Electrochemical Energy Conversion

by Andrew M. Herring and Vito Di Noto

The ECS Energy Technology Division was formed in 1983 to provide an overview of current and future energy sources, electrochemical energy conversion, and storage. With ever increasing amounts of renewable energy and the need for load leveling, rapid inter-conversion of electrical energy to chemical energy and vice versa presents an attractive solution to many contemporary energy issues. The devices that are of primary interest to the Division — fuel cells, electrolyzers, their reversible counterparts (e.g., redox flow batteries) and their light driven counterparts — hold the key to a sustainable global energy economy in this context. These technologies are modular and scalable from small (portable) to large (grid) applications. The key to making these devices practical is to fundamentally understand the issues that drive cost and durability, as well as to enable fuel/oxidant flexibility. In this issue of *Interface*, we present an overview of some recent advances in this arena.

We begin with a historical perspective on all fuel cells, and present the reasons why fuel cells have yet to find widespread commercial adoption. This article points out areas where fuel cells are close to market adoption. This is followed by a fascinating article from researchers at Toyota Motor Co., explaining the advances in the fuel cell stack, system, and the car itself that have given rise to their next generation MIRAI fuel cell vehicle. This paper summarizes the huge amount of innovative work that is needed to reach the point where thousands of fuel cell vehicles can realistically be produced.

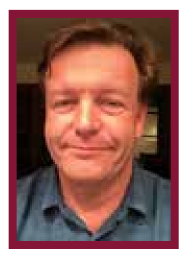
Electro-fuels—chemicals produced by electrolysis, which can be subsequently used in fuel cells or thermal engines—are a topic of increasing interest. In addition to being a potential electro-fuel in an alkaline fuel cell, ammonia, as a feedstock for fertilizer manufacture, is an essential chemical for large-scale production of an agricultural commodity. Alternatives to the energy-intensive Haber-Bosch process are still lacking. However, electrochemical production of ammonia can approach the efficiencies of this thermal process, and can be practiced on a distributed scale using off-grid renewable electricity. We have, therefore, included an article on the history of this "newly rediscovered" technology.

There has been a huge amount of interest in carbon nitride-based catalysts for applications in low temperature fuel cells. These materials have the potential to enable low temperature fuel cells, by allowing non-precious metal or very low precious metal loadings to catalyze the oxygen reduction reaction. A perspective on this material is therefore included, elucidating the effects of synthesis protocols such as precursors and pyrolysis temperature, nitrogen density and distribution, and morphology on the *ex situ* and *in situ* electrochemical performance and durability of these electrocatalysts.

Finally, keeping in mind the ultimate need for reversible fuel cells and metal-air batteries to sustain a renewable energy economy, it will be necessary to develop bi-functional electrodes that enable both the oxygen reduction reaction and the oxygen evolution reaction. The final article in this issue addresses the current state of the art in reversible oxygen electrodes, the developing area of the dual functional catalyst layers that will be necessary to prepare such bi-functional electrodes, and the remaining challenges.

We hope that this collection of articles provides the readership with an overview of the ongoing activities within the Energy Technology Division of ECS.

About the Author



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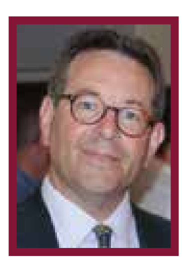

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