In-situ Monitoring of Solid Oxide Electrolysis Cells

Denis Cumming[a,b], Rebecca Taylor[c], Jevgenija Manerova[a], Derek Sinclair[b], Chris Hardacre[c], Rachael Elder[a]

[a]Department of Chemical & Biological Engineering, [b]Department of Materials Science & Engineering, University of Sheffield, Mappin St, Sheffield S1 3JD UK
[c]School of Chemistry & Chemical Engineering, Stranmillis Road, Belfast, Northern Ireland BT9 5AG UK

High temperature co-electrolysis of steam and carbon dioxide using a solid oxide cell (SOC) has been shown to be an efficient route to produce syngas ($CO + H_2$), which can then be converted to synthetic fuel using Fischer-Tropsch technology. Co-electrolysis is significantly more complex than either steam or carbon dioxide electrolysis, in part, due to the contribution of the water gas shift reaction (WGSR) in addition to the two electrolysis reactions:

$H_2O + 2e^- \rightarrow H_2 + O^{2-}$	Steam Electrolysis
$CO_2 + 2e^- \rightarrow CO + O^{2-}$	Carbon Dioxide Electrolysis
$H_2O + CO \rightleftharpoons CO_2 + H_2$	WGSR

Optimization of co-electrolysis requires detailed understanding of the reactions, transport processes and degradation mechanisms occurring in the SOC during operation. Whilst much work has investigated the operation and degradation of solid oxide fuel cells (