Applications of a Compact Titanium Sublimator and a Simple Gas Injector to Tokamak NOVA II

By

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A compact titanium sublimator has been developed and mounted to the Tokamak NOVA II[1] in combination with a slowly pulsed gas injector for additional gas puffing. By this combination, both the gas recycling and the low-Z impurity ions, previously observed in the NOVA II plasma, are suppressed so efficiently that the plasma density can be controlled by means of the additional gas puffing.[2]

The developed sublimator is shown in Fig. 1(a). The tip of the titanium rod of 3 mm diameter is bombarded by electrons emitted from a filament. The filament is made of a 0.2 mm$^{\phi}$ tungsten wire, which had been wound 10 times, having a dimeter of 1 mm. They are mounted into a stainless-steel tube with an 18 mm outer diameter. This sublimator can be mounted through an aperture not smaller than 18 mm in diameter. The filament current is controlled by SCR so as to maintain a constant bombardment current. Typical operational conditions are a filament current of 2 A (6 V) and a bombardment current of 40 mA (1200

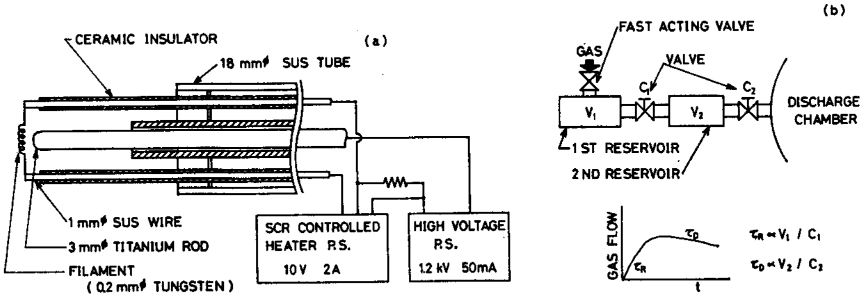

Fig. 1. (a) A compact titanium sublimator of electron bomardment type. (b) Schematic drawing of the slowly pulsed gas injector. The rise and decay time of the gas flow are variable by varying the value conductances C_1 and C_2.

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V). The consumed electric power amounts to about 60 W. Under these conditions, the sublimation rate of the titanium is 0.08 g/h. The measured pumping speed is 2400 l/s after 2-hours sublimation. The titanium rod is supplied from outside through the vacuum vessel according to its consumption.

The torus is filled by a fast-acting valve some 2 to 3 ms before the ignition (pre-ignition gas puffing). A slowly pulsed gas injector, which is shown in Fig. 1 (b), is used for additional gas puffing. This injector consists of a fast-acting inlet valve and two gas reservoirs of volumes of V_1 and V_2, with the outlet valves of conductances of C_1 and C_2, respectively. The rise time of the gas flow into the torus is determined by the time constant V_1/C_1, and the decay time by V_2/C_2.

The characteristics of the non-gettered discharges have been described in detail in previous publications.[1] The time behaviors of the loop voltage, the plasma current and the line-averaged density (measured with a 6-mm microwave interferometer) are shown in Fig. 2(a). The electron density reaches its first maximum about 0.5 ms after the ignition. A rapid fall follows the peak, and

