Modeling of ITER glow discharge cleaning

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We present a self-consistent 2D hybrid model of a glow discharge cleaning plasma, a low-temperature plasma used for wall conditioning of tokamak vessels, sustained by a dc hollow-cathode-type discharge inside the vessel. The aim of the model is to predict the glow current density distribution over the ITER vessel walls and to improve understanding of the mechanisms involved.

Glow discharge cleaning (GDC) is a common tool for the conditioning of tokamak vessels in order to achieve reproducible tokamak plasma conditions and performance. [1] It is one of the primary conditioning techniques which ITER will use to prepare in-vessel component surfaces prior to machine start-up and thereafter for plasma operations following maintenance procedures requiring in-vessel access. [2]

The GDC discharge is a dc low-temperature plasma discharge, operated when the magnetic field is off, between several anodes inserted into the tokamak vessel, and the vessel walls serving as a cathode. Typical conditions are: discharge gas H_2, D_2, He or Ne, gas pressure 0.01-1 Pa, voltage 200-600 V, average wall current density 0.1-0.4 A/m^2. An important concern for ITER is the distribution of the GDC current density over the vessel walls as a function of the number and poloidal location of the anodes. The existing fundamental knowlegde of the GDC discharge is limited so that it is difficult to extrapolate the GDC performance on existing tokamaks to the much larger dimensions of ITER. In this paper we present the first self-consistent model of the GDC discharge, aiming to improve fundamental understanding and predict the wall current density distribution in ITER.

From a physics point of view, the GDC plasma is interesting because it involves nonlocal electron kinetics characteristic of negative-glow plasmas and hollow-cathode discharges. The plasma is sustained by beam-like fast electrons, emitted from the cathode by ion impact, accelerated through a thin cathode sheath up to nearly the discharge voltage, and then penetrating very far into the plasma. However, the electric potential distribution in the plasma bulk, which governs the ion flux distribution to the walls, seems to be controlled by low-energy bulk electrons. The model presented in this paper attempts to capture this discharge operation with a 2D hybrid approach, combining a fluid model of the bulk electrons and ions [3] with a Monte-Carlo simulation of the fast electrons. A point of particular interest is the connection between the two electron populations. Another interesting aspect is the extremely high current density at the anodes, which induces reversal of the anode sheath (electron-attracting sheath) associated with an anode glow.

We present preliminary model results for simplified cylindrical geometries. If available we include preliminary comparisions with experimental results on a small scale test stand.

References

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