HENRY ROYCE INSTITUTE

ADVANCED MATERIALS RESEARCH & INNOVATION

MATERIALS CHALLENGES TO ENABLE HYDROGEN DEPLOYMENT AT SCALE BY 2050

Challenge: Reducing iridium loading in polymer electrolyte membrane (PEM) electrolysers to realise global electrolysis capacity ambitions at a terawatt (TW) scale.

CONTEXT

Maximising the efficiency of hydrogen production via electrolysis is important to minimise the costs of green hydrogen, as input energy is a key component of the production cost. PEM electrolysers are currently the leading technology option.

PEM electrolysers use catalysts based on rare metals at both the anode and cathode, to minimise the specific energy consumption (kWh/kg) of the stacks. Choice of catalyst is currently limited to the relatively rare and costly platinum group metals due to the harsh conditions in PEM electrolysers – low pH, high potential, and high oxygen concentration.

PEM electrolysers, such as those produced by ITM Power, can achieve a specific energy consumption of below 60kWh/kg. In 2018 a European partnership, The Fuel Cells and Hydrogen Joint Undertaking (FCH JU), set a target specific energy consumption for PEM electrolysers of 55 kWh/kg in 2020, improving to 50 kWh/kg by 2030. New catalysts will therefore need to maintain or improve the efficiency of PEM electrolysis.

The previous Henry Royce report on materials needs for low-carbon hydrogen production estimated the length of time to produce sufficient iridium and platinum to support 1TW of PEM electrolysis capacity. While this is a long-term challenge for PEM electrolysers, which are currently only manufactured in the tens of MW per year, if hydrogen is adopted globally then significantly more electrolysis capacity will be required. IRENA estimate that between 4 and 16 TW of wind and solar capacity could be required for hydrogen production alone by 2050.

State-of-the-art PEM electrolysers require 1–3mg/cm² of platinum group metals (iridium and ruthenium-based oxides) to catalyse oxygen evolution at the anode. The Henry Royce study on materials for low-carbon hydrogen production estimated that over 27 years of the 9 tonne/year global iridium production would be required to develop 1TW of PEM electrolyser capacity, which is clearly a limitation. It is estimated a 40-fold reduction in PEM electrolyser iridium loading is required for large-scale electrolysis. High demand for iridium, long processing times, limited supply, and an undiversified supply chain have already caused the price of the metal to increase nearly four-fold, from $1,670/Oz at the start of December 2020 to $6,000/Oz by the end of March 2021. Without new materials solutions to reduce iridium loading in PEM electrolysers, volatility in iridium price and lack of availability will impact the viability of large-scale PEM electrolysis.

Platinum is used to catalyse hydrogen evolution at the cathode of PEM electrolysers. The Royce materials for low-carbon hydrogen production report estimates that, with 0.025mg/cm² platinum loading, the production of 1TW of PEM electrolysis would require only 0.02 years of the annual 200 tonnes/year global platinum production capacity. Reducing iridium loading is therefore a more urgent research challenge than reducing platinum loading.

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MATERIALS RESEARCH CHALLENGE

Materials research should aim to enable reductions in rare material loading in electrolysers while maintaining (or ideally improving) electrolyser efficiency and durability. Incremental improvements to catalyst performance may be achieved by screening large numbers of catalyst materials (through a combination of computational aided design and physical testing). It is expected that step-changes in catalyst performance will be delivered via deeper understanding of methods to reduce catalyst loading. Nanoengineering will play a key role in turning inactive sites into active sites, thus minimising catalyst loading requirements.

Research to support the reduction of rare material use in electrolysers is not limited to the development of new catalysts. It will need to consider all materials in the overall electrolyser system. For example, it is likely the development of new substrates (such as titanium dioxide-based substrate materials) that are stable in the acidic, oxygen rich environments found in PEM electrolysers, will be required to support single-site catalysis.

Development of new materials should be aligned with an understanding of the economic and life cycle impact of raw materials on the electrolyser supply chain. Industry collaboration is required to benchmark catalyst properties, and to share data on catalyst performance characteristics, to help focus research efforts on the most promising areas.

UK CREDENTIALS AND WAY FORWARD

The UK is well placed to work on this challenge, given the expertise in PEM electrolysis from businesses such as ITM Power, one of the world's leading PEM electrolyser manufacturers. ITM Power is in the process of significantly increasing its manufacturing capacity and the size of the electrolyser modules. Further, the UK has specialists across academia and industry in catalysis, from companies such as Johnson Matthey, and expertise from the UK Catalysis Hub, Cardiff Catalyst Institute, and Imperial College. Beyond catalyst expertise, knowledge of nanoengineering is also expected to lead to new insights about catalyst performance, through organisations such as the London Centre for Nanotechnology.

A cross industry/academic group is currently developing a more detailed proposal outlining the research challenges, resources and capabilities required to achieve a breakthrough in this area to enable widescale hydrogen deployment by 2050. This proposal will be available by the end of July for consideration for inclusion in the November spending review.

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