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High flux ion beam acceleration at the 100-eV level for fusion plasma facing material studies

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Abstract

For the investigation of interactions between the low energy ions in fusion edge plasmas and plasma facing materials, new electrodes for beam extraction have been developed to achieve a 100-eV level, high-flux and steady state operation with large irradiation area in the super low energy ion source (SLEIS) facility. The structure of these electrodes has a multi-aperture triode electrodes, whose size is smaller than conventional ones. Namely, these electrodes with the thickness of 0.5 mm have a multi-aperture of 0.9 mm in diameter. The gap distance between electrodes is 0.5 mm. Ion fluxes have been achieved from 1.7×10^{20} to 5.3×10^{20} H/m^2 s with the energy from 32 to 102 eV/H. This paper also presents a study about the temperature dependence of blister formation of tungsten by using this new hydrogen ion beam.

Keywords: Ion beam; Low energy; High flux; Plasma–wall interaction

1. Introduction

It is important to investigate the interactions between the low energy ions in fusion edge plasmas and plasma facing materials (PFMs) for the estimation of the lifetime of PFMs, the contamination of fusion plasma by eroded particles, and the tritium retention in PFMs [1,2]. PFMs will be exposed to high-flux hydrogen isotope ions with the energy of less than 100 eV at the divertor in fusion reactors and eroded by sputtering or blistering. In the case of ITER, for example, the ion flux is expected to be 10^{20}–10^{24} (DT/m^2 s) [2]. Therefore, it is necessary to develop a 100-eV level, high-flux, steady state and large irradiation area ion source for material studies.

We have developed new electrodes for the beam extraction to achieve a 100-eV level, high-flux ion beam acceleration. The structure of these electrodes has multi-aperture triode electrodes, whose size is smaller than conventional ones. These electrodes were installed in the super low energy ion source, SLEIS [3,4].

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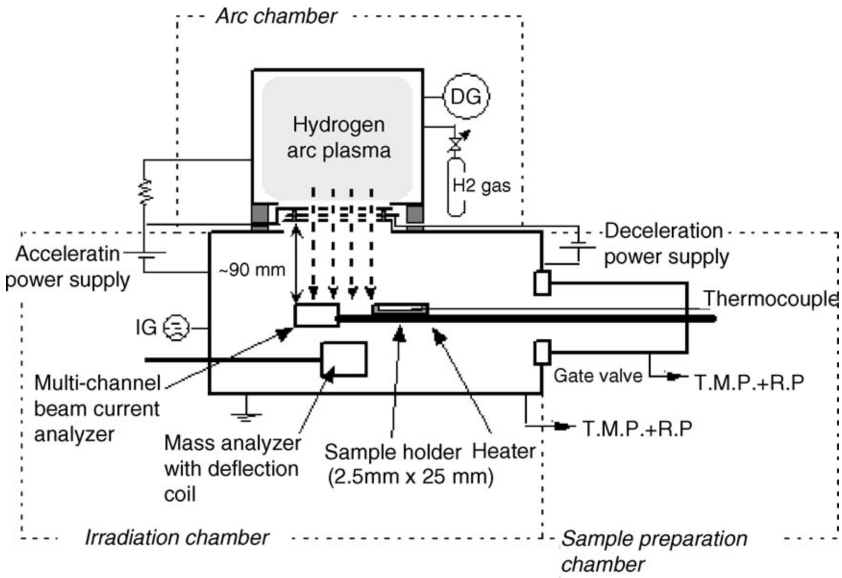

Fig. 1. Schematic diagram of super low energy ion source (SLEIS).

To demonstrate the efficiency of developed ion beam, this paper also presents the study about hydrogen ion irradiation of tungsten. Tungsten is a candidate for the PFMs at the divertor, and so the interaction between hydrogen ions and tungsten is one of the critical issues for plasma wall interactions [1,2]. Some researchers recently reported that blistering was observed after hydrogen ion irradiation with an energy of less than 100 eV [5–7]. However, there are few data about the temperature dependence of the blister formation, though the temperature is expected to significantly affect the blistering. Here we perform hydrogen ion irradiation of tungsten at various temperatures to address this issue.

2. Experimental

The schematic diagram of SLEIS [3,4] is shown in Fig. 1. Source plasmas are produced by hydrogen arc discharge with tungsten filaments. Hydrogen ions are extracted by the new electrodes. Fig. 2 shows a photograph and schematic diagram of the new electrode set, which consist of three electrodes, namely acceleration, deceleration and ground electrodes. To simplify the structure and the installation, the deceleration and ground electrodes are mounted on the accelera-

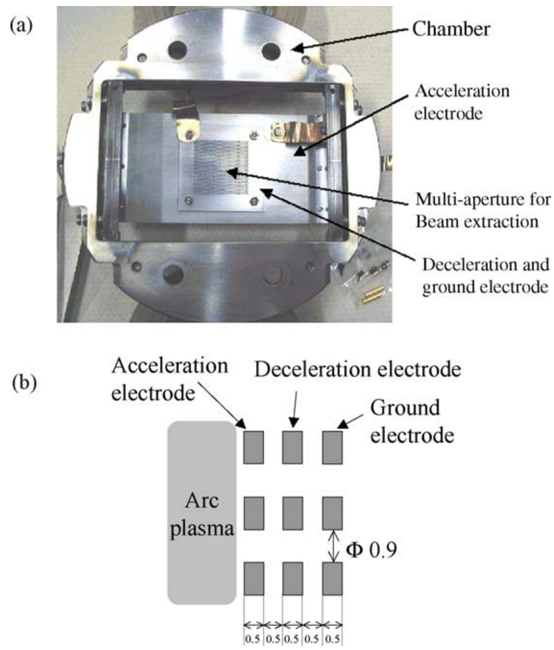

Fig. 2. (a) Photograph of the new electrodes. To simplify the structure of electrodes and the installation, the deceleration and ground electrodes are installed on the acceleration electrode with insulators. (b) Dimension of new electrode system. The number of aperture is 725 in the area of 38 mm × 38 mm.