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Formation of Deep Potential Well and its Structural Transition in Small Tokamak Device

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Abstract

A negatively deep potential well was induced (~ –0.6kV) when the radial arcing current flows between the small electrode inserted into the plasma center and the wall of vacuum vessel in the small tokamak device CSTN-IV. Under the regions of both low plasma current and strong toroidal magnetic field, we have obtained that the potential well is formed efficiently (resulting in an increase in the plasma resistance).

1. Introduction

The radial electric field and the associated ExB plasma poloidal rotation are well known to have an important role in tokamak plasma confinement. There are several methods for controlling the radial electric field externally. Electrode biasing is one of them and has shown to modify the spatial profile of the radial electric field in several tokamak devices [1]. The radial electric field is exited by cross field currents from electrodes located in the interior of the plasma. In small tokamak devices with relatively weak toroidal magnetic field, biasing with a cold electrode is not so efficient to generate a steep potential profile, especially for potential well formation with negative baising. However, a large amounts of electron emissive current driven by arc discharge between vacuum vessel and electrode have a great potential for formation of very deep electrostatic potential well [2,3].

We succeeded in the formation of the deep potential well with electron emissive electrode. In this paper, properties of the formation of the deep potential well are investigated in detail under a variety of experimental conditions.

2. Experimental set up

CSTN-IV tokamak device, whose top view is shown in Fig. 1(a), has the major radius of 0.4m and the minor radius of 0.103m, and has no limiter. The steady toroidal magnetic field B_T is 0.13T at maximum. The maximum plasma current I_p is 1.5kA. The typical plasma parameters at center are as follow: density $0.5 - 1.5 \times 10^{18}$ m-^{3}, electron temperature < 10 eV.

An electrode inserted to the plasma center is loop shaped and made of Tantalum, having a diameter of 6mm as shown in Fig. 1(b) and (c). The negative biasing voltage is applied between the electrode and vacuum chamber at the flattop of plasma current during 0.25 ms.

A movable triple probe on the equatorial plane measures the floating potential V_f, the ion saturation current I_{sat} and the electron temperature T_e. Measurements were taken at different radial positions in a series of similar and reproducible plasma shots.

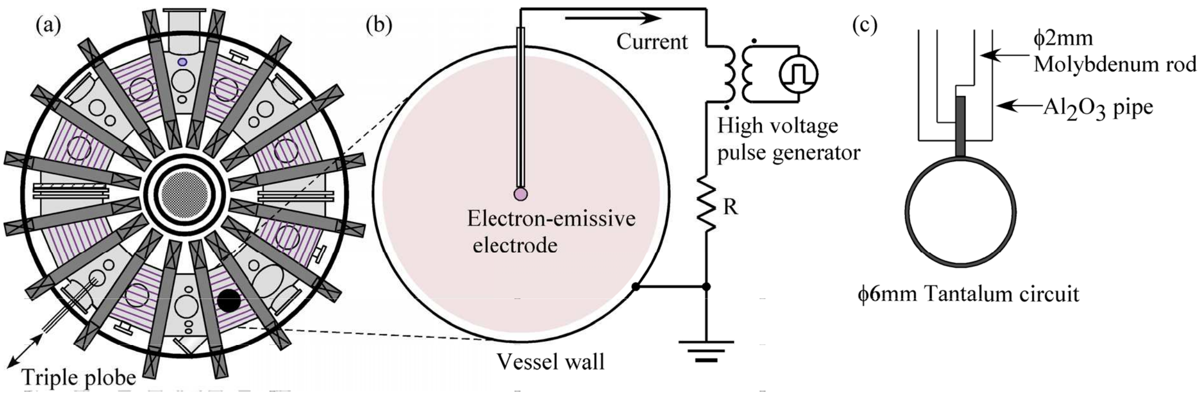

Fig. 1. Experimental devices: (a) top view of the CSTN-IV tokamak, (b) bias circuit and (c) the configuration of electron emissive electrode.

3. Experimental results and discussion

3.1 Deep potential well formation

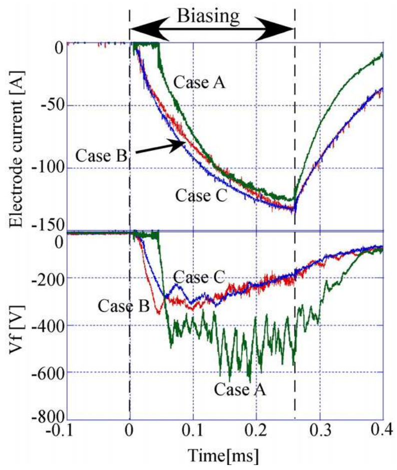

Fig. 2. Time evolutions of the electrode current and floating potential at r = 0 cm.

