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Formation of Very Deep Potential Well with Electrode Biasing in a Toroidal Device

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Abstract

In a small toroidal device CSTN-IV a negatively deep potential well (~-1 kV) was induced when the radial cross-field arcing current (~180A) flows between the small disc electrode (LaB_6) inserted into the plasma center and the wall of the vacuum vessel. As the plasma current becomes lower and the toroidal magnetic field stronger, the deeper potential well is formed. The poloidal magnetic field seems to increase the cross-field electrical conductivity with a large radial current.

1. Introduction

It is well known that a radial electric field E_r and associated $E_r x B_T$ plasma rotation is involved in plasma confinement. There are several methods for controlling the radial electric field with experimental means. Electrode biasing is one of them, and there have been many studies to modify the spatial profile of the radial electric field in several tokamak devices by using the electrode biasing [1]. The radial electric field is induced by cross-field current from electrode located in the interior of the plasma. Biasing with a cold electrode is sometimes not so effective to generate a large E_r. However, a large amount of electron current driven by an arc discharge between the vacuum vessel and the electrode have a great effect on the formation of very deep electrostatic potential well [2,3,4]. On the other hand, the formation of the deep potential well has a possible application to a neutron source in a method similar to SCBF (Spherically Convergent Beam Fusion).

We succeeded in a formation of very deep potential well with the electron emissive electrode. In this research work, we aim to investigate the physical mechanism of the formation of the deep electrostatic potential well and its dynamics under a variety of the experimental conditions.

2. Experimental set up

The outline of the A.C. tokamak device, CSTN-IV is shown in Fig.1: the major radius R =

0.4m, the minor radius a = 0.1 m, the plasma current I_p < 1.5 kA, the toroidal magnetic field B_T < 0.13 T, the plasma density $n_e \geq 1.0\mathrm{x}10^{18}$ m^{-3}, and the electron temperature T_e < 15 eV. A small disc electrode made of LaB_6 with the diameter of 6 mm and the thickness of 0.5 mm (Fig.1. c) is inserted into the plasma center (Fig.1. b). The tantalum frame is welded to the molybdenum rod. The negative biasing voltage is applied between the electrode and the vacuum chamber usually at the flattop of I_p during 250 μs.

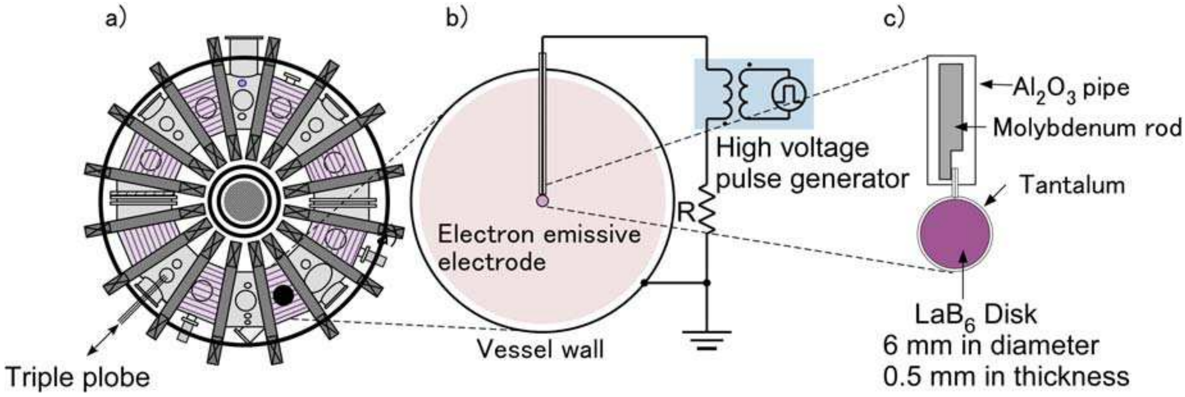

Fig.1. Experimental set up, a) top view of the CSTN-IV, b) biasing circuit, c) configuration of electron emissive electrode.

The floating potential V_f, the ion saturation current I_{sat} and the electron temperature T_e were measured with a movable triple probe. The floating potentials at different radial positions were simultaneously measured with a radial probe array.

