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Plasma window for electron beam welding in atmosphere

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Plasma window (PW) is a plasma application technology that virtually separates the atmosphere and vacuum without solid materials such as metal or glass. PW is shown in Figure 1. The pressure difference between atmospheric pressure and vacuum is maintained by increasing the viscosity of the neutral gas. Due to this nature, PW enables to transmit quantum beams such as electrons and ions generated in vacuum into the atmosphere. Therefore, if a PW can operate stably for a long time, the PW may pave the way for the new application of the quantum beam technology, such as electron beam welding under atmospheric pressure. Electron beam welding is known to realize precise joining than arc welding because of its narrower bead width and greater penetration depth [1]. However, because electron beam welding is performed in a vacuum vessel, the size of the object to be welded is limited. If the electron beam generated in the vacuum vessel can be extracted into the atmosphere for welding, the restrictions on the object size can be significantly reduced.

The purpose of this study is to realize atmospheric pressure electron beam welding using PW. For this purpose, it is necessary to achieve a pressure barrier that separate 100 kPa and 1 Pa for sufficiently long-time using argon PW with a flow channel diameter of 3 mm. Previous works performed by Harshcovich and others used a needle cathode, but it is known that PW with needle electrodes suffer significant electrode wear due to high heat loads [2][3].

In view of these previous results, we employed a hollow cathode to increase the cathode surface area and reduce thermal load. . Figure 2-(a) shows a detail view of the PW used in this study. In this study, high-temperature, high-density plasma is generated by a cascade arc discharge to heat neutral gas. The cathode is made of cylindrical LaB_6. The LaB_6 is heated by a solenoid-like heater installed around the hollow cathode to heat the cathode to enhance the thermal electron emission. The previous PW designed with the same concept successfully created a pressure difference between 100 kPa and 27.7 Pa. However, the vulnerability of the heater to thermal changes and water leakage from the silver brazed part of the middle electrode hampered the long-duration discharge. We developed a new PW to overcome these problems. Its overall diagram is shown in Figure 2-(b). The diameter of the tungsten heater was changed from 0.5 mm to 1 mm to prevents the heater from breaking during PW operation and allows stable plasma to be maintained for a long time. In addition, the new heater can supply more power to the cathode material, allowing the cathode to be heated more efficiently. Also, the material of the middle electrode was changed from molybdenum to oxygen-free copper, and the parts were welded together by electron beam welding. This change prevents cooling water from leaking into the vacuum vessel during PW operation. Furthermore, the thermal conductivity has been increased by a factor of approximately 2.5, enabling more efficient cooling of the wall surfaces inside the channel. In this presentation, the pressure barrier characteristics and long-time operation results obtained with the newly developed PW will be presented. This work was supported by JSPS Gant numbers JP23K03361, 24K069940A and NIFS Collaboration Research program (NIFS24KIIQ004).

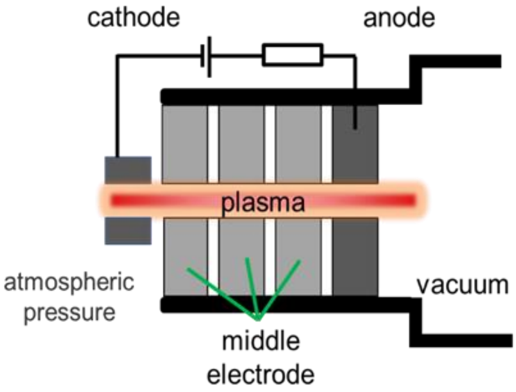
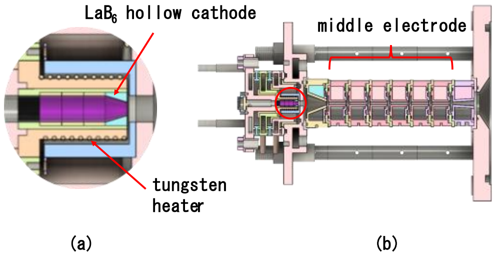


Fig.1. Schematic diagram of PW



(a) (b)

Fig.2. Schematic diagram of the new PW

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