§3. Optical Emission Spectroscopy in Large Negative Ion Source for LHD-NBI

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A hydrogen negative ion (H^-) source is important device for high-energy neutral beam (NB) injector. We have operated three NB injectors with negative ion sources as a main heating device in LHD. Inside of the negative ion source, H^- ions are produced around plasma grid by surface effect used cesium (Cs) vapor. In order to investigate Cs behavior and impurity history in this source, we have installed the optical diagnostic tools at one of the negative ion source, which are filament-arc discharges.

We have observed neutral Cs (Cs^0) emissions and ionized Cs (Cs^+) emissions. The data analysis result of Cs^+ density is much higher than Cs^0 density, because the electron temperature is higher than the ionization potential around arc discharge region. The emission signal of Cs^+ is rapidly increased during beam extraction by sputtering Cs from the surface of the back plate due to a positive-ion back streaming.

Figure 1 shows the history of the beam conditioning and optical emission in the third NB injector with two ion sources. The IS3A is the rebuild source after the maintenance, and its grid systems are exposed to air condition in seven month. The IS3B is the operated ion source in one month before opening the ion source for changing filaments and wiping inner wall by water, and it is exposed to air condition in only one day. After the Cs seeding with same oven temperatures, it has a different behavior of oxygen signal in IS3A and IS3B as shown in Fig. 1(c). Oxygen impurities seem to sputter from the IS3A grid system. We have clearly observed the decreasing beam width with the peaked beam profile and rapidly increasing of Cs signals at the same time as shown in Fig. 1(b). This behavior corresponds to the decreasing of oxygen signals. Growth of the H^- beam production may be obstructed by oxygen impurities adsorbing the surface Cs on plasma grids at the beginning of the beam conditioning. We find that the period of the beam conditioning for the negative ion source becomes several days slow, but it does not become the serious delay.

In the short arc discharges until 30 sec, time trace of the Cs signal is almost constant. We have usually extracted high current density neutral beam with a good divergence angle from the ion source optimized short pulse operation. On the other hand, we have found much heat loading on the beam injection port due to the NB with large divergence angle at the long pulse operation used the same ion source in BL3. We have observed Cs behavior in this ion source at the long arc discharge. At 100sec long arc discharges without beam extraction, the Cs signal increases after passing 70 seconds discharge. The Cs emission signal at 100 sec is two times larger than that at the beginning of the discharge. In this case, Cs signal dose not decrease shot by shot with Cs vapor. After closing the Cs valve, however, the Cs signal decreases shot by shot. This is a simple behavior of the Cs removal from the arc camber wall by the heat load of the arc discharge. The decreasing rate of the Cs signal depends on the time duration of the arc discharge. Figure 2 shows the Cs signals normalized by Hγ emission in the case of both long arc discharges and short arc discharges without additional Cs vapor. Horizontal axis is the summation of arc discharge time. There are almost same Cs evaporation rate between 11 sec and 26 sec arc discharge. At long 100 sec discharges, however, this decreasing is much higher than that of the short arc discharges (< 30sec) for same discharge accumulation. This result indicates a lot of Cs consumption in the long pulse operation. Cs that has decreased work function on surface of the plasma grids, is also evaporated from the plasma grids by the long discharge. This behavior is important information to optimize the Cs delivery rate at the long pulse operation in negative ion sources using arc discharges.

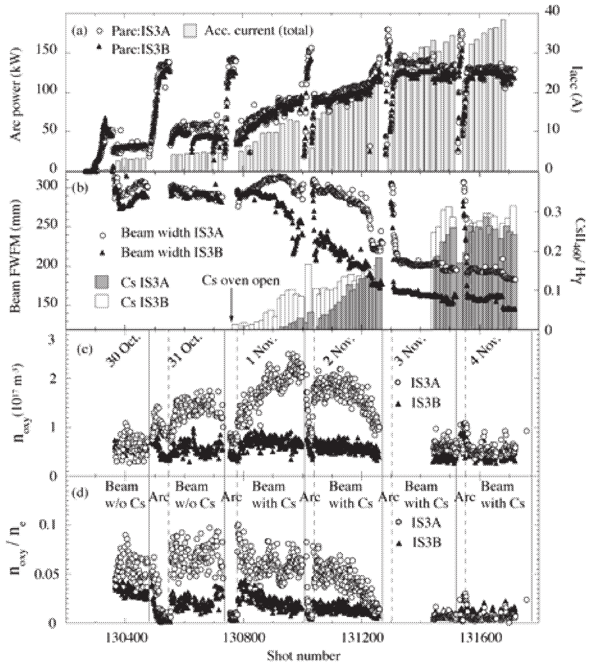

Fig. 1. History of the beam conditioning with Cs vapor.

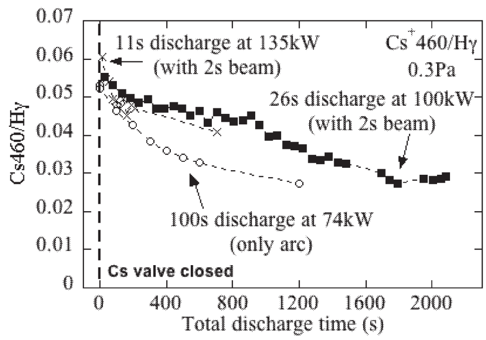

Fig. 2. Cs evaporation of both short arc discharge and long arc discharge without additional Cs vapor.