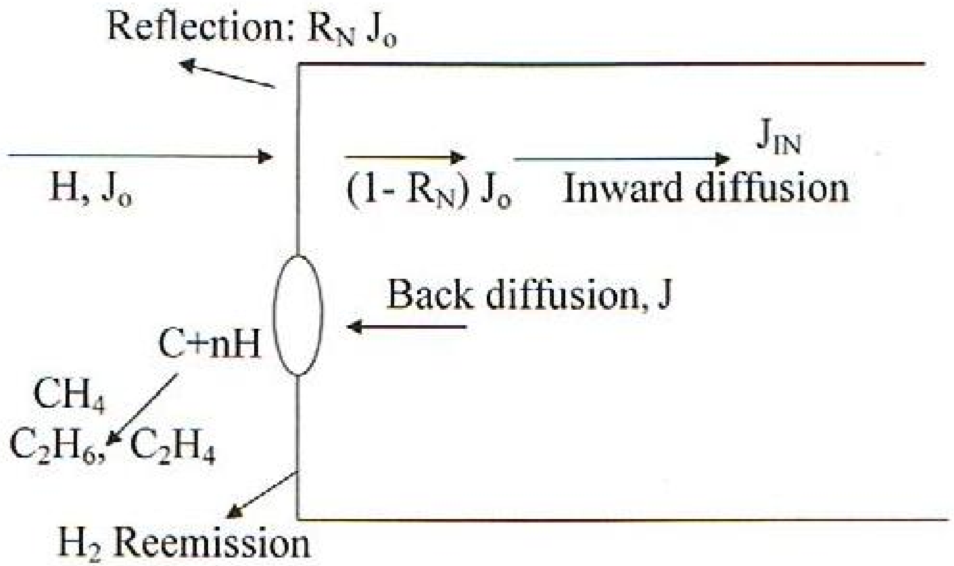


E-dependence of dopant effects



Model: pure graphite

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



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

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

ion-induced desorption   thermal desorption

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

Q_2: 228kJ/mol

R_N: Reflection coefficient

B depth profile

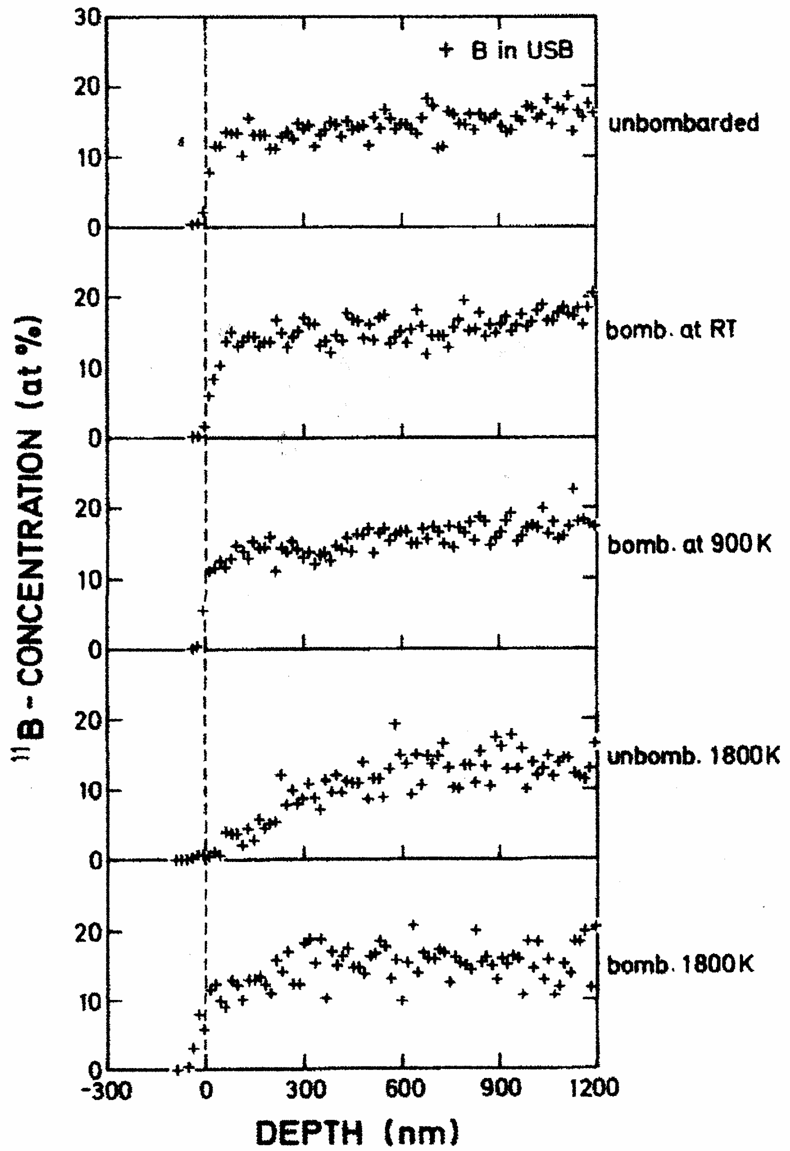


Fig. 5. Depth distribution of boron before and after bombardment of USB 15 with 1 keV D^+-ions at different temperatures. The depth resolution of the nuclear reaction technique is around 30 nm.

Rosales, Gauthier, Roth, Schworer, Eckstein, JNM 189(1992)1.

Summary

- **Survey of chemical sputtering data: dopant effects**
- **Dopant-carbide near the surface?**
- **H concentration at surface?**
- **Mechanism??**

Future problems

- **2008:Other ions than H**
- **Isotope effect**
- **A simple analytical formula?**
- **Reemission, Retention**