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A new facility for studying plasma interacting with flowing liquid lithium surface

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ABSTRACT

A new facility to study plasmas interacting with flowing liquid lithium surface was designed and is constructing in Sichuan University. The integrated setup includes the liquid lithium circulating part and linear high density plasma generator. The circulating part is consisted of main loop, on-line monitor system, lithium purification system and temperature programmed desorption system. In our group a linear high density plasma generator was built in 2012. Three coils were mounted along the vessel to produce an axial magnetic field inside. The magnetic field strength is up to 0.45 T and work continuously. Experiments on plasmas interacting with free flowing liquid lithium surface will be performed.

1. Introduction

Due to its thermal properties, radio-resistance to neutron irradiation and low vapour pressure, liquid lithium has been considered as a promising first wall material in future fusion reactors [1–10]. As for plasma-facing materials, understanding and controlling plasma-surface interactions are key to their successful applications in reactors [11–16]. In order to develop the liquid plasma-facing components, an experimental research project is being launched to study free flowing liquid lithium surface interacting with plasmas in China. We explore the project (1) to obtain free flowing liquid lithium on solid surfaces (W, Mo or 316 stainless steel) exposing to the high density plasma beam produced by the linear device; (2) to study and understand the interaction mechanisms. We report here on an integrated facility for this project. The integrated facility consists of the liquid lithium loop and the linear plasma device. The lithium loop and the linear device provide free flowing liquid lithium surface and high density plasma, respectively.

2. Aims of the project

In order to understand the interactions between free flowing liquid lithium and plasmas, in the project the linear plasma device is employed to create a high density plasma beam exposing to the flowing stream of liquid lithium. A series of experiments will be launched in the integrated device. The aims of project can be summarized as follows:

(1) to obtain the free flowing liquid lithium surface with stability and uniformity;
(2) to understand physical sputtering and evaporation of lithium during plasma irradiation, retention of hydrogen, its isotopes and helium, impurity transport in incident plasmas;
(3) to study the compatibility of structural materials in liquid lithium in the presence of plasma irradiation.

3. Linear plasma device

Fig. 1 shows the schematic of the linear plasma device with reference to the Pilot-PSI setup developed at FOM institute [17]. The device consists of three main components: the coils, the vacuum vessel and plasma source. The setup consists of a 1.2 m long and 0.3 m diameter cylindrical vacuum vessel by 304 stainless steel. Around the vessel three coils were mounted to produce the maximum magnetic-filed strength of 0.45 T measured at the axis of the vessel. A mechanical fore-pump and a root blower were used to evacuate the vessel up to the base pressure of 10^{-2} Pa and maintain the working pressure varying between 1 and 100 Pa on plasma operation. In all measurements no oxygen and hydrogen emission lines were observed by the optical emission spectroscopy. In addition, the vacuum system is being updated, one molecular pump

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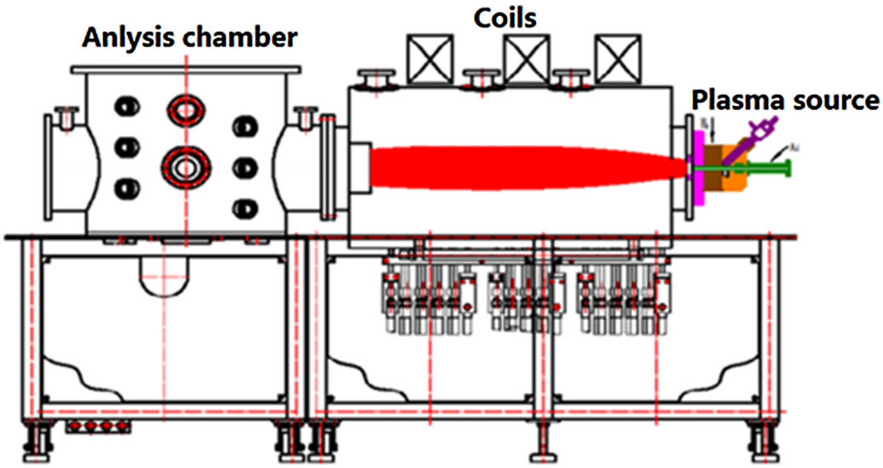

Fig. 1. Linear plasma device.

type FD-150/450B manufactured by Chengdu SDIC Nanguang company will be installed. The vessel can be evacuated to 10^{-5} Pa (the base pressure) in future.

