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Characterization of a Large Diameter Cascade Arc Discharge Plasma

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In cascade arc discharges, electrically floating intermediate electrodes are installed between an anode and cathode. Thus, high-temperature and high-density plasma can easily be generated, and gas flow is significantly suppressed by a high-viscosity of the hot gas. In such cases, neutral gas and plasma pressures could be balanced, enabling us to separate the atmosphere and vacuum without large pumping system. This device is called *plasma window* (PW) [1]. The PW can transmit charged particles (electrons and ions) as well as X-rays through the plasma channel, while air gas constituents cannot do due to pressure force by plasma and hot gas. As one of the applications of the PW is an electron beam welding in the atmosphere. Hershcovitch *et al.* demonstrated the electron beam welding under atmospheric pressure by means of the PW technology [2]. However, the channel diameter of the cascade arc discharge device (PW) was as small as 2.36 mm, and its application has been limited so far. In this study, therefore, we have developed a large diameter of 8-mm cascade arc device capable of generating high- temperature and high-density He plasma [3].

The cascaded arc device constructed in this study is shown in Figure 1. Ten intermediate electrodes are inserted between the anode and the cathode electrodes. The water-cooled intermediate electrode has an inner diameter of 8 mm, and the central portion facing the hot dense plasma is Mo. A spacer made of Teflon is inserted between the electrodes to prevent spark discharge between the electrodes from taking place. The cathode is LaB_6 disk with a hole of 29mmϕ, through which we can directly observe the discharge section. The discharge current and voltage are up to 100 A and ≤ 200 V, respectively. He gas is fed into the cathode section through a mass flow controller. The discharge assembly is mounted a large main vacuum chamber and evacuated by large vacuum pumps. The pressures of the discharge P_d and the expansion region P_e were measured by vacuum gauges. To characterize the plasma, a visible and vacuum UV spectrometers are used. The observation are carried out from both the cathode side and the anode exit.

The performance as vacuum interface was examined by measuring pressures of the cathode section and main chamber. With decreasing the gas flow, the chamber pressure also decreased, and the pressure ratio, P_d/P_e, reached ~300 at 50-A discharge and 0.1 L/min. The discharge characteristic was investigated by measuring the electrode potentials. The potential decreased smoothly toward the cathode, indicating that the plasma was accelerated throughout the discharge channel. Electron density and temperature were determined by spectral analysis of He I. In the high-density plasma, the line profile is broadened due to the Stark effect, by which the plasma density at the anode exit was determined to be $\geq 10^{13}$ cm^{-3}, as shown in Fig. 2. As for the electron temperature, recombination continuum spectra attributed to He I resonance transition yielded ~1 eV

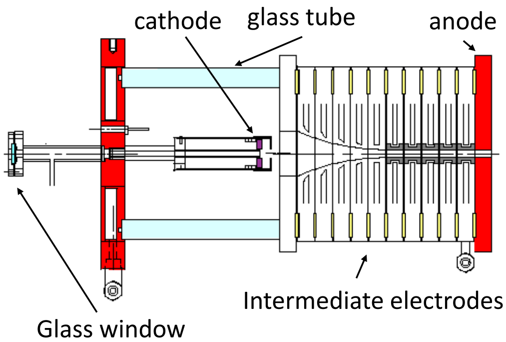

Figure 1. Schematic of the cascade arc device.

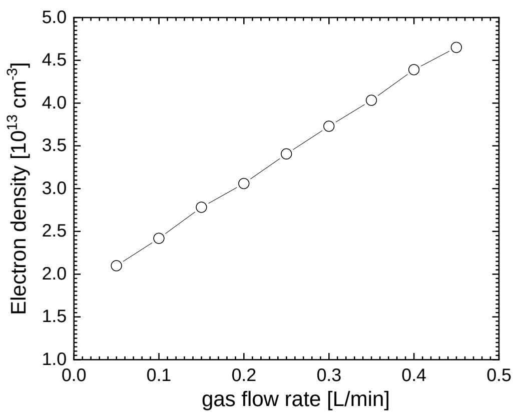

Figure 2. Electron density for various gas flow rates at a 100-A discharge.

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