Fusion Engineering and Design 89 (2014) 2919–2922

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Expanding argon plasma interacting with lithium surface

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HIGHLIGHTS

- The interactions between argon plasma and lithium were examined.
- With increasing temperature greater than the melt point, the evaporation of lithium significantly increases.
- With increasing discharge current, gas flow rate and magnetic field, the emission intensity of Li at 670.78 nm, the electron temperature and the electron density increase.

ARTICLE INFO

Article history:
Received 30 November 2013
Received in revised form 25 July 2014
Accepted 28 July 2014
Available online 10 September 2014

Keywords:
Lithium
One-cathode
Argon plasma
Emission spectrum
Fusion

ABSTRACT

In this thesis, the interaction between Ar Plasma and lithium is studied by Langmuir probe and Spectrometer. We have studied the effects of the applied discharge current, the gas flow rate, the magnetic field on emission spectrum, electron temperature and electron density. The experimental results show that spectrum intensity, electron temperature and electron density all increase with the increasing discharge current, gas flow rate or magnetic field when the other experimental conditions were fixed, and it is also found that the intensity of Li-670.78 nm increases slowly at first and then increases rapidly, at last, it tends to be stable figure at the beginning of experiment. What is more, spectrum of lithium (670.78 nm) is also detected at the first diagnostic window (viewing window).

1. Introduction

With many advantages of removing the high heat flux directly, removing impurities and self-renewing continuously, liquid lithium as plasma facing component (PFC) materials is attracting more and more attention [1–8]. In order to understand the interactions between plasma and free lithium surface, lots of experiments have been done on different tokamak devices such as T-3M, TFTR T-10M, T-11M, NSTX, JIPP-TIIU, DIII-D, HL-1M [4,7,9–14]. However, due to the extreme fusion environments in these facilities, it is experimentally difficult to characterize plasmas interacting with surfaces. Therefore, many laboratory experiments on plasma–lithium interactions have been performed in the linear plasma devices to reproduce a fusion reactor relevant environment. The PISCES-B [15–17] linear device at UCSD was used to explore the deuterium retention in liquid lithium exposing to the deuterium plasma beam by Baldwin et al. [17]. Their results confirmed the full uptake of all incident deuterium ions in the liquid lithium. The deuterium retention was independent of the surface temperatures below 673 K. Allain [18] simulated the sputtering of solid lithium. Their results showed that the retention atoms occupied the interstitial locations in the BCC lithium lattice. They also found that the retention of deuterium atoms played a major role in preferential self-sputtering and decreased the sputtering yield of lithium.

In present study, in order to verify the feasibility of the one-cathode linear plasma device, argon plasma interacting with lithium free surface was investigated. Some preliminary experimental results (including sputtering, erosion and redeposition) are presented and discussed. In this study, the effects of the applied discharge current, the gas flow rate and the magnetic field strength on the emission spectrum of lithium, electron density and electron temperature were measured by spectrometer and Langmuir probe.

2. Experimental setup

A schematic diagram of the setup is shown in Fig. 1. In this device a one-cascaded plasma source shown in Fig. 2 was mounted

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http://dx.doi.org/10.1016/j.fusengdes.2014.07.020

