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Study of the chemical etching of carbon surfaces facing argon/hydrogen plasmas in a helicon type reactor

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In the route to the achievement of controlled nuclear fusion as a secure and sustainable energy source, one of the remaining obstacles to overcome is the chemical and physical erosions of the reactor walls by the fusion plasma. A better understanding of the process is an essential issue to solve in order to improve the quality of the carbonic compound and prevent it from polluting the fusion reaction, especially in ITER. Our work focuses on this matter: we study the chemical erosion by atomic hydrogen of different carbon surfaces (graphite and N11 composite used in Tore Supra) in the purpose of characterizing etching and redeposition growth kinetics.
The helicon-type reactor is surrounded by two sets of copper coils allowing a static magnetic field up to 200G. Pure H_2 or Ar/H_2 plasmas are generated by a 13.56MHz RF 2kW power supply. Etching experiments are performed on carbon samples lying on a heating substrate-holder (up to 650°C).
To investigate plasma/surface interactions, several diagnostics were carried out for the characterization of the plasma and the carbon samples. We used Two-photon Absorption Laser Induced Fluorescence (TA-LIF) to determine relative atomic hydrogen density (in the ground state). Langmuir probe measurements completed the plasma characterization (electronic density and temperature). We observed the etching outcomes with mass loss and structure comparison. The latter was achieved via Scanning Electron Microscopy (SEM). Furthermore, we analyzed the redeposited carbon structures by means of micro-Raman Spectroscopy.
The results show that the optimal pressure to obtain the highest etching rate in pure hydrogen plasma is around 10mTorr (this rate is inversely proportional to the pressure) and even below for Ar/H_2 mixtures, Ar being necessary to stabilize the plasma at low pressure. Since the diffusive loss term becomes prominent with respect to the source term when the pressure decreases, the TA-LIF signal drops. Eventually, we observe carbon structures resembling those seen on the carbon tiles of Tore Supra.

Keywords
Atomic hydrogen source
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TA-LIF, micro-Raman spectroscopy