3. Experimental results

The potential structure depends on the radial electrical resistance and the intensity of radial current. Therefore, we attempt to evaluate experimentally the radial plasma resistance under variety of experimental conditions, and to study its dependence on several discharge parameters. We defined the radial plasma resistance as $R_r = V_p / I_g$, V_p : the plasma potential, I_g: the electrode current. In CSTN-IV, T_e is about 10 eV, so that at the center we may assume with a good accuracy $V_p \fallingdotseq V_f$: the floating potential at r = 0 cm.

Figure 2 shows the time evolutions of floating potential V_f and electrode current I_g with the plasma current I_p of 300 A (CASE A), 500 A (CASE B) and 1 kA (CASE C) and the toroidal magnetic field B_T is 0.13 T. As soon as the electrode is negatively biased, floating potential immediately drops and becomes deep in time. Especially, the potential in CASE A and CASE B suddenly drops, accompanied by very strong potential oscillations (30 ~ 50 kHz).

Figure 3 shows the radial plasma resistance experimentally obtained. This figure indicates that the radial plasma resistance is large when B_T is strong (> 0.12 T) and I_p is small (< 500 A), with a kind of bifurcation nature. In this "high resistance" condition, such strong oscillations were always observed, particularly in the inside (r < 5 cm) is very hard (Fig.4). Figure 4 shows the time evolution of floating potential at several places measured by an array an electrostatic probe. We found that the floating potential in r = 1 cm is deeper than the floating potential in r = 0 cm.

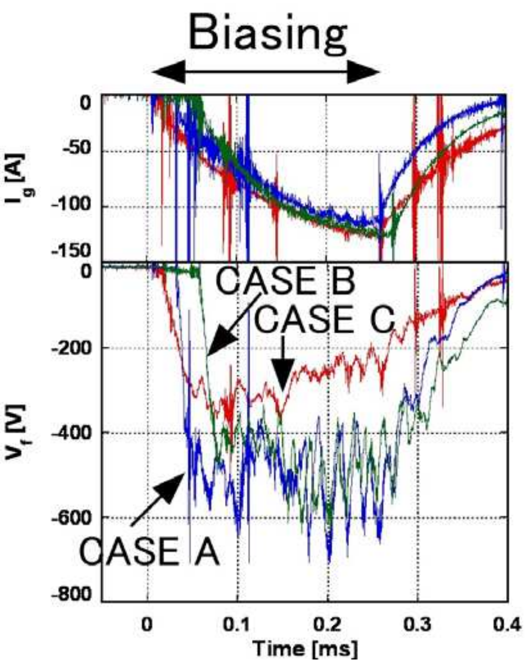

Fig.2. Time evolution of electrode current (I_g) and floating potential (V_f) at r = 0 cm with plasma current (I_p) = 300 A (CASE A), 500 A (CASE B) and 1 kA (CASE C) and toroidal magnetic field (B_T) is 0.13 T.

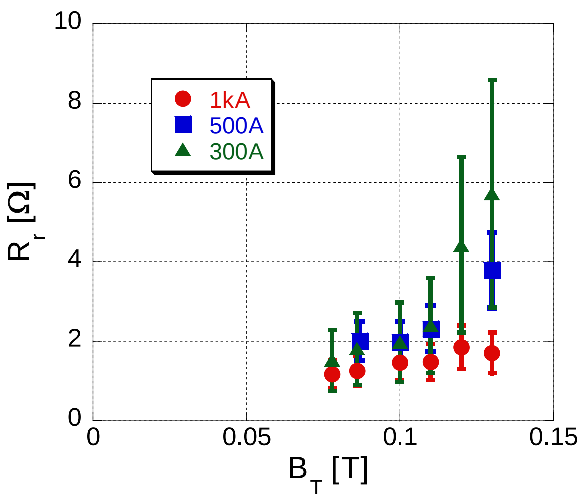

Fig.3. Radial plasma resistance as a function of B_T.