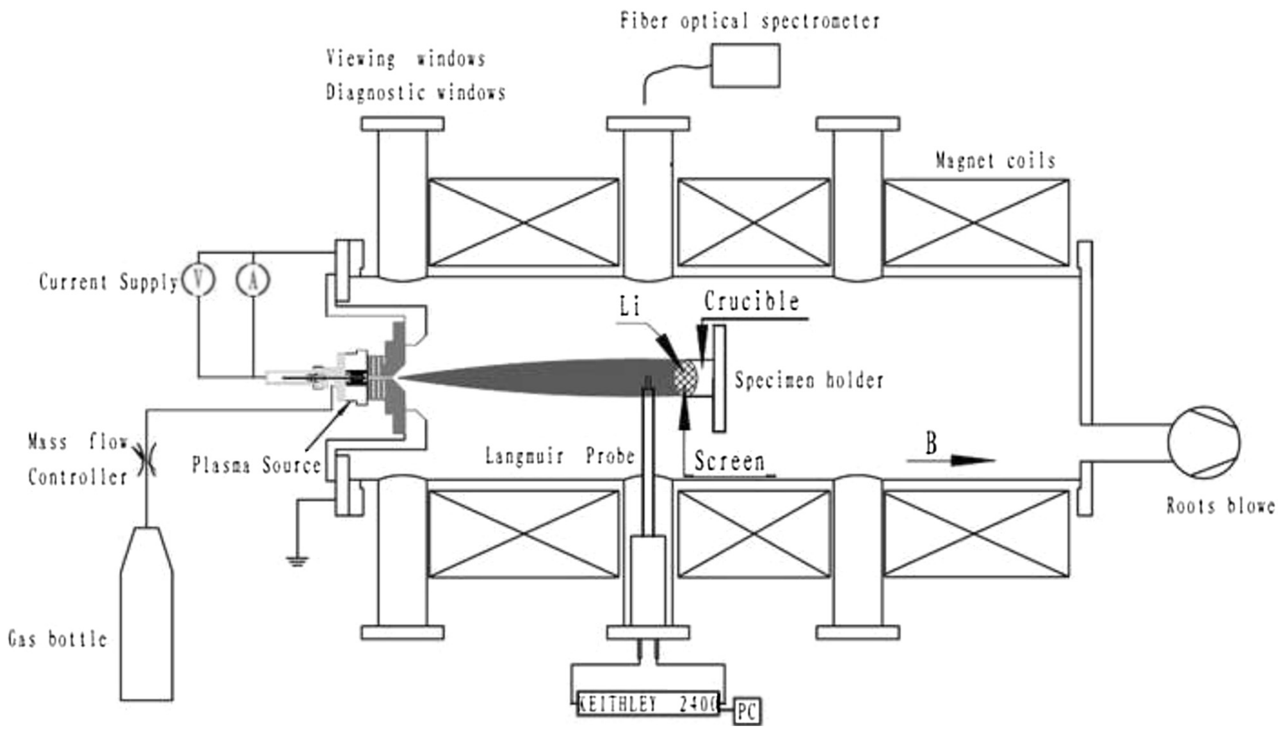

Fig. 1. A schematic diagram of an outline of setup.

at the one end of the vacuum vessel. Argon plasma produced by the cascaded arc source expands from the nozzle into the vacuum vessel. The vacuum vessel consists of a stainless cylinder with a length of 1.2 m and a diameter of 0.28 m. Six quartz windows were used to view and diagnose. Three magnet coils were wound around the vessel to produce a maximum magnetic field of 0.45 T at the center of the vacuum vessel. The vessel was pumped by one mechanical rotary pump and one roots blower in order to keep the background pressure below 10^{-2} Pa.

Diagnostic system includes a double Langmuir probe and spectrometer. Langmuir probe, made of two cylindrical tungsten wires of 10 mm length and 0.2 mm in diameter, moved over 140 mm in the radial to the plasma axis freely, is installed in the second diagnostic window. Data collection system of the probe includes KEITHLEY 2400 and PC. The fiber-optics probe of the spectrometer on which data are transmitted by five channels, is set parallel to experiment table in the front of the other second diagnostic window.

Before the experiment, a solid lithium sample with the weight of about 2 g was pressed into the crucible under argon gas environment in one glove box. One stainless steel mesh with the size of 1 mm × 1 mm coved the crucible to avoid liquid lithium splashing out the crucible. Then the lithium atoms were transferred quickly to the sample holder in the vessel.

3. Experimental results

Electrons released by the thermionic cathode collide with argon atoms. Many complex reactions through excitation and ionization occur in the small cathode house. Plasma including ions, electrons and neutral particles is forced into the plasma channel due to the pressure difference and the strong electric field force. The particles and wall collide with each other in the channel. Then the argon plasma expands into the vacuum chamber through the nozzle. Fig. 3 shows one snapshot of the sample holder with the lithium in the crucible after exposing to the argon beam for about 2 h. It is found that some lithium atoms was redeposited around the crucible. The experimental results showed that much lithium atoms was redeposited around the target plate, while only little was on the vessel wall. In previous experiments performed by Allain, it is found that most of the ejected lithium atoms from the liquid lithium surface are ionized via collision with argon plasma [20]. The lithium ions are moved back to the lithium surface (target) by the magnetic force in the direction of magnetic field lines. The direction of magnetic field lines is parallel to the axis of the vessel that points toward target. Then the lithium ions are redeposited around the target. Tests showed that if no stainless steel mesh covered on the crucible, all lithium in the crucible splashed out after exposing to the plasma for less than 30 min. During the experiment it was observed that some liquid lithium splashed out of the crucible when the mesh size is not small enough. The effect of mesh size on the loss of lithium will be investigated and the data will be presented in future papers.

Fig. 4(a) shows the intensity of Li at 670.78 nm as a function of the applied discharge current with the magnetic field strength of 0.2 T at flow rates of 1500 and 2000 sccm, respectively. It is noted from the figure that the light intensity of the emission line at 670.78 nm increases with increasing applied current and gas flow rate. A linear relationship is noticed between light intensity of Li at 670.78 nm and the discharge current at the flow rate of 2000 sccm. However, at the flow rate of 1500 sccm it almost remains constant between 90 and 100 A. When the applied current exceeds 100 A, it begins to increase significantly.

Fig. 4(b) shows the light intensity of Li at 670.78 nm as a function of the magnetic field strength with the current of 100 A at flow rates of 1500 and 2000 sccm, respectively. The light intensity increases and then approaches a saturated value with increasing the magnetic field strength at the flow rates of 1500 and 2000 sccm. The light intensity increases abruptly around 0.267 T.

Fig. 5(a) shows the electron density as a function of the discharge current with the magnetic field strength of 0.2 T at the flow rates of 1500, 2000 sccm, respectively. It is noted from the figure