Fusion Engineering and Design 86 (2011) 1797–1800

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

New linear plasma devices in the trilateral euregio cluster for an integrated approach to plasma surface interactions in fusion reactors

B. Unterberg[a,*], R. Jaspers[b], R. Koch[c], V. Massaut[d], J. Rapp[e], D. Reiter[a], S. Kraus[a], A. Kreter[a], V. Philipps[a], H. Reimer[a], U. Samm[a], L. Scheibl[a], B. Schweer[a], J. Schuurmans[d], I. Uytdenhouwen[d], R. Al[e], M.A. van den Berg[e], S. Brons[e], H.J.N. van Eck[e], W.J. Goedheer[e], M.F. Graswinckel[e], T. van der Grift[e], A. Kleyn[e,f], W.R. Koppers[e], O. Kruyt[e], A. Lof[e], H.J. van der Meiden[e], W. Melissen[e], M. van de Pol[e], G.J. van Rooij[e], P. Smeets[e], J. Scholten[e], D.C. Schram[e], G. De Temmerman[e], W. Vijvers[e], P.A. Zeijlmans van Emmichoven[e], J.J. Zielinski[e]

[a] *Institut für Energieforschung - Plasmaphysik, Forschungszentrum Jülich GmbH, Association EURATOM- Forschungszentrum Jülich, D-52425 Jülich, Germany*[1]
[b] *Science and Technology of Nuclear Fusion, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands*
[c] *Laboratoire de Physique des Plasmas/Laboratorium voor Plasmafysica, ERM/KMS, EURATOM-Association, B-1000 Brussels, Belgium*[1]
[d] *SCK-CEN, The Belgian Nuclear Research Centre, EURATOM-Association, Boeretang 200, 2400 Mol, Belgium*[1]
[e] *FOM-Institute for Plasma Physics Rijnhuizen, Association EURATOM-FOM, PO Box 1207, 3430 BE Nieuwegein, The Netherlands*[1]
[f] *Leiden Institute of Chemistry, Leiden University, Leiden, The Netherlands*

ARTICLE INFO

Article history:
Available online 15 August 2011

Keywords:
Plasma surface interactions
Linear plasma devices
Surface diagnostics

ABSTRACT

New linear plasma devices are currently being constructed or planned in the Trilateral Euregio Cluster (TEC) to meet the challenges with respect to plasma surface interactions in DEMO and ITER: i) MAGNUM-PSI (FOM), a high particle and power flux device with super-conducting magnetic field coils which will reach ITER-like divertor conditions at high magnetic field, ii) the newly proposed linear plasma device JULE-PSI (FZJ), which will allow to expose toxic and neutron activated target samples to ITER-like fluences and ion energies including in vacuo analysis of neutron activated samples, and iii) the plasmatron VISION I, a compact plasma device which will be operated inside the tritium lab at SCK-CEN Mol, capable to investigate tritium plasmas and moderately activated wall materials. This contribution shows the capabilities of the new devices and their forerunner experiments (Pilot-PSI at FOM and PSI-2 Jülich at FZJ) in view of the main objectives of the new TEC program on plasma surface interactions.

1. Introduction

Plasma surface interactions will decisively determine the availability and thus the economy of a fusion reactor because of their impact on lifetime of the first wall (erosion) and on safety (tritium retention and dust production). In view of plasma surface interactions in ITER and DEMO new challenges have to be met:

- extended operational regimes with respect to particle and heat flux densities onto plasma facing components, both steady-state and transient:
- the use of toxic first wall materials (Be in ITER)
- the presence of Tritium
- the impact of neutron irradiation onto first wall material

To meet the challenges just described, the use of a large variety of facilities is needed: experiments on tokamaks and stellarators are necessary since the topology of the magnetic field plays an important role and the non-linear dependence between wall and plasma performance must be addressed. Dedicated plasma-wall interaction facilities on the other hand are important to address questions for which magnetic confinement devices are either not suitable at present (e.g. large fluences at steady state conditions) or not available (e.g. because of limited flexibility and time constraints). In addition, better diagnostic access in general allows more detailed investigations of dedicated PSI processes compared to what is possible in tokamaks or stellarators.

The Trilateral Euregio Cluster (TEC) will address the urgent research needs described before and exploit the capabilities of linear plasma facilities with a suite of new devices (MAGNUM-PSI at FOM, VISION I at SCK-CEN and JULE-PSI at FZJ), which are presented in this contribution with their forerunner experiments (Pilot-PSI at FOM and PSI-2 Jülich at FZJ).

* Corresponding author.
E-mail address: b.unterberg@fz-juelich.de (B. Unterberg).
[1] Partners in the Trilateral Euregio Cluster.

0920-3796/$ – see front matter © 2011 Forschungszentrum Jülich, Institut für Energieforschung-Plasmaphysik. Published by Elsevier B.V. All rights reserved.
doi:10.1016/j.fusengdes.2011.03.082

Table 1
Overview of the main specifications of the new linear devices in the TEC.

