# §13. Simulation Calculations of Physical Sputtering Yields for Plasma-Irradiated Surface and a Fitting Formula for the Numerical Results

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Physical sputtering yields depend on the initial energy as well as on the incident angle of the primary particles. Then, the yields averaged over primary particles with a Maxwellian distribution are needed for more realistic estimation of the erosion rate due to the boundary plasma irradiation.

In this study physical sputtering yield from the carbon surface irradiated by the boundary plasma are obtained with the use of a Monte Carlo simulation code ACAT[1) ]. The yields are calculated for many random initial energy and angle of incident protons or deuterons with a Maxwellian distribution, and then averaged. Here the temperature of the boundary plasma, the sheath potential and the angle $\delta$ between the magnetic field line and the surface normal are taken into account. A new fitting formula for an arrangement of the numerical data is introduced, in which six fitting parameters are determined from the numerical results. These results provide a way to estimate the erosion of carbon material irradiated by boundary plasma.

As examples of the results the sputtering yields for deuterium ions from the boundary plasma with the temperature ratio $T_i/T_e=1$, where the magnetic field lines obliquely intersect the solid surface with indicated $\delta$ values, are given in Fig.1. The fact that the yields become larger for larger $\delta$ is attributed to the increase in the number of ions with glancing angles of incidence.

As a formula to fit the numerical sputtering data for incident particles with a velocity distribution, we have used a function $Y\ (T)$ of the plasma temperature $T$ [eV] of the form

$$Y\ (T) = Q_1 \sqrt{T}\ \frac{(1-(Q_2/T)^{Q_3})^{Q_4}}{1+Q_5 T^{Q_6}} \qquad (1)$$

where $Q_i$ (i=1,2,...,6) are parameters to be determined with a fitting procedure. Temperature $T$ is meant to be electron temperature. Ion temperature $T_i$ is introduced through a parameterized ratio of $T_i/T_e$ in the present calculation. The derived values of $Q_i$ of a fitting formula (1) for the projectiles indicated are listed inTable 1. The solid curves shown in Fig.1 are drawn using the fitting formula with the $Q_i$ values given in Table 1.

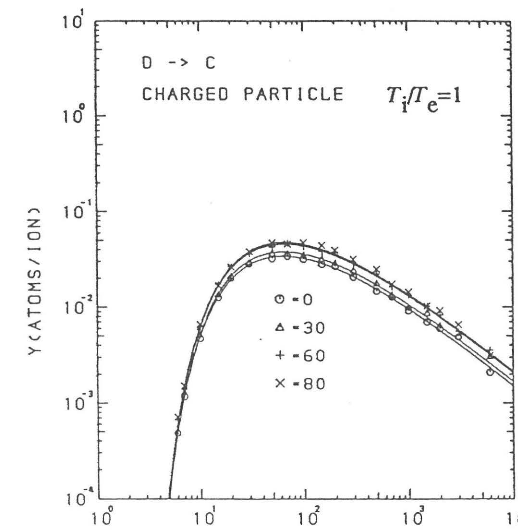


Fig.1

| projectile | Ti/Te | $\delta$ | $Q_1$ | $Q_2$ | $Q_3$ | $Q_4$ | $Q_5$ | $Q_6$ |
|---|---|---|---|---|---|---|---|---|
| $H^0$ | ---- | ---- | 2.978 | 0.1 | 0.38 | 84.68 | 0.0340 | 1.231 |
| $D^0$ | ---- | ---- | 6.494 | 0.1 | 0.40 | 80.74 | 0.0760 | 1.182 |
| $He^0$ | ---- | ---- | 20.27 | 0.1 | 0.31 | 54.04 | 0.0253 | 1.190 |
| $H^+$ | 1 | 0° | 1.141 | 3.6 | 0.65 | 8.284 | 0.41 | 1.41 |
| | 1 | 30° | 1.295 | 3.7 | 0.65 | 8.083 | 0.41 | 1.41 |
| | 1 | 60° | 1.496 | 3.7 | 0.65 | 8.116 | 0.41 | 1.41 |
| | 1 | 80° | 1.593 | 3.7 | 0.65 | 8.129 | 0.41 | 1.41 |
| $D^+$ | 1 | 0° | 2.330 | 2.7 | 0.52 | 7.158 | 0.35 | 1.40 |
| | 1 | 30° | 2.591 | 2.8 | 0.52 | 7.015 | 0.35 | 1.40 |
| | 1 | 60° | 3.186 | 2.7 | 0.52 | 7.268 | 0.35 | 1.40 |
| | 1 | 80° | 3.323 | 2.7 | 0.52 | 7.256 | 0.35 | 1.40 |
| $H^+$ | 5 | 0° | 1.093 | 0.12 | 0.58 | 48.09 | 0.50 | 1.37 |
| | 5 | 30° | 1.236 | 0.16 | 0.58 | 40.50 | 0.50 | 1.37 |
| | 5 | 60° | 1.627 | 0.20 | 0.58 | 35.56 | 0.50 | 1.37 |
| | 5 | 80° | 1.869 | 0.17 | 0.58 | 39.46 | 0.50 | 1.37 |
| $D^+$ | 5 | 0° | 2.950 | 0.10 | 0.51 | 36.21 | 0.39 | 1.42 |
| | 5 | 30° | 3.518 | 0.13 | 0.51 | 31.54 | 0.39 | 1.42 |
| | 5 | 60° | 4.564 | 0.16 | 0.51 | 28.27 | 0.39 | 1.42 |
| | 5 | 80° | 5.346 | 0.19 | 0.51 | 25.84 | 0.39 | 1.42 |

Table 1

1) Y.Yamamura and Y.Mizuno, IPPJ-AM-40, Institute of Plasma Physics, Nagoya University,1985