Linear machines for plasma-material interaction studies: experiments and modelling

A. Uccello

Istituto per la Scienza e Tecnologia dei Plasmi, CNR, via Cozzi 53, 20125 Milan, Italy

Plasma-wall interaction (PWI) is one of the most critical challenges with respect to the performance, safety and availability of ITER and DEMO [1,2]. Plasma-facing components (PFCs) should withstand high particle and heat fluxes, both in steady state and during transient events (like ELMs and disruptions). They will be eroded by particle bombardment, negatively affecting their lifetime and also the purity of the plasma. Moreover, eroded atoms can be promptly re-deposited or can migrate and be co-deposited far from the sputtering source together with radioactive tritium.

Operating tokamaks are close to ITER with respect to many relevant discharge parameters. However, there are still significant limitations in terms of crucial PWI factors, like ion flux and fluence, PFCs temperature, wall and plasma composition. Linear plasma machines, with their versatility to produce stable, steady state multi-species plasmas, allow closing this research gap, cost-effectively [1]. Their general setup consists of a cylindrical vacuum chamber, filled with the working gas, surrounded by magnetic field coils in a linear configuration. Plasma is typically produced and sustained by arc or radiofrequency sources. Plasma exposure of the specimen under investigation is done via a properly designed sample holder. Together with the possibility to accurately define the exposure conditions, linear machines allow an easy access to the samples by diagnostics and for post-mortem characterizations.

This lecture provides an overview of the principal linear plasma devices, describing also their plasma parameters and frequently used diagnostics. As a specific example, we will consider the medium flux (up to $5x10^{20}$ ions $m^{-2}s^{-1}$) linear machine GyM [3], designed and built at Istituto per la Scienza e Tecnologia dei Plasmi (ISTP-CNR).

Some of the possible experimental and numerical approaches to address the PWI issues with linear devices will then be described. In the framework of the activities carried out with GyM at ISTP, also in collaboration with Politecnico di Milano, emphasis will be given to the experimental investigation of the erosion and surface morphology evolution of PFCs and tokamak re/co-deposits. Finally, the modelling approach currently being developed in support of experiments, which relies on the coupling between the edge plasma code SOLPS-ITER [4] (properly adapted to take the linear geometry into account) and the plasma-material interaction ERO2.0 Monte-Carlo code [5], will be finally presented.

[1] Linsmeier Ch. et al 2017 Nucl. Fusion 57 092012

[2] Brezinsek S. et al 2017 Nucl. Fusion 57 116041

[3] Ricci D. et al Proceeding of the 39th EPS Conference, 26 July 2012, Stockholm, Sweden, ECA, 36F P-4.164

[4] Wiesen S. et al 2015 J. Nucl. Mater. 463 480-484

[5] Eksaeva A. et al 2017 Nuclear Materials and Energy 12 253-260