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Study of sputtering and redeposition behavior of wall materials by high energy particle loads tests

高熱粒子負荷試験による壁材料の損耗・再堆積測定に関する研究

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Experimental setup of hydrogen ion/neutral loads facility in Kyoto University is prepared. This device is designed to study the sputtering and redeposition behavior of the plasma facing materials, in particular, tungsten. Monte Carlo simulations for the sputtering and redeposition behavior were performed in order to ensure the amounts of sputtered materials reaching to diagnostics. Calculation result indicates that the ion beam flux produce well enough sputtered particles in order to determine its quantity.

1. Introduction

In the fusion devices, plasma facing materials are required to survive irradiations by ion and neutral particle loads. Tungsten is expected to be a primary option for the first wall of the nuclear fusion power reactors such as DEMO [1, 2]. Although tungsten is one of the most resistant materials to sputtering and should not be sputtered by hydrogen ions with small energy, heavier particles, hydrogen ions and charge exchange neutrals with energy of 1 keV and above can cause sputtering from the tungsten surface. Although irradiation to the first wall by these particles should be avoided in the fusion power reactors, it is more realistic to assume presences of these particles. Because these ions and neutrals cause many physical phenomena in the complex environment at the fusion devices, a simple configuration ion/neutral beam device is useful to study the plasma-wall interactions of tungsten. In particular, behavior of sputtered material is difficult to observe by small energy ions from linear plasma devices commonly used for the wall studies [3]. Thus an experiment is designed to test the behavior of tungsten wall samples by the high energy hydrogen ion beam. This paper introduces experimental setup, preliminary result, and calculation result for this experiment.

2. Experimental

Experiments are performed in a main cylindrical vacuum chamber (length ~ 2 m, diameter ~ 1 m) connected to an ion source chamber. In the ion source chamber, hydrogen or deuterium arc plasma is discharged at the DuoPIGatron ion source. Produced positive ions are accelerated by the applied 30 kV potential and transported to the main chamber through a gate valve with a 60 cm diameter. It is expected that some of ions are neutralized during its transportation. In the main chamber, experimental setup is placed as shown in Fig.1. *In vacuo* movable diagnostics of Faraday's cup and calorimeter are set in front of this experimental setup in order to evaluate the beam property. Size of the beam is reduced to 30 cm diameter by a molybdenum cover before reaching to the sample holder. Target sample is a tungsten tile of a square 50 mm on a side with a 1 mm thickness, and tilted at 45^{o} to the beam. This angle can be changed to study the dependence of the angle of incidence. Sputtered materials are collected by a collector plate or a Quartz Crystal Microbalance (QCM.) It is possible that this configuration slightly changed in future so that QCM collects "thirdly" sputtered materials from the

