§14. Response of Plasma Facing Materials by High Fluence Particle Irradiation

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In the last year, chemical sputtering of graphite materials (isotropic graphite, carbon fiber composite, and boron doped graphite) was studied by irradiation of 5 keV D_3^+ beam with the flux up to 4 x 10^{**} m-2s-1, which is more than one order of magnitude higher than the previous low flux experiments (< 10^{20} $m^{-2}s^{-1}$). In this study, it was found that the methane yield at peak temperatures is almost independent of flux from 5 x 10^{20} $m^{-2}s^{-1}$ to 4 x 10^{21} $m^{-2}s^{-1}$. Peak temperatures range between 900 K and 1000 K, which is higher than those of the previous low flux experiments (< 900 K).

In order to construct comprehensive model of chemical sputtering, we made a comparison between our experimental results and chemical sputtering models. In 1990's , detailed study on bonding of hydrogen and carbon in amorphous C/H films was intensively carried out. These data provided a reliable picture of chemical reaction in C-H system[1]. By considering this chemical reaction, a new chemical sputtering models were proposed by Roth[2]. According to this model, the methane yield as a function of temperature is shown in Fig. 1.

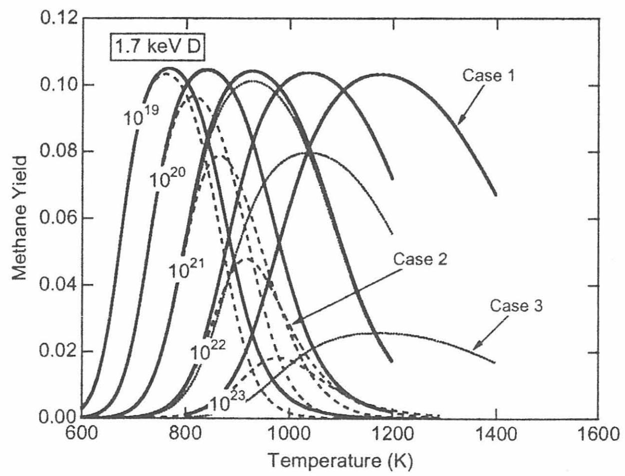

Fig. 1. Calculation results of methane yield based on Roth's model.

In Fig. 1, only thermal chemical reaction is considered for Case 1, while the effects of annealing (Case 2) and hydrogenation time (Case 3) are considered. The latter two effects cause yield reduction in high flux regime. In addition for Case 2, the peak temperature almost saturates with the increase of flux, while the other two cases, it increases continuously with flux.

By comparing these calculation results and our experimental results, it is found that the peak temperature change with flux shows good correspondence with those of Case 1 and Case 2. Therefore, it is inferred that the annealing effects of graphite is unimportant in our experimental conditions.

So far, the reason why the annealing effect do not reveal themselves in our experimental conditions is unclear. One of the conjectures for this is that high density active deuterium in graphite prevents graphitization to some degree.

In our experiments, a new high flux effects of methane release was found. In Fig. 2, the transient behavior of methane release just after beam termination is shown.

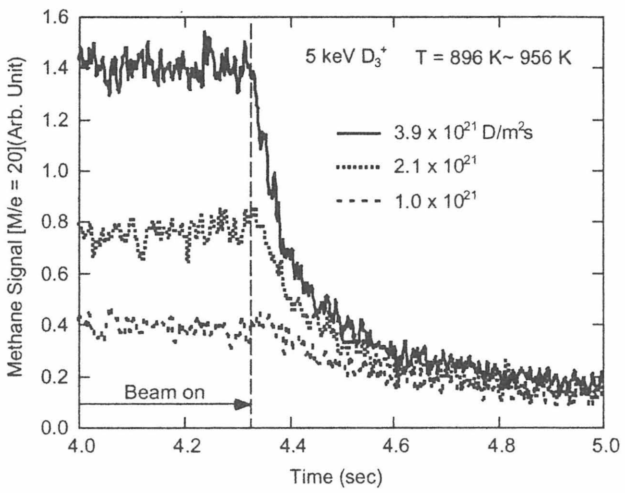

Fig. 2. Evolution of methane signals for different irradiation flux.

From this figure, it is clearly found that the decay behavior are clearly flux dependent. As the irradiation flux increases methane signal decays faster after beam termination. Eventually the methane signals for different fluxes approached to almost the same value after the time of 4.6 sec. This phenomena could relate to the behavior of dynamic retained methane molecules in graphite. In the case of the highest flux (3.9 x 10^{21} $m^{-2}s^{-1}$), it could be considered that large amount of methane molecules existed within the ion range and were desorbed during this fast decay period.

Reference
[1] A. Horn et al., Chem. Phys. Lett. 231 (1994) 193.
[2] J. Roth, J. Nucl. Mater. 266-269 (1999) 51.