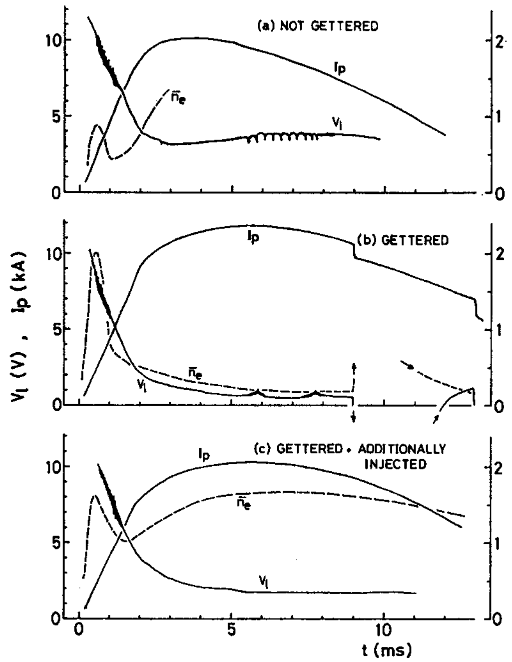

Fig. 2. Typical time dependence of the loop voltage V_1, the plasma current I_p and the line-averaged electron density $\bar{n}_e$ in (a) a non-gettered discharge, (b) a gettered discharge with a fast pre-ignition gas puffing, and (c) a gettered discharge with pre-ignition and additional gas puffing.

then the density continues to increase, indicating a large influx of gas.

The characteristics of the gettered discharges are shown in Fig. 2(b) and (c). A dramatic change is observed in the behavior of the density, as is shown in Fig. 2 (b), with only the pre-ignition gas puffing. The electron density decreases rapidly after the peak, and is maintained very low, $n_e \lesssim 10^{12}\text{cm}^{-3}$. The recycling fraction is estimated to be 0.8 from the density decay curve by using a 1-dimensional tokamak transport code.[3] The hard-X-ray flux (measured with a NaI(Tl) scintillation detector) begins to increase from about 5 ms after the ignition. A large fraction of the flux is absorbed by the lead shield with a 1 mm thickness, which indicates that this low-density discharge is not of a runaway mode.[4] A large scale current disruption, observed about 10 ms after the ignition, is beyond the scope of this note.

By using the slowly pulsed gas injector for the additional gas puffing, a stable discharge with a high density can be realized, as shown in Fig. 2(c). The timing of the additional gas puffing coincides with that of the ignition. The first maximum of the density is determined by the pre-ignition gas puffing, while the second maximum and its decay time of the density are determined by the additional gas puffing.

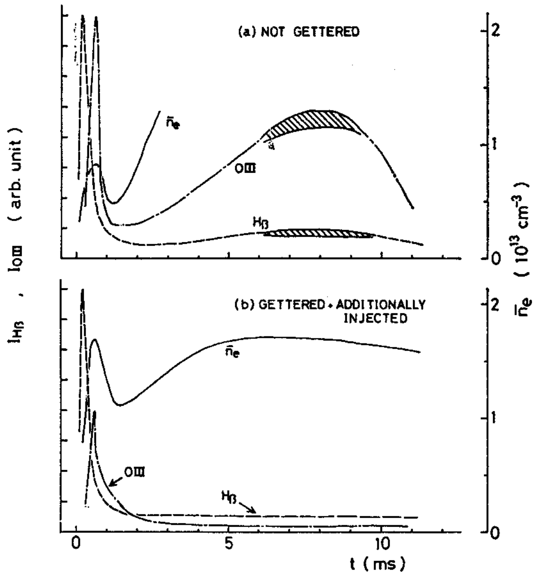

Fig. 3. Typical time dependence of the line intensities of Hβ($I_{H\beta}$) and OIII (I_{OIII}) with the density $\bar{n}_e$ in (a) a non-gettered discharge and (b) a gettered discharge with pre-ignition and additional gas puffing. The maximum value of I_{OIII} is reduced by a factor of 2 to 3 by means of titanium sublimation.

The results of the spectroscopic measurements are shown in Fig. 3(a) and (b). The time behaviors of the H_β and OIII (3265 A) line intensities are shown with the electron density. The monochromator is located 90° away in the toroidal direction from the additional gas injector. In the non-gettered discharge, shown in Fig. 3(a), the line intensities of both H_β and O III begin to increase from about 3 ms after the ignition, although the increase in the O III line is much greater. This can be attributed mainly to a large influx of recycling gas and impurities, and, at least partly to a change in the electron temperature profile. In contrast to this, as shown in Fig. 3(b), the line intensities show no significant increase in the gettered discharge with additional gas puffing. Furthermore, the peak intensity of the O III line is reduced by a factor of 2 to 3 by applying the titanium sublimation.

References

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