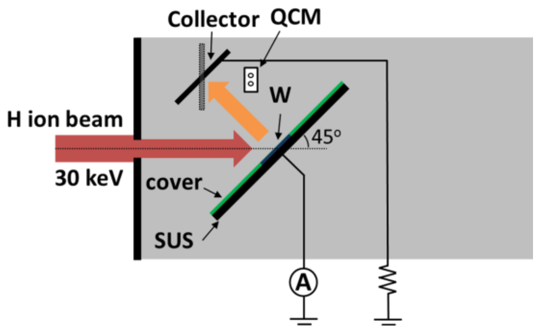

Fig.1. Experimental setup

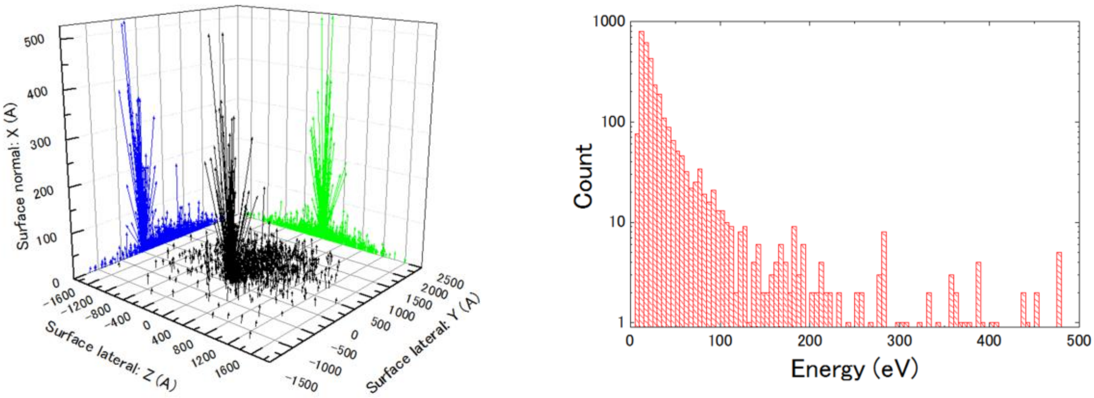

Fig.2. Monte Carlo calculation result of space distribution (left) and energy distribution (right) of tungsten particles sputtered by the 30 keV H^+ ions with 45 ^{o} of the angle of incidence.

collector. In addition, the experimental setup is designed to be able to apply a magnetic field in order to observe the prompt redeposition.

A LaB_6 filament is installed in the DuoPIGatron ion source and tested with several shots. Optimizing length and timing of the hydrogen gas injection, hydrogen arc plasma is maintained for a second with ~ 60 A. Combined with the reference data, it is expected that the incident flux reaches 10^{21} - 10^{22} /m^2/s.

3. Simulations

Sputtering behavior is simulated by a Monte Carlo simulation code; TRIM [4]. Calculated result of distributions of sputtered tungsten particles are shown in Fig.2. As shown in this figure, it is expected that there are two groups of sputtered particles. One group is originating from a spot near the incident point and having the cosine distribution. Particles from this group contains small amounts of particles with a energy of > 100 eV. The secondary particles ejected from Y > 0 are another group. It is expected that the momentum of the incident hydrogen ions transfer to the atoms over the incident point because of the 45 degree of the angle of incidence

In the experiment, tantalum tape is attached on the collector surface in order to examine the sputtered tungsten particles. TRIM calculation shows that reflection coefficients are < 10 % for sputtered tungsten particles with < 100 eV of energies and 45^o of the angle of incident. Thus, at least 90 % of sputtered particles remain on the tantalum plate while tantalum is sputtered with sputtering yields of around 0.01 - 0.05. In order to have a monolayer of tungsten, it is estimated that ~ 10 seconds of irradiation is enough. If a quartz crystal microbalance is used to measure the weight of sputtered particles, assuming 0.1 % of sputtered particles reach to the crystal surface, frequency change of crystal reaches ~ 10 Hz/s which is enough for the weight determination.

5. Summary and future works

Experimental setups with preliminary result and simulation result for the experiment of ion and neutral irradiation to the tungsten target are introduced. Recently installed LaB_6 filament improves the arc performance of the ion source. It is shown that the ion/neutral beam facility has a capability to measure the sputtering of tungsten by hydrogen particles.

References

[1] K. Tobita, S. Nishio, M. Enoeda, H. Kawashima, G. Kurita, H. Tanigawa, H. Nakamura, M. Honda, A. Saito, S. Sato, T. Hayashi, N. Asakura, S. Sakurai, T. Nishitani, T. Ozeki, M. Ando, K. Ezato, K. Hamamatsu, T. Hirose, T. Hoshino, S. Ide, T. Inoue, T. Isono, C. Liu, S. Kakudate, Y. Kawamura, S. Mori, M. Nakamichi, H. Nishi, T. Nozawa, K. Ochiai, H. Ogiwara, N. Oyama, K. Sakamoto, Y. Sakamoto, Y. Seki, Y. Shibama, K. Shimizu, S. Suzuki, K. Takahashi, H. Tanigawa, D. Tsuru, T. Yamanishi and T. Yoshida: Nuclear Fusion **49** (2009) 075029.

[2] D. Maisonnier, I. Cook, Sardain Pierre, Boccaccini Lorenzo, Bogusch Edgar, Broden Karin, Di Pace Luigi, Forrest Robin, Giancarli Luciano, Hermsmeyer Stephan, Nardi Claudio, Norajitra Prachai, Pizzuto Aldo, Taylor Neill, Ward David: Fus. Eng. Des. **75-79** (2005) 1173.

[3] N. Ohno and T. Shuichi: J. Plasma Fusion Res. **77** (2001) 864.

[4] J. F. Ziegler, J. P. Biersack and M. D. Ziegler: *SRIM –The Stopping and Range of Ions in Matter* (SRIM Co., 2008.)