§13. Study of the Physics of IDB Plasma and the Density Limit in Helical Devices

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In stellarators, there is no hard limit of the high-density operation, unlike the Greenwald density limit in tokamaks, which is one of great advantages for future reactor operation. Especially in LHD the operation condition for the IDB (Internal Diffusion Barrier) plasma was discovered and the high density/high pressure plasma was successfully produced. Therefore, it is important to study high-density plasma production and to explore the high-density operation in stellarators.

In experiments on the TU-Heliac, the role of the radial electric field on the transition to improved modes has been investigated by electrode-biasing experiments. By negative biasing with a hot cathode electrode (electron-emission), the radial electric fields can be actively controlled by changing the electrode current, I_E[1-3]. Consequently, the new type electrode made of hydrogen storage metal has been developed for the particle injection (electron, ion and neutral particle). Using an electrode made of a hydrogen storage metal, such as titanium (Ti) or vanadium (V), the following can be expected: (1) the electrons injected from the negative-biased electrode allow the biasing experiments for study of LH transition by control of the electrode current and (2) the electrons/neutral particles injected from the negative-biased electrode provide production of high-beta plasma and high-density plasma, if hydrogen can be stored successfully in the electrode and released from the electrode. In the TU-Heliac, the high-density plasma was produced ($>10^{19} m^{-3}$) using a titanium (Ti) or vanadium (V) or gold (Au)-coated palladium (Pd-Au) electrode after the hydrogen gas charging in the negative electrode biasing[4-6]. Specifically, when the V and Pd-Au electrode was negatively biased in an Ar plasma, under the low magnetic field in the standard operation, the beta value increased up to about 0.5 %, allowing the realization of a new field of high-beta experiments. Negative biasing experiments using a hydrogen storage electrode have the potential to realize high-beta experiments in some small-sized devices.

The experimental set-up of the hydrogen storage electrode is shown in Fig. 1 together with the cross-section of the vacuum magnetic flux surfaces at toroidal angle ϕ = 0°. Figure 2 shows the relation between the electron densities of the biased plasma and the electrode voltage for the biasing in the cases of titanium (Ti), vanadium (V), palladium (PD) and gold (Au)-coated palladium (Pd-Au).

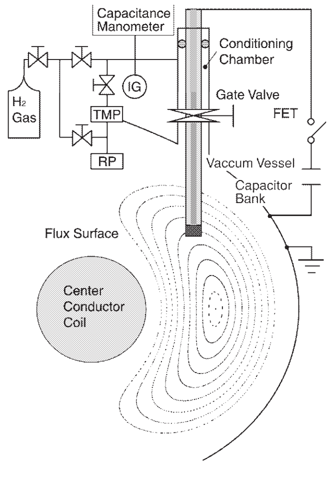

Fig. 1. The position of the hydrogen storage electrode and the computed cross-section of the vacuum magnetic flux surfaces at ϕ = 0°. The hydrogen storage electrode (10 mm in diameter and 2 mm in length) was inserted vertically into the plasma from the low magnetic field side.

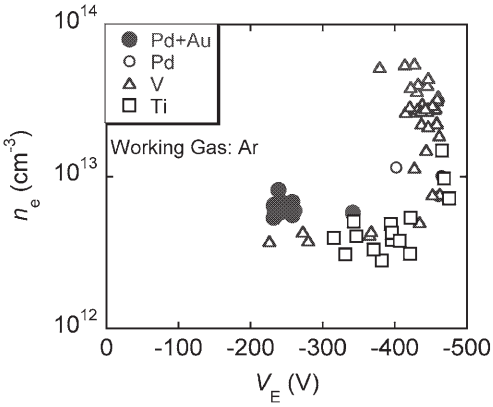

Fig. 2. Relation between the electron densities of the biased plasma and the electrode voltage for the biasing in the cases of titanium (Ti), vanadium (V), palladium (PD) and gold (Au)-coated palladium (Pd-Au).

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