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Hydrogen transport in liquid metals under steady state plasma bombardment

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Introduction

The application of liquid metals for plasma-facing components (PFC) draws increasing interest as a potential means to resolve the technical issues associated with exhaust power and particle handling in magnetic fusion devices. Molten Lithium is one of the candidates and has been used in fusion devices such as NSTX [1] and EAST [2]. In these confinement devices, it is believed that the interaction between plasma and lithium plays an important role in determining edge plasma characteristics and hence core confinement performance. GaInSn, with low reactivity and toxicity, is a kind of liquid metal at room temperature. In JxB-force convected liquid metal experiment, flowing GaInSn has also shown ability of reducing both hydrogen and helium recycling when facing to plasma bombardment [3]. Then it is deduced that GaInSn is also promising for PFC in fusion reactors, though more information is needed to evaluate the feasibility.

Hydrogen diffusivities in the bulk of materials and surface recombination coefficients are essential parameters to study hydrogen retention and hydrogen transport [4]. However, little information is available in literature for liquid lithium and GaInSn. Due to their critical importance to the application of liquid metals in fusion reactors, these technical issues must be clear addressed.

Experimental

In the present work, an innovative experimental technique holding liquid metals on a sheet mesh by surface tension has been put together for the plasma-driven permeation (PDP) experiments. Shown in Fig. 1 is the PDP setup in a laboratory-scale plasma device, VEHICLE-1. The electron temperature is~ 10eV and the plasma density is of the order of 10^{10} cm^{-3}. The ion bombardment flux is of the order of 10^{16} cm^{-2}, and the bombarding energy is set at 100 eV by applying a negative DC bias on the sample tray. A liquid metal sample is fixed in such a way that the upstream surface is exposed to hydrogen plasma, while the downstream side is pumped to ultrahigh vacuum (10^{-6}-10^{-5} Pa). A resistive heater is positioned beneath the mesh to control the sample temperature, which is measured by a thermocouple. The hydrogen permeation flux due to PDP is monitored by the partial pressure of H_2 measured by a quadrupole mass spectrometer (QMS).

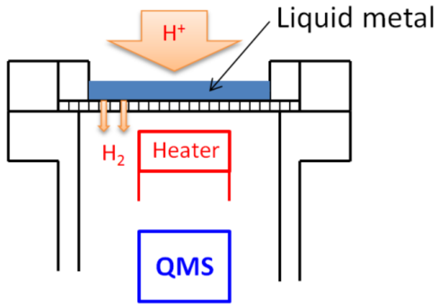

Fig.1 Schematic diagram of the experimental setup for PDP through liquid metals

Results

Hydrogen PDP experiments through liquid lithium and GaInSn have been conducted respectively in the temperature range of ~300-500°C. It has been found that hydrogen PDP through lithium is recombination limited. As a result, hydrogen surface recombination coefficients have been obtained. For GaInSn, hydrogen PDP breakthrough curve has been obtained, which is compared with simulation results for different hydrogen diffusivities, shown in Fig.2.

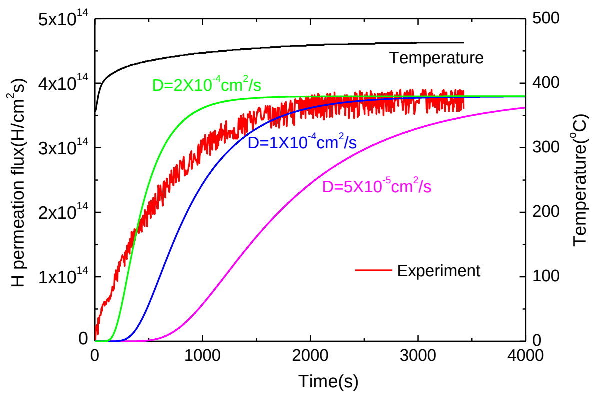

Fig.2 A comparison of experimental data and simulation results on hydrogen PDP breakthrough curve for GaInSn.

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