Design and qualification of a low pressure / high density ECR dipolar plasma reactor used for synthesis of mixed material dust

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In this paper we present an experimental and theoretical qualification of a low pressure / high density ECR plasma reactor. The main application is the synthesis of mixed material dust (C / W / Be-*like*), in order to simulate plasma-wall interaction in the divertor regions of controlled fusion devices. Plasma experimental characterization by means of Optical Emission Spectroscopy, Langmuir Probe and Mass Spectrometry is completed with electromagnetic simulations. Examples of composites dusts generated in the device are also presented.

Electron Cyclotron Resonance (ECR) sources are well-known to be able to produce low pressure / high density plasma. An innovative dipolar plasma source has been developed and first characterised by the group of J. Pelletier [1-3]. This technology has been chosen to develop our process system: CASIMIR II, which is a low temperature high density plasma reactor envisioned to simulate some plasma/surface processes occurring under the divertor dome and in the far Scrape-off Layer (SOL) regions of tokamaks. The CASIMIR II (Chemical Ablation, Sputtering, Ionization, Multiwall Interaction and Redeposition) device is composed of 16 dipolar plasma sources close enough together to ensure large enough homogenous plasma density (from 10^{10} cm^{-3} to 10^{12} cm^{-3} depending on the nature of the gas and pressure). The idea is to study the formation under plasma exposure of mixed materials with compositions similar to those foreseen in fusion devices (C/W/Mg, stand-in for Be).

We will first present main results of an extensive measurement campaign realized to fully characterize the plasma inside the CASIMIR reactor, both when excited by a single ECR source and in the complete reactor. Electronic parameters (electron density and temperature, and more accurately the energy distribution function), gas temperature, neutrals and ions relative densities, and ion energy distribution functions, were collected in various reactor operating conditions. The varying parameters were the gas pressure (10^{-3} to 10^{-2} mbar), the injected microwave power (1 to 3 kW), and gas mixtures (H_2, D_2, Ar).

In a second part, the experimental approach is completed with a comprehensive study of the magnetic field strength within the CASIMIR vessel performed by using the electromagnetic toolbox of the Multiphysics software Comsol©. These results were compared with set of measurements obtained thanks to a gaussmeter. The CASIMIR ECR sources indeed include a permanent magnet for electron confinement and a microwave supply which heats the electrons. The plasma is thus generated at the electron cyclotron resonance location, here 875 G for a 2.45 GHz excitation frequency. We first did a magnetostatic study, mapping the magnetic field lines and determining the magnetic flux densities around the magnet. Second, we did an electrostatic study, mapping the electric field at the entrance of the microwave supply port. This was done for a single source, then a pair of sources, and finally for the full 16 sources in the exact CASIMIR II configuration. Experimental results obtained in CASIMIR II in pure hydrogen plasma are presented with its corresponding magnetic configuration. An energy balance of the reactor with a single ECR source is performed in order to estimate the *power absorbed by the plasma* to the *power supplied to the system* ratio P_{abs}/P_{sup}.

To finish, first results of carbon target and tungsten target exposure to the plasma are presented.

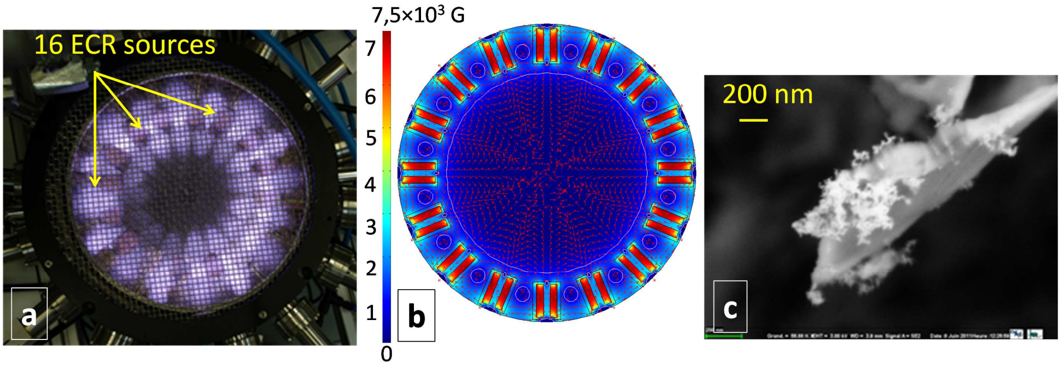

Fig. 1: a) Picture of CASIMIR II in pure hydrogen plasma, b) Magnetic configuration of CASIMIR II, c) SEM micrograph of a carbon surface target after hydrogen plasma exposure: Presence of spherical nanoparticules.

References

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