Fuel Cells: Powered by Hydrogen, Inspired by Nature

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Fuel cells (Fig. 1a) are at the heart of the hydrogen economy. They convert hydrogen into electricity, with only water and heat as by-products. Fuel cells do not generate CO_2, are highly efficient, run silently, and are reliable. As such they are already being deployed in various commercial applications including fuel cell electric vehicles (FCEVs); combined-heat-and-power (CHP) systems, and portable generators. However, the rapid advancement of renewable energy technologies is creating new challenges in the sourcing of materials. The list of "critical raw materials" (CRMs) includes key elements used in fuel cells, such as platinum group metals (PGMs) which are currently used as catalysts. If fuel cell technologies are deployed at a global scale, the demand for platinum will rapidly outstrip production.

As such, the search is on for replacement non-PGM electrocatalysts. The most successful candidate thus far is a class of catalysts based on transition metal-decorated nitrogen-doped carbon (Me-N-C). The most commonly used metal is iron, and the chemical structure of these catalysts resembles that of the active centre in biological catalysts such as chlorophyll or haemoglobin (Fig. 1b). I will summarise some of the work we have done in developing our own Me-N-C catalysts, and the lessons we have learned along the way.

Another fuel cell component which is cause for concern is the electrolyte membrane, which transports protons from the anode to the cathode. Sulfonated fluoropolymers such as Nafion or Aquivion are the current state-of-the-art. However, they constitute a high proportion of the cost of a fuel cell stack and pose an ecological threat. To make fuel cells more affordable, we developed electrolytes based on the biopolymer, cellulose. As a result, we report possibly the cheapest functional fuel cell electrolytes in the literature (Fig. 1c).

Dr Lyth obtained his M.Sci in Physics from Durham University in the UK, and a PhD in Electronic Engineering from the University of Surrey. In 2008 he moved to Tokyo Institute of Technology, as a postdoc for a national NEDO hydrogen energy project. He became WPI Assistant Professor at I2CNER in Kyushu University in 2011 and was promoted to WPI Associate Professor in 2015. He joined the Platform for Inter/Transdisciplinary Energy Research (Q-PIT) and the Department of Automotive Science as Associate Professor in 2017. He maintains ties with the UK, holding an RSC Mobility Fellowship from 2014-17, and is a Visiting Professor at the University of Sheffield. He recently received the prestigious NICE-STEP Researcher Award from MEXT, for significant contribution to science and technology.

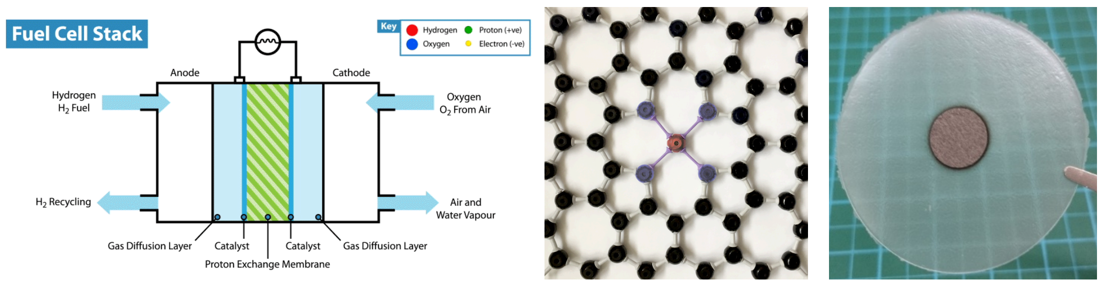

Figure 1: (a) A schematic of a hydrogen fuel cell; (b) the proposed chemical structure of Me-N-C electrocatalysts; (c) paper fuel cell developed by our team.