Wall conditioning in fusion devices with superconducting coils

T. Wauters[1], D. Borodin[2], R. Brakel[3], S. Brezinsek[2], S. Coda[4], A. Dinklage[3], D. Douai[5], A. Hakola[6], E. Joffrin[5], T. Loarer[5], H. Laqua[3], A. Lyssoivan[1], V. Moiseenko[7], J. Ongena[1], D. Ricci[8], V. Rohde[9], ASDEX Upgrade team, TCV Team, EUROfusion MST1 team, JET contributors and W7-X Team

[1]Laboratory for Plasma Physics, LPP-ERM/KMS, Brussels, Belgium, TEC Partner; [2]Forschungszentrum Jülich, Institute of Energy and Climate Research – Plasma Physics, TEC, 52425 Jülich, Germany; [3]Max-Planck-Institute for Plasma Physics, Greifswald, Germany; [4]Ecole Polytechnique Fédérale de Lausanne (EPFL), Swiss Plasma Center (SPC), CH-1015, Lausanne, Switzerland; [5]CEA, IRFM, F-13108, St-Paul-Lez-Durance, France; [6]VTT Technical Research Centre of Finland Ltd., PO Box 1000, 02044 VTT, Finland; [7]Institute of Plasma Physics of the NSC KIPT, Kharkov, Ukraine; [8]Istituto di Fisica del Plasma CNR, Milano, Italy; [9]Max-Planck-Institut für Plasmaphysik, Boltzmannstrasse 2, 85748 Garching, Germany

This contribution reviews the currently applied wall conditioning methods in fusion devices with special emphasis on wall conditioning in the presence of a permanent magnetic field by applying RF discharges at the ion- and electron cyclotron range of frequencies (ICRF resp. ECRF). The review is built upon the results of tokamaks JET, TEXTOR, TCV, ASDEX Upgrade and JT60-U. Stellarators experience is based on W7-X, U2-M and LHD. The roles of traditional wall conditioning methods such as baking, glow discharge conditioning (GDC) and low-Z wall coatings on superconducting devices will also be discussed.

Wall conditioning is essential to increase the plasma performance in fusion devices by reducing the release of volatile plasma impurities from the first wall due to plasma–surface interactions, and to control the recycling of hydrogenic fuel fluxes [1]. In particular, ITER relies on conditioning to mitigate the tritium inventory build-up in the plasma-facing materials [2].

Current research efforts on RF conditioning aim at developing reliable RF plasma production methods for tokamaks as well as stellarators using ICRF and ECRH systems to produce a currentless plasma. RF conditioning plasmas, in reactive or noble gases, are characterized by a significant higher density than glow discharge plasmas. This enhances desorption of volatile species during conditioning, although requires pulsed plasma operation to reduce their re-ionisation. The location and size of the plasma-wetted area is determined by the shape of the confining magnetic field, allowing targeted interaction with limiters or divertor. For example, stellarator He-ECRH plasma, produced by localised power absorption at the EC resonance layers, was shown to effectively desaturate the divertor targets from hydrogen on W7-X.

ECRH plasma production in the tokamak vacuum magnetic field, with much reduced confinement, is hampered by a low single pass absorption. To increase the single pass absorption, high densities and temperatures at the resonance layer are required, and hence considerable launched power. Strong and volumetric collisional absorption at low density and temperature is characteristic for ICRF plasmas, relaxing the power requirements for these plasmas and simultaneously improving the discharge homogeneity. While not necessarily accessing the same areas, the amount of retained fuel in the plasma facing materials accessible to ICRF conditioning is larger than that of L-mode plasmas by a factor 2, and approaches that of GDC in isotopic exchange experiments on the JET-ILW.

RF wall conditioning discharges in future devices such as ITER and JT60-SA are studied with help of the codes TOMATOR, KIPT-RF and RFDINITY. A brief description of these simulations and the underlying physical principles will be presented.

[1] Winter J. Plasma Phys. Control. Fusion 38 (1996) 1503–1542.

[2] ITER Research plan, 17 Sept 2018, report no ITR-18-003