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# テスト粒子法によるトロイダル磁場中での高周波グロー放電の挙動解析
# Test particle simulation for high frequency glow discharge in magnetic field

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In future fusion devices with superconducting coils, it is requried to perform wall conditioning under the influence of strong magnetic fields. High frequency glow discharge cleaning (HF-GDC) is a candidate which has been shown to be available with the presence of magnetic fields, and possibly be applicable to future superconducting devices, such as ITER.

This work reports on numerical studies on the pre-breakdown process of high frequency glow discharge plasma in strong toroidal magnetic field. In this work, the particle-induced electric fields are assumed to be negligible since the degree of ionization is low at the beginning of the discharge. Thus, the test particle method is used, wherein the particle trajectories are calculated using the guiding center equation and electron-neutral collisions are treated based on Nanbu's method [1].

According to the experiments in EAST, the high frequency glow discharge plasma with toroidal magnetic field becomes more uniform at lower filling pressure [2]. This indicates that the mechanism of plasma uniformity would be clear at the low-pressure limit, wherein the electron mean free path is sufficiently long in comparison with the size of the torus. So, firstly, the collision-less electron trajectories in toroidal magnetic field are calculated to find out the difference between the constant voltage and the pulsed voltage discharges.

For the constant voltage case, the electrons show periodic motion along the magnetic field line. Therefore, their trajectories in phase space are closed as shown in Fig. 1.

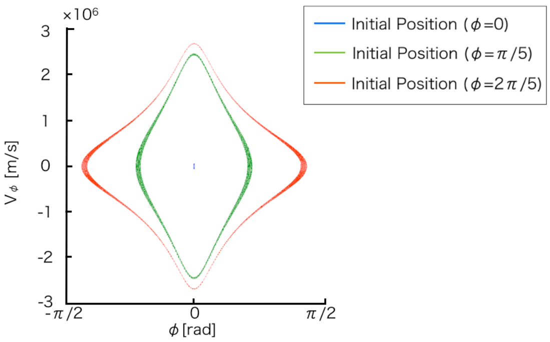


Fig. 1 Electron trajectories in phase space
(Constant voltage case)

In the pulsed voltage case, all electrons follow the open-straight trajectory during the inactive periods of pulses as shown in Fig. 2. By contrast with the constant voltage case, the energies of some electrons can be high, and these high-energy electrons can move freely along the magnetic field line for the pulsed voltage case.

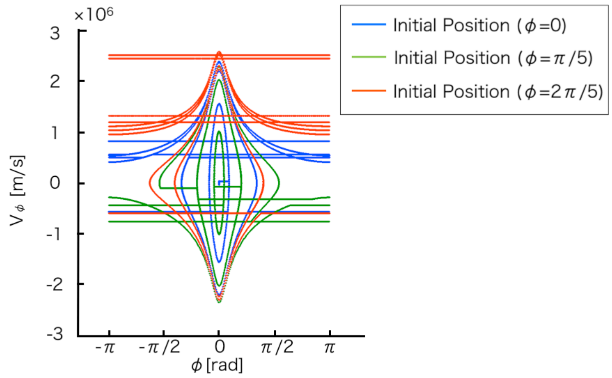


Fig. 2 Electron trajectories in phase space
(Pulsed voltage case)

Secondly, to understand the impact of the pulsed voltage discharges on ionization process, the test particle simulation has been carried out. For the constant voltage case, it turned out that the multiplication factor became progressively saturated (See Fig. 3). This is because there are only energy loss processes, such as excitation and ionization, in the constant voltage case. In the pulsed voltage case, however, the number of electrons continued to increase during the active periods. As shown in Fig.2, all electrons can move freely during the off periods and therefore some of them can get away from the electrodes. These electrons in turn have larger potential energy at the beginning of the next pulse. Thus, there is a process for obtaining energy in the pulsed discharge case.

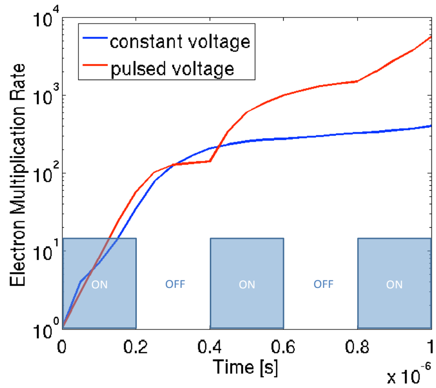


Fig. 3 Electron multiplication rate

References
[1] K. Nanbu, Jpn. J. Appl. Phys., vol. 33, pp.4752 - 4753 , 1994.
[2] J. Li et al, Wall conditioning towards the utilization in ITER, J. Nucl. Mater (2010)