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プロトン導電体ポンプによる水素同位体移送

Hydrogen transport characteristics of proton conductor pump

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1. Abstract

Kyoto Fusioneering Ltd. is developing a proton conductor pump for selective recovery and pumping of hydrogen isotope gas in the fuel exhaust system of a fusion reactor. In this presentation, we will report experimental results of the basic characteristics of the hydrogen transfer capability by the proton conductor pump, which indicates the selective pumping of purified hydrogen isotope gas that could be potentially used for recycling to the plasma. This feature will simplify and reduce the primary fusion fuel cycle for burning plasma and reduces total tritium inventory.

2. Purpose

The recycling of unreacted gas in the fusion core must be recovered and used as fuel for the operation of a fusion reactor. The exhaust in ITER is planned to be evacuated by cryopump, which leads to very large amount of tritium-inventory due to the condensation. It is desirable to evacuate plasma exhaust in gas phase, and immediately return to the plasma as fuel. This fuel cycle concept (Direct Recycle DIR) reduces the throughput of the exhaust processing system and isotope separation system, resulting significantly smaller inventory. Our study focuses on proton pumps conductor contain Yb3+, Y3+, and In3+ in perovskite-type oxides (BaCeO3, CaZrO3, and SrZrO3) to develop a selective pumping capability of hydrogen isotopes for DIR.

3. Experimental methods

Gas transfer characteristics were measured using a proton conductor disk (1 mm thick, 20 mm diameter, supplied by TYK). Figure 1 shows the apparatus for the evaluation of the proton conductor cell. The electrochemical potential of both sides of the cell is measured at the platinum electrodes painted on the surface of the conductor disk. Measurements of the electromotive force between the inside and outside of the cell with different gas atmospheres indicate the concentration cell function of the proton conductor pump. When voltage and current are applied between the electrode, hydrogen transport is driven.

4. Result and Discussion

The obtained proton transport current is confirmed to follow the Nernst equation. The hydrogen transport capability is confirmed. The time constant of several tens seconds, measured from the capacity and conductivity of the proton conductor shows very short residual time of proton within the cell. which indicates the possibility to significantly reduce the inventory of the DEMO fuel system. The proton conductor pump is a new exhaust technology and fuel system concept for the divertor exhaust.

Figure 2 indicates a isotope effect between H and D is about 2.0 by the difference between both ionic current across the proton conductor cell. The hydrogen isotope transfer difference was confirmed by changing the concentrations of H_2 and D_2. This result suggests that deuterium-enriched and tritium-enriched portions can be separated and recovered from the DT exhaust gas mixture, which is supplied from the divertor, and can be utilized to adjust the plasma composition. These results indicate the possibility of application for plasma exhaust processing with reduced inventory and short time constant.

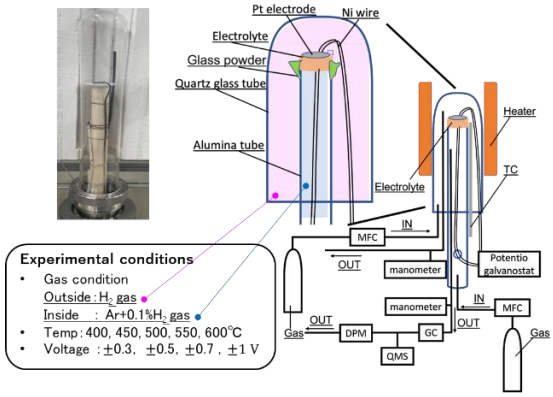

Figure 1. Experimental equipment to evaluate proton conductor cells. *Adapted from [Yamaguchi et al. 2022]

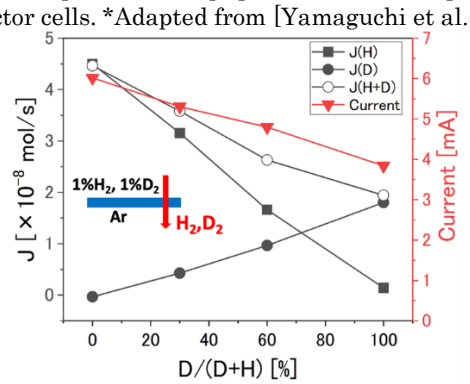

Figure 2. The fluxes of H and D and their current values for each ratio of D/(D+H).