Exemplary text

Plasma characterisation and wall conditioning studies on the TOMAS device

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The successful commissioning and operating of superconducting fusion devices, such as W7-X, JT-60SA and ITER, depends strongly on various aspects of wall conditioning, plasma surface interaction and plasma production. Several of these topics can be studied and prepared in a dedicated experimental setup: the TOMAS device (TORoidal MAgnetic System), which has been significantly upgraded over the past years [1]. The TOMAS experiment is located at the Forschungszentrum Jülich in Germany. The research focus of the device is the study of wall conditioning techniques, including methods based on ion- and electron cyclotron (IC/EC) plasmas. It is a flexible machine, which complements plasma-wall interaction research in tokamaks and stellarators. The plasma is confined by a toroidal magnetic field with values up to 125 mT on axis, realized by 16 copper coils. The major radius R = 0.78 m and the minor radius a = 0.26 m with a total plasma volume of about 1.1 m³. A schematic view and a picture of the TOMAS device are given in Fig. 1. Both IC and EC systems can provide up to 6 kW of power, the EC frequency is 2.45 GHz, and the IC frequency range is 10 – 50 MHz. In addition, a direct current glow discharge cleaning (GDC) system is installed, based on a graphite anode with maximum voltage 1.5 kV and a current of 6 A. Material samples can be exposed to the plasmas by a load-lock system with a vertical manipulator. The device is equipped with various plasma diagnostics and more measuring tools are being commissioned [2]: there is a Langmuir probe system and optical and particle diagnostics including video cameras, a photodetector, optical emission spectroscopy, a time-of-flight neutral particle analyser, a retarding field energy analyser, a residual gas analyser (quadrupole mass spectrometer) and vacuum gauges.

Figure 1: (left) Schematic view of the TOMAS device. (middle) Photo of the TOMAS device, the horizontal Langmuir probe system is visible, as well as the ICRH amplifier.

Recently an intensive set of experimental campaigns were completed, and an overview of the main results will be presented. The main three topics are sample exposure, plasma characterisation and diagnostics commissioning.

With the exposure of material samples to TOMAS plasmas moreover the removal efficiency of co-deposited boron layers is studied. Samples were exposed to GDC in helium and to IC wall conditioning plasmas in helium and hydrogen. The plasma parameters were changed systematically to determine the best exposure conditions. The power level of the IC was varied from 1 to 4 kW. Additionally, the electrical...
connection of the sample holder was altered, i.e., samples were at floating potential, grounded to the vessel or biased with a negative voltage. Pre- and post-exposure analyses were carried out with heavy ion elastic recoil detection analysis and nuclear reaction analysis [3].

Next, to complement wall conditioning research in TOMAS, a characterisation of IC, EC and combined IC/EC plasmas has been performed using a radially movable triple Langmuir probe [4-6]. An example of experimental measurements of electron temperature and density radial profiles at different magnetic field strengths and neutral pressures is shown in figure 2 [4].

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Figure 2: Experimental radial profiles of (left) electron temperature and (right) electron density from triple Langmuir probe data for two different magnetic field values at a pressure of P = 1.0×10^-4 mbar. The vertical line shows the position of the RF antenna at r = 21 cm, close to the low-field side (LFS) wall at r = 26 cm.

The TOMATOR 1D hydrogen-helium plasma simulator numerically describes the evolution of currentless magnetised RF plasmas in a tokamak. The code is used to reproduce the measurements and to interpret the behaviour of the waves and the power deposition inside the plasma.

Finally, new diagnostics have recently been taken in operation on the TOMAS device. An update will be given of the RFEA, used to study ion fluxes [7], and of the optical emission spectrometer, applied to scenarios for plasma start-up [8].

References

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