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TOF measurement of electron volt energy hydrogen atoms reflected by stainless-steel surface

Masafumi Akiyoshi *, Hiroyuki Sakamoto, Ryusuke Haraguchi, Kimikazu Moritani, Ikuji Takagi, Hirotake Moriyama

Department of Nuclear Engineering, Kyoto University Yoshida, Sakyo-ku, Kyoto 606-8501, Japan

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Abstract

Reflection behavior of hydrogen ions with electron volt energy on stainless-steel surface was investigated by time-of-flight (TOF) measurement. First, the flight time of atomic hydrogen ions (not molecular ions or neutral atoms) from the RF plasma was measured. Good agreement with a Maxwell–Boltzmann (M–B) distribution was found, with a temperature of 11,000 or 12,000 K depending on plasma and vacuum conditions. Next, the flight time of atomic hydrogen ions reflected 90° by a stainless-steel surface was measured. In this case, the velocity distribution consisted of two components, corresponding to M–B distributions, one with 9500 or 6000 K and a second one with 300 K. The former and the latter correspond to direct reflection and desorption, respectively. In case of direct reflection, the observed energy reflection coefficient for hydrogen is in the range 0.86–0.5. Lower values of the energy reflection coefficient are an indication that the incident hydrogen atom has interacted with two or more hydrogen atoms on the surface before being released. In case of desorption, a hydrogen atom will be desorbed by a non-thermal process such as electron-induced or particle-induced desorption, since by thermal desorption hydrogen particles are desorbed as molecules, not as atoms.

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1. Introduction

The reflection of hydrogen particles from plasma-facing walls in fusion reactors is a process important in tritium inventory and in hydrogen fuel recycling. In the kilo electron volt energy regime, many experimental and simulation

* Corresponding author. Tel./fax: +80 75 753 4837.
E-mail address: akiyoshi@nucleng.kyoto-u.ac.jp (M. Akiyoshi).

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investigations have been carried out on the interaction between energetic particles and various materials [1,2]. However, at and below electron volt energies, little information is available, because only very few methods permit to determine the energy of particles at such low energy. Simulations of the hydrogen particle reflection from a clean metallic surface showed that the reflection coefficient was very low and hydrogen atoms form molecules when being desorbed [3,4].

Recently, we studied experimentally the reflection of atomic hydrogen using a plasma-driven permeation (PDP) probe [5,6]. It had been generally assumed that a hydrogen atom with an energy of a few electron volts tends to recombine and is subsequently desorbed as a molecule from solid surfaces that are covered with hydrogen. Our results, however, indicated that a large amount of hydrogen atoms with an energy of a few electron volts survived recombination and the atomic fraction among reflected particles was very significant. In addition, the amount of hydrogen atoms reflected from a solid surface exhibited a temperature dependence that was very close to that of the surface density of hydrogen, measured by nuclear reaction analysis (NRA). In those studies, a palladium membrane was used as an atomic hydrogen detecting PDP probe. With this probe, only the number of atoms could be counted, and no information was obtained on the energy of the particles. Thus, also the energy of hydrogen atoms effused from RF plasma, before a reflection, was not resolved.

In this study, we used a time-of-flight (TOF) method to measure the velocity distribution of the low-energy particles. Using this method, energy reflection coefficients were obtained for several plasma conditions by measuring the energy of the atoms before and after reflection.

2. Experimental

In this study, an RF plasma was used as an atomic hydrogen source, and a mechanical chopper and a quadrupole mass analyzer (QMA) were used to obtain the time-of-flight (TOF), and from this, the energy of the particles was calculated.

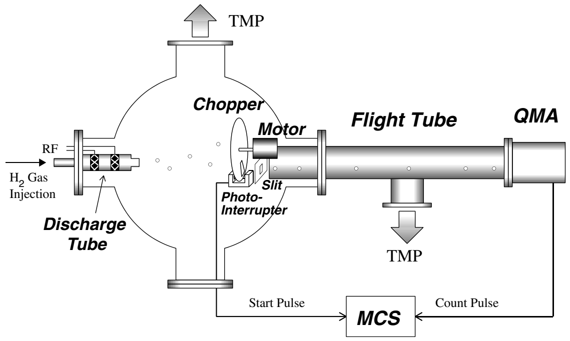

Fig. 1. A scheme of experimental setup for RF plasma energy measurement.

Usually, an ion source in front of the QMA is used to ionize the neutral particles, but at very low energy, the particles suffer serious energy change during the ionizing process. Therefore, no ion source was used and particles ionized in the RF plasma were detected. In addition, as the mass number was fixed to 1, only atomic hydrogen ions were detected, that is, neutral hydrogen atoms or molecular hydrogen ions were not measured.

Our experimental setup is schematically shown in Figs. 1 and 2. A slit was fixed on a plate that covered one end of the flight tube, and a rotating disk with a slit was set in front of the fixed slit. These two slits composed a mechanical chopper, and a photo interrupter was used to generate the start pulses. The rotating speed of the disk was

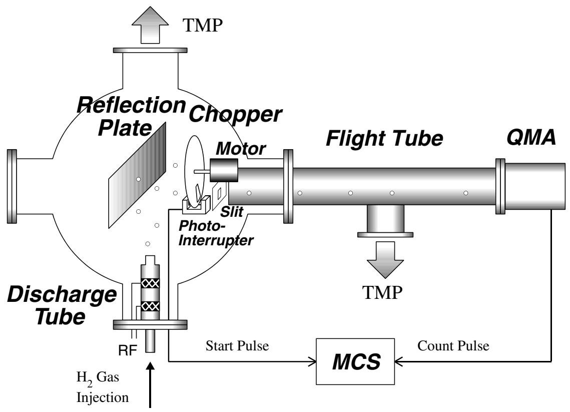

Fig. 2. A scheme of setup for reflection experiment.