Scaling up proton ceramic electrolysis: current status and perspectives

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Abstract

Proton-conducting oxides have several unique characteristics that distinguish them from both higher temperature oxygen ion conducting oxides and lower temperature proton-conducting polymers. By enabling proton-mediated electrochemistry under both dry and wet environments at moderate temperatures (e.g. 400–600 °C), these materials provide unique opportunities to enhance a diverse range of complementary electrochemical and thermochemical processes while providing storage solutions. Significant efforts are devoted to the development of proton conducting ceramic electrolysers (PCE) for the direct production of pressurized hydrogen at intermediate temperature. In this work, we are focusing on the technology developed in several European projects* (WINNER, GAMER, PROTOSTACK), which is based on tubular stack technology. This enables e.g. lowering production cost due to reduction of materials costs and processing steps, lowering environmental footprint, and mitigating mechanical failure to the stack geometry and reduced sealing areas.

The stack technology to produce pure dry pressurized hydrogen uses high volume production of tubular PCEs containing BZCY-based electrolyte, BZCY-Ni tubular hydrogen electrode and BGLC-BZCY composite steam + O_2 electrode. The cells are integrated in tubular steel shells forming the so called "single engineering units" (SEU). The SEUs have ca. 50-60 cm^2 active surface area and are qualified for pressurized steam electrolysis operation at intermediate temperature (600°C) and up to 10 bar pressure demonstrating high faradaic efficiency and reasonable area specific resistance. A dedicated design assembly of the SEUs to produce racks of 16 SEUs mounted in series has been developed in the project, as well as an integrated system design with necessary balance of plant components (see fig. 1). Preliminary results of system operated at ambient pressure and up to 7 bar will be presented, and insights on degradation mechanisms will be discussed.

Furthermore, new results obtained on operating novel PCE cell architectures in pressurized reversible mode of operation (fuel cell and electrolysis) for more than 3000 hours will be presented. We will show how each mode of operation impacts the performance and evolution rate of the cell as function of time and operating conditions (temperature, steam content, fuel utilization, etc.). Opportunities and current challenges of this technology will be summarized to provide insights into possible research and industrial development pathways.

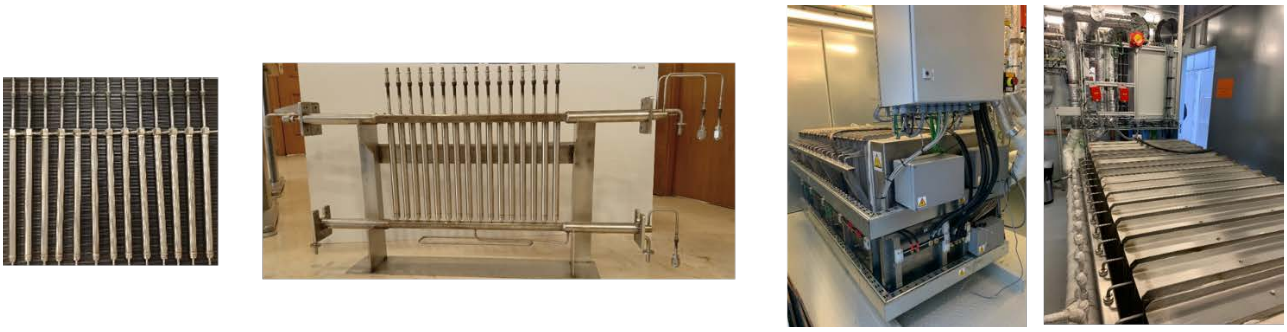

Fig. 1: Camera pictures showing the SEUs, rack, and hot-box and system.

*The projects WINNER, GAMER, PROTOSTACK are supported by the Clean Hydrogen Partnership and its members Hydrogen Europe and Hydrogen Europe Research.