§71. Simultaneous Measurements of Molecule Pressure and Atomic Flux in QUEST Divertor for Understanding of Neutral-plasma Interaction

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Molecular pressure is measured in QUEST with ASDEX gauges[1] (AG) – specially designed ionization gauges for normal operation in the strong magnetic field. AGs are located below the bottom p1ate (AG2) and at the side wall in the extension port (AG1), as shown in Fig.1. Partial gas pressures (H_2 and He) are measured by a quadrupole mass-analyzer (QMA). All gauges are calibrated using standard (H_2 and He) leaks. Since AG signal depends on the magnetic field, AGs are calibrated at different magnetic fields under the various vertical field conditions.

Atomic H flux to the walls is measured by the plasma driven permeation probes (PDPs) using PdCu membrane. Membrane material choice is dictated by the diffusion properties of the material. It is crucial for PDP to have high sensitivity and hydrogen (H) permeability to improve time response and to decrease minimum detectable incident retention flux Γ_{inc}. Highest known diffusivity at low temperatures of any metal-hydrogen system has β phase of a PdCu alloy[2]. Alloy composition is 60 wt.% Pd and 40 wt.% Cu was selected for PDPs. This composition has stable β phase in wide temperature region below 400°C.

For measurements of the distribution of the Γ_{inc} four probes were installed in QUEST, at top and bottom plates (PDP5 and PDP4) and on the 'side' wall far from the main plasma-wall interaction (PWI) area (PDP6 and PDP7), see Fig. 1. PDP4 and 5 are subjected not only to atomic fluxes, but also to the ion fluxes. Distribution of the permeated flux Γ_{pdp} is different in ECRDC (cylindrical plasma) and in a tokamak configuration. All probes have their own pumping and measuring systems. Pumping system consists of a turbo-molecular pump (TMP), rough pump and gauges, vacuum vessel base pressure is ~1-3×10^{-5} Pa. Γ_{pdp} is registered using QMA. Cylindrical PdCu membrane, thickness of 20 μm is supported by a stainless steel mesh. Cylindrical heater inside the membrane cylinder is kept by the feedback controlled power supply at the given temperature. Since thermocouple (TC) is connected to the heater outside surface, membrane is heated by the conductivity and radiation from the heater, the membrane temperature deviates from TC readings not more than 5 K. In permeation experiments membrane temperature T_{pdp} = 573 K was kept constant. The detection area A_{pdp} is ~ 7.5×10^{-3} m^2. Transparency of the SS mesh is 45-55%. Dimensions of the rectangular window facing to the plasma are 28×83 mm. No influence of the ionized particles moving along magnetic field line is expected. To calculate Γ_{inc} numerical methods are required to solve diffusion problem. We use the diffusion code TMAP7[3] for calculations. In case of PdCu membrane diffusion is in the surface limited regime, all equations for diffusion model are the same as in [3].

Time evolution of molecular hydrogen pressure P_{H2}, total AG pressure P_{AG2} (red), measured Γ_{pdp} calculated Γ_{inc} are shown in Fig. 2 for longest tokamak discharge (820 s). In this discharge the plasma current I_p was almost constant ~ 15 kA and line density $n \cdot l$ ~ 1×10^{17} m^{-2}. Noticeable difference in P_{AG2} compared to P_{H2} could be due to H2 and N2 release from the heated plates. Different behavior of the Γ_{inc} at PDP4 and PDP6 compared to PDP7 could be ascribed to a change in plasma position before plasma termination. H retention in the wall materials, estimated from Γ_{inc} is comparable with that estimated using global gas balance[4].

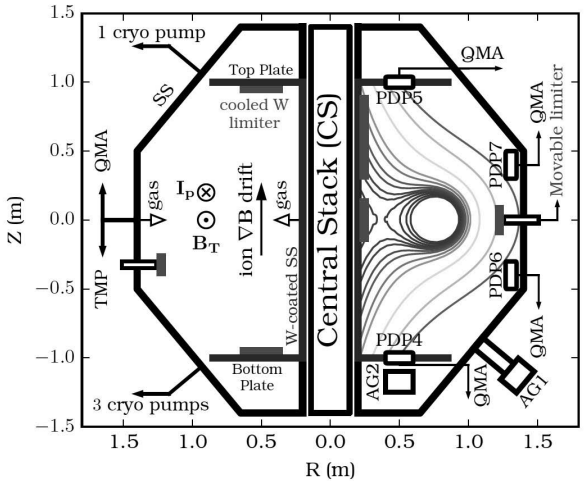

Fig 1. Schematic view of the AG and PDP location in QUEST. Plasma inboard null configuration is shown.

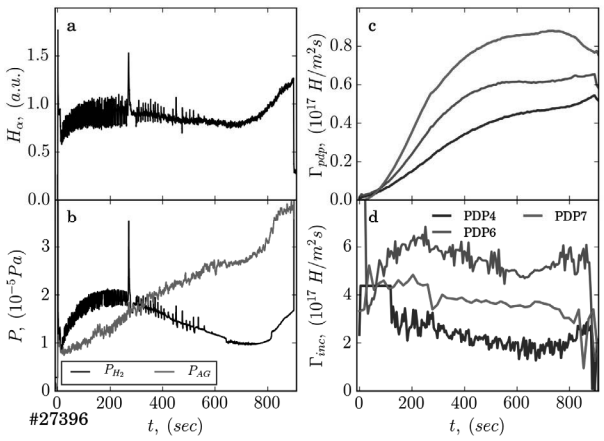

Fig. 2. a. H_α signal, b. P_{H2} (black) and P_{AG2} (red), c. measured Γ_{pdp} d. calculated Γ_{inc}.

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2) J. Piper, J. Appl. Phys. 37 (1996) 715
3) G. R. Longhurst, J. Ambrosek, Technical Report INEEL/CON-04-01593, 2004
4) A. Kuzmin et.al, JNM, PSI-2014 paper in print