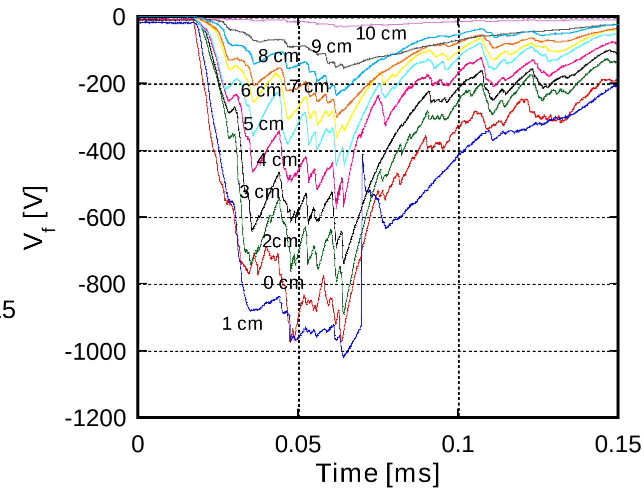

Fig.4. Time evolution of floating potential at the each place measured by probe array.

With that, we found that the parameters B_T and I_p contribute to this bifurcation nature of the potential well formation. Before the electrode is biased, the plasma is generated only by Joule heating due to induction electric field in CSTN-IV so that the plasma density may increase with the toroidal plasma current. The condition of low plasma current but high-density plasma can be produced by carrying out the biasing in the falling edge of plasma current. The result of the biasing under such an experimental condition is shown in Fig.5.

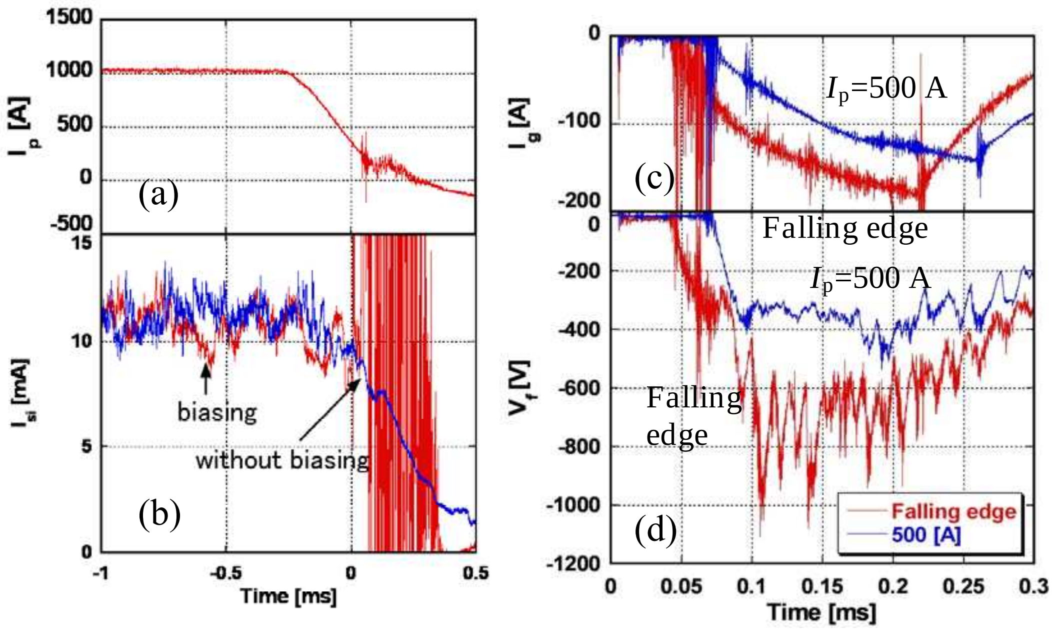

Fig.5. Biasing in the falling edge of plasma current (a) plasma current, (b) ion saturation current, (c) electrode current, (d) floating potential, B_T = 0.11 T.

The plasma current drops less than 200 A at the moment of biasing. But the ion saturation current at that moment has a substantial value which is larger than the ion saturation current at the flat top when the plasma current is 500A. The floating potential when the plasma current is falling edge is considerably deeper than the floating potential when the plasma current is 500 A. As a result, we think that the poloidal magnetic field generated by plasma current is related to the bifurcation nature of floating potential.

4. Summary

We have demonstrated formation of deep potential well deeper than –1.0 kV by a cross-field arcing current. It was found that the radial plasma resistance depends on the toroidal magnetic field as well as the plasma current, that is the poloidal magnetic field. Especially, when the plasma current is low with a strong toroidal magnetic field, the plasma potential rapidly drops, associated by a strong potential oscillation.

Reference

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