New challange	MAGNUM-PSI	JULE-PSI	VISION I
Reactor like divertor conditions (steady state loads)	Yes, divertor simulator	No, but reactor like plasma fluence and ion energies	No
Reactor like transient heat loads	Yes, pulsed plasma source under development	Yes, JUDITH (electron beam facility inside Hot Cell), additionally laser heat pulses in JULE-PSI	No
Tritium	No	No T-plasma but moderate T handling capabilities	Yes
Toxic materials (Be)	No	Yes	Yes
Neutron activated materials	No	Yes	Yes, but limited to moderately activated samples

The main objectives of the new TEC research program on plasma surface interactions are:

- Investigation of erosion and re-deposition for lifetime prediction of plasma facing components and contamination of plasma
- Investigation of tritium retention (and removal) for safety and fuel cycle
- Investigation of dust production for safety
- Investigation of structural integrity of the plasma facing components under the influence of high particle and heat fluxes including irradiation
- Investigation of processes in boundary plasma
- Development of advanced boundary plasma and plasma surface interaction diagnostics and control tools
- Development and validation of computational models for interpretation and prediction to fusion reactors

2. The TEC PSI facilities

The TEC research programme will be conducted with a suite of new and complementary devices to meet the urgent challenges described before, their characteristic properties for this mission are summarized in Table 1. As can be noted the devices can altogether address all challenges stated before, and the plasmas can cover the conditions in ITER with respect to particle flux density and ion energy ($E_i = 3T_e + 2T_i$) from the wall to the divertor strike zones (parameters taken from [1], cf. Fig. 1).

Note, that the attainment of higher ion energies in linear devices requires target biasing or additional RF heating (as foreseen in MAGNUM-PSI [4]) and that the particle flux densities depicted are normal to the target surfaces. The very particle high fluxes delivered from the cascaded arc source in MAGNUM-PSI will allow to realize ITER flux conditions at inclined surfaces because it matches both densities and temperatures of the ITER divertor strike point as seen in Fig. 2. Here, ITER parameters are show in comparison to the plasma parameters already realized in the forerunner experiments PILOT-PSI and PSI-2.

2.1. MAGNUM-PSI

The MAGNUM-PSI machine at FOM (cf. [4] for an extended description of the device), currently under constructions at FOM Rijnhuizen, The Netherlands, will employ a high-pressure cascaded arc source [5]. A prototype of the source has successfully been tested at the Pilot-PSI machine [6], the forerunner of MAGNUM-PSI and proved the plasma parameters anticipated for MAGNUM-PSI and listed in Table 2.

The plasma in MAGNUM-PSI is magnetized, steady-state ($B = 3T$, generated by SC coils) with a large cross section (80 cm^2), characterized by high particle flux (up to 10^{25} H^+ ions $m - 2s - 1$ at normal incidence) and simulates the conditions expected in the ITER divertor. It will allow to investigate both the processes in the plasma (including detachment) and at the surface. The resulting steady state heat flux density of up to 40 MWm^{-2} perpendicular to the targets facilities reactor relevant heat flux tests. Moreover, a pulsed operation mode of the source is under development aiming at a transient power flux density of 2 GWm^{-2} for 0.5 ms to simulate transient loads [7]. Neutron damaged or toxic material cannot be handled but it is envisaged to simulate the impact of neutron activation by in situ high energy ion beam irradiation [4].

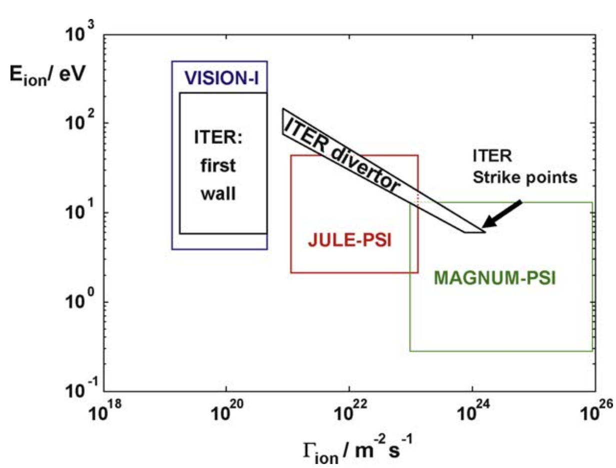

Fig. 1. Parameter range of plasma flux density and ion energies for the new TEC devices in comparison to plasma parameters expected at the wall and in the divertor of ITER (taken from [1]).

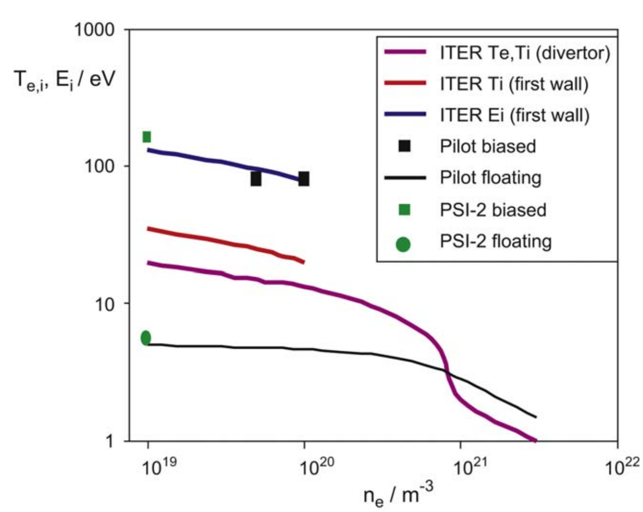

Fig. 2. Parameter range of electron densities, temperatures and ion energies for the forerunner devices Pilot-PSI [4] and PSI-2 [3] in comparison to plasma parameters expected in t ITER (taken from [2] [1]).