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International Collaborative Study on Edge Plasma and Plasma-Wall Interaction by Using Linear Plasma Device toward Steady State Operation

直線型装置を用いた定常運転のための周辺プラズマ・PWI 国際連携研究

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Linear plasma devices (LPDs), sometimes called divertor plasma simulators, have contributed greatly to understanding of egde plasma physics and plasma-wall interactions (PWI) in fusion devices toward a steady state operation. In addition, research in LPDs aimed at ITER and future DEMO is already underway. This presentation describes the present status of international collaboration study by using LPDs especially under IEA Implementing Agreement on the Development and Research on Plasma Wall Interaction Facilities for Fusion Reactors (PWI IA), and some of the key contributions of the research performed in LPDs. Further, the next-steps facilities based on LPDs aimed at obtaining long-tem solutions for future fusion reactor will be reported.

1. Introduction

As nuclear fusion research continue to progress toward burning plasma, ITER and DEMO, more and more stress is placed on the systems surrounding the confined plasma. However, present fusion devices are not able to solve all critical issues, which are relevant to ITER and DEMO devices.

Linear plasma devices (LPDs), sometimes called divertor simulators, are able to bridge this gap between present plasma confinement devices and future ITER and DEMO. This presentation describes the benefit of LPDs including key contributions, and the present status of international collaboration studies.

2. Property of Linear Plasma Devices

LPDs has good properties as follows:

- Ability to produce plasma relevant to future devices at relatively low cost
- Steady-state plasma production allowing equilibration between the plasma and the material
- Ample diagnostic access to the plasma-material interface
- Ability to easily vary individual exposure parameters to allow systematic investigations
- Ability to control plasma composition and add controlled amounts of impurities

Fig. 1 shows operated or planned LPDs in the world. Excellent research on divertor simulation and PWI have been done in LPDs by utilizing their characteristics based on uniqueness and innovative ideas. For examples, PISCES-B in UCSD can handle beryllium (Be) with in-situ surface analysis and Be effusion cell for impurity seeding. MAGNUM-PSI in DIFFER has high B field generated by superconducting coils and produces transient heat load like ELMs. TPE in Idaho National Lab. can generate tritium plasma and handle radioactive materials. GAMMA 10/PDX in Tsukuba Univ. can produce plasma with high ion temperature and investigate edge-core plasma coupling.

International collaborative studies using LDSs have been started under new implement agreement: "Implementing Agreement on the Development and Research on Plasma Wall Interaction Facilities for

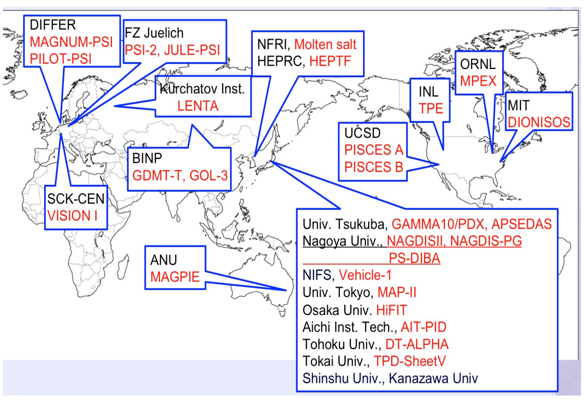

Fig.1 Linear plasma devices in the world[1].

Fusion Reactors" (in short: PWI IA) under the umbrella of the International Energy Agency (IEA)[2]. The PWI IA aims at contribution to a wide rage of activities in the fusion program, including the topics: (1) characterization of plasma edge properties, (2) development and qualification of first wall materials, (3) surface characteristics under intense particle and heat loads, (4) development of diagnostics for edge plasma and material surface characterization, (5) modelling of plasma wall interaction processes.

3. Key Contributions

Some of the key contributions of the research performed in LPDs are described. In order to overcome the difficulty to reduce heat loads onto the divertor plate, the gaseous divertor concept was proposed. LPDs have contributed extensively to the investigation of gaseous divertors associated with plasma detachment [3], because LPDs can generate a steady-state detached plasma with a simple geometry. It should be mentioned that the QED LPD at PPPL was the first to verify the feasibility of the gaseous divertor concept [4]. Fig. 2 shows the detached plasma observed in the NAGDIS-II device in Nagoya University. Molecular Assisted Recombination (MAR) has been firstly observed under Japan-US collaboration [5].

LPDs also offer the opportunity to begin investigations related to long-term solutions to PWI issues. One typical example of this is the surface temperature dependent response of tungsten(W) material exposed to a plasma containing helium. At temperature above 1000 K, fiber-form nanostructure W, so called “W fuzz”, was found to be formed in LPDs as shown in Fig. 3[6]. The W fuzz becomes one of the critical issues in the next fusion device, such as ITER, which is intended to use W as a plasma-facing material.

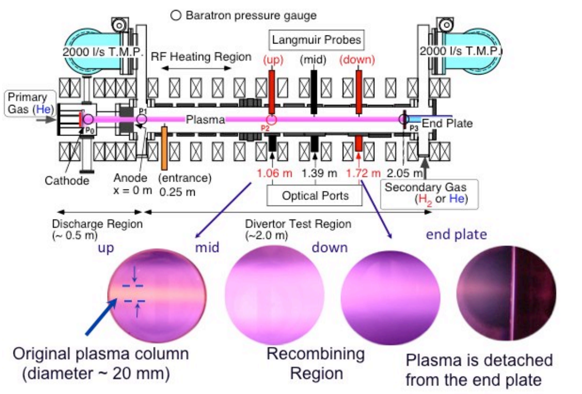

Fig. 2 Plasma detachment observed in NAGDIS-II in Nagoya University.

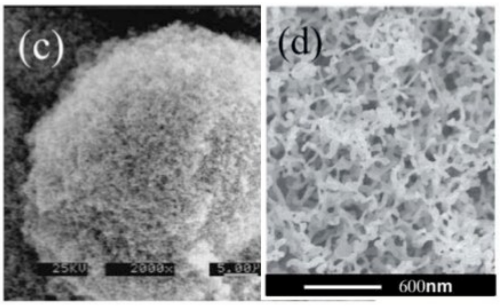

Fig. 4 SEM photos of W fuzz structure formed in the LPD[6]

4. Advanced PWI Study

Transient plasma events in steady state plasma such as Edge Localized Modes (ELMs) determines the lifetime of plasma-facing materials. To produce transient plasma events in steady state plasma, the possibility to superimpose transient plasma pulses to the steady-state plasma was studied on the NAGDIS and Pilot-PSI devices. A Magnetized Co-axial Plasma Gun (MCPG) was mounted on the NAGDIS-I device[7]. On the other hand, in the PILPO-PSI, the cascaded arc source used to produce the steady-state discharge is connected in parallel to a pulsed power supply and the current regulated DC supply[8]. The discharge power is pulsed in a sub-ms timescale from the DC level (~30 kW) to up to 1 MW creating heat fluxes in excess of 1 GWm^{-2}.

Further, toward DEMO, systematic studies of hydrogen isotope retention in neutron-damaged materials will be required. In order to perform this experiment, PMTS (Plasma Material Test Stand) at ORNL is planned and JULE-PSI (Jülich Linear Experiment for PSI studies in a hot cell) in Jülich is under construction. C_DPS/IG-TDS (Compact Divertor Plasma Simulator/Ion Gun with TDS) at Tohoku Univ. will be operated in the radiation controlled area and perform TDS analysis without air exposure in near future.

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