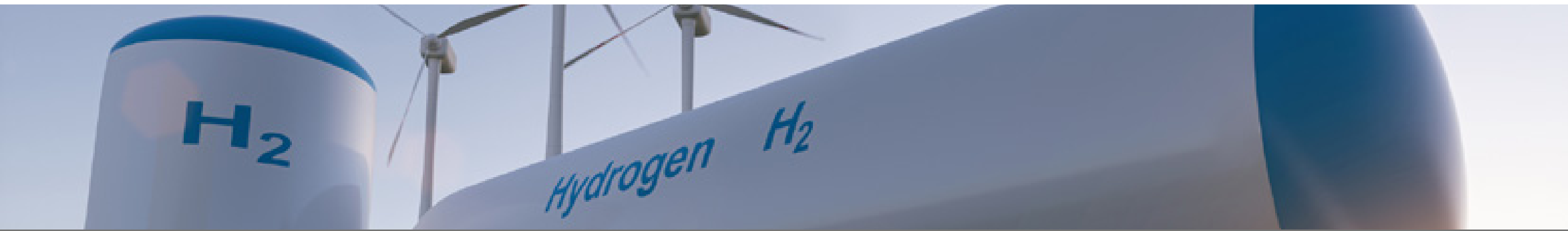
HENRY ROYCE INSTITUTE

ADVANCED MATERIALS RESEARCH & INNOVATION

MATERIALS CHALLENGES TO ENABLE HYDROGEN DEPLOYMENT AT SCALE BY 2050

Challenge: Improving point of use hydrogen purification technologies, enabling large scale fuel cell hydrogen supply from the gas grid.



CONTEXT

Hydrogen can be effectively distributed using existing gas grid infrastructure, reducing the cost of hydrogen distribution, and allowing gas grids to transition to a net zero future. Given that hydrogen leaving the grid will be at relatively low purity, and hydrogen fuel cells currently require high levels of hydrogen purity (>99.97%), improvements are required in downstream purification technologies close to point of use. Leading materials-based solutions include the use of membranes and pressure swing adsorption.

When hydrogen production is not co-located with the source of demand, it is currently transported from production sites to end uses (such as hydrogen refuelling stations for fuel cell vehicles) by tube trailer in most cases. Gaseous tube trailers can carry around 300 – 900 kg of hydrogen. While this is a relatively large amount of fuel compared to the size of existing hydrogen refuelling stations (typically with capacity of low hundreds of kilograms per day), there is a trend towards larger capacity refuelling stations for heavy duty vehicles. Designs are emerging for hydrogen refuelling stations with a capacity of multiple tonnes per day, for which delivery of hydrogen via tube trailer in either gaseous or liquid form will become increasingly impractical. While various other solutions are available, using existing gas grids to transport hydrogen from centralised production sites to strategically placed hydrogen refuelling stations is potentially an attractive option.

Given the number of UK projects examining the possibility of hydrogen blending in the gas grid (Hy4Heat, HyNet, FutureGrid, and H21) there is a need to develop solutions to allow hydrogen from the UK gas grid to be used in fuel cell applications.

ROYCE

MATERIALS RESEARCH CHALLENGE

The most common hydrogen purification technology is currently pressure swing adsorption (PSA), in which the gas stream is passed over an adsorbent material, which captures impurities. The pressure of the system is cycled to regenerate the adsorbent material. This method allows transport-purity hydrogen to be produced, however significant costs are introduced due to the relatively low hydrogen recovery of circa 90% owing to ~10% losses on system purging. PSA units typically contain materials such as zeolite 5A, silica gel, alumina, and activated carbon. Metal organic framework (MOF) based materials may also be used for PSA in the future. New materials would aim to improve hydrogen recovery by increasing the binding between the adsorbent material and the impurity molecules.

Membranes that selectively allow hydrogen to pass through could be used to purify hydrogen from the gas grid at the point of use, either in combination with PSA or as a standalone solution. Palladium-based membranes have been tested at small scale (3.6 kg/hour), but the current operating temperatures of 300 – 600°C make operation as part of the gas grid impractical. Polymer-based membranes are also available, however are unable to achieve the level of purity required for fuel cell applications. These membranes could be combined with other purification technologies to achieve sufficiently high purity levels. Membrane cost is particularly challenging since the failure of a purification membrane at the point of use could cause significant damage to fuel cells. Gas network operators suggested installation of multiple membranes to provide redundancy should costs be low enough. Several approaches to lowering the cost of palladium-based membranes exist, for example including Pd-alloy thin films on porous supports, and the use of transition-metal-based amorphous alloys to replace palladium. Materials research challenges for hydrogen separation membranes include ensuring high selectivity, resistance to impurities such as sulphur, and mechanical and thermal stability, while also achieving a high rate of hydrogen transfer across the membrane. The rate of hydrogen transfer and capital cost are optimised by reducing membrane thickness, but thinner membranes allow increasing quantities of impurities to pass through. There is therefore a clear materials optimisation challenge to improve these membranes.

UK CREDENTIALS AND WAY FORWARD

Linde and Evonik have collaborated on a combined polymer-based membrane and PSA system, designed to be used at hydrogen refuelling stations supplied by the gas grid, with a full-scale demo plant due to go online in 2021. The UK has significant academic expertise in hydrogen purification, with research on membranes at the University of Birmingham and PSA at the University of Edinburgh.

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.

ROYCE