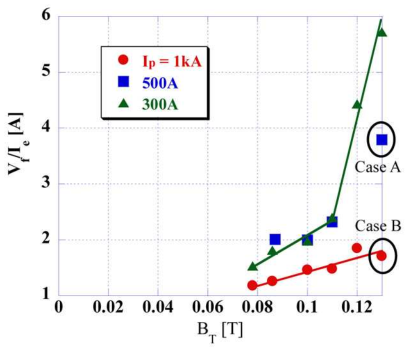

Fig. 3. The radial plasma resistance as a function of B_T.

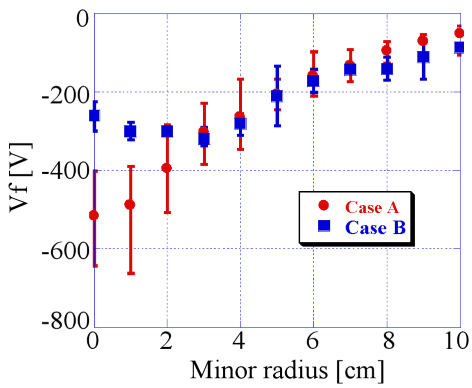

Fig. 4. Radial profiles of floating potential for Ip = 500 A and Ip = 1 kA at t = 150 μs.

Figure 2 shows the time evolution of floating potential and electrode current with I_p = 500 A (Case A), 1kA (Case B) and 1.5 kA (Case C). Only the Case A, the floating potential suddenly drops at t ~ 0.12 ms. And after this transition, very strong potential oscillations superposed by a slowly varying waveform are produced (~ 50 kHz). Since the values of radial current are almost same in that three cases, this indicates that the radial plasma resistance is high in Case A, as shown in Fig 3. With increasing B_T (≥ 0.12 T) and decreasing I_p to less than 500 A, the resistance quickly becomes large. As indicated by the potential profile sketched in Fig. 4, for the Case A, the potential drops more deeply and oscillation amplitude is also larger than that in the Case B inside of the radius 3 cm. In this "high resistance" condition, the plasma density and the poloidal magnetic field is relatively low, and the toroidal magnetic field is strong. We assumed that these parameters determine this transition phenomena (high plasma resistance area).

3.2 Discussion

A very strong radial electric field may provide a strong poloidal rotation, which is also determined by B_T. Both the plasma density and the poloidal magnetic field determine so-called poloidal Alfvén velocity ($v_A = B_\theta / \sqrt{\mu_0 n_i m_i}$). As shown in Fig. 5, these two velocity approach each other with decreasing Ip. This condition probably have an important role for increasing effective radial plasma resistance.

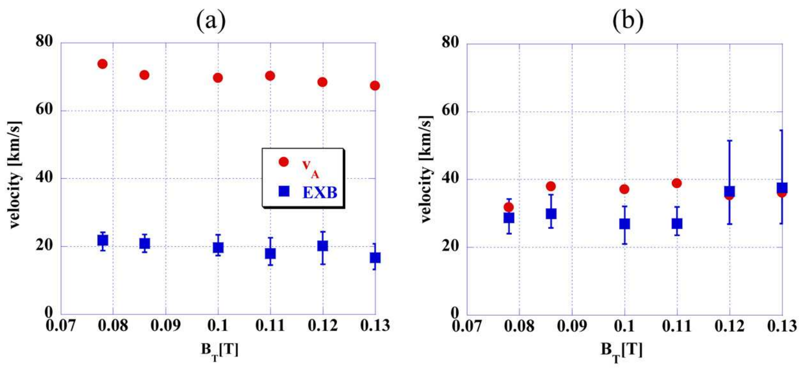

Fig. 5. A comparison between the ExB velocity and a propagation velocity of poloidal Alfvén wave at r = 8 cm for (a) I_p = 1000 A and (b) I_p = 300 A.

4. Summary

We achieved a potential well down close to −0.6kV by a cross-field radial current. In a parameter range (low I_p and strong B_T), the radial plasma resistance becomes large. Under the same condition, very hard potential oscillations and strong electric field have been observed at the inner region.

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