In the setup the cascaded arc plasma source is employed. In our group we developed one-cathode cascaded arc source. Fig. 2 shows the cascaded arc plasma source. In the Pilot-PSI setup of FOM institute three-cathode arc source is used. The one-cathode source consists of a cathode chamber with one sharp 2% ceriated tungsten needle, a central arc channel with a set of thick copper plates and an anode with a nozzle. O rings are used to seal these components. The anode plate is connected to the flange of the expansion chamber and grounded. In order to prevent burning out on operation, the channel and the anode plates are water-cooled.

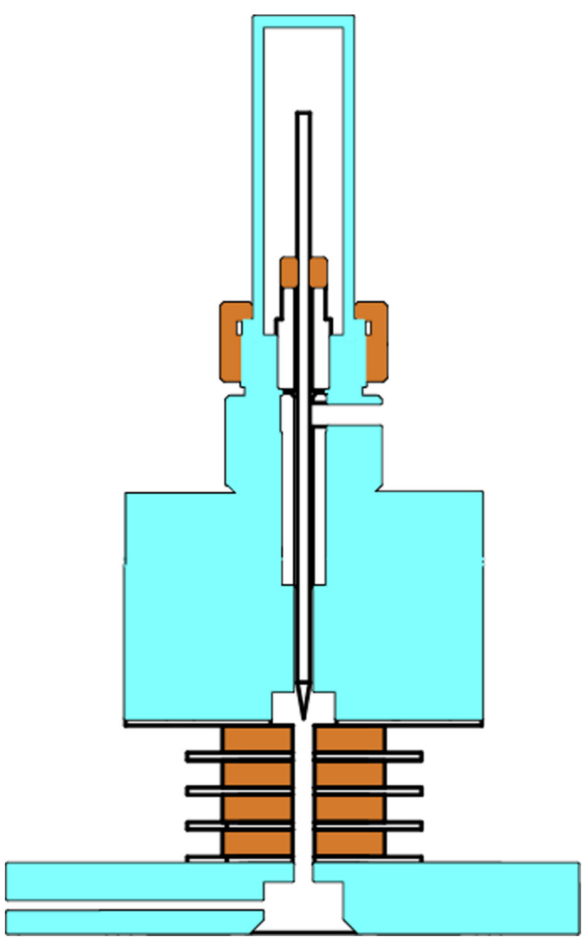

Fig. 2. The one-cathode cascaded arc plasma source.

Two double Langmuir probes are designed to determine the electron density and temperature of plasmas in the vessel. In order to measure the spatial distribution of the plasma properties in the vessel, the probe is controlled by a movable arm. The optical emission system of an AvaSpec-2048-USB-5 spectrometer equipped with an optical fibre is used to analyze the plasma optical emission through a quartz window.

In order to verify the feasibility of the one-cathode linear plasma device and obtain some preliminary experimental results, argon plasma interacting with lithium free surface was studied. At low applied currents (≦95 A) and small magnetic fields (≦0.2 T), some preliminary plasma measurements by the Langmuir probe were performed. It is found that the probe is not applicable when the discharging currents are higher than 95 A. In future experiments, H_2/He plasmas with higher electron densities ($>10^{20}$ m^{-3}) and electron temperatures (>1 eV) by applying greater discharging currents up to 300 A will be investigated by Thomson scattering (TS) diagnostic system and the date will be presented in future papers. The TS system is being constructed. Fig. 3 shows the electron density and electron temperature as a function of the applied discharging current measured at a distance of 108 mm from the nozzle. It is noted that both the electron density and electron temperature increase with discharging current and argon flow rate. The experiment results show that the electron density and temperature are up to 6×10^{19} m^{-3} and 0.72 eV, respectively, at the argon gas flow rate of 2000 sccm with the discharge current of 95 A and the magnetic field of 0.2 T.

4. Lithium test loop

The liquid lithium loop and the free flowing liquid lithium surface are two critical elements in our integrated setup. The schematic of loop design is shown in Fig. 3. With reference to the design of IFMIF, it is composed of the following components: (1) Electromagnetic pump with the maximum volumetric flow rate of 13,000 m^3 per hour with a pressure head of 0.4 MPa. The pump was manufactured by Shi Jia zhuang Magnetic Flux Eletric Company with air cooling system. With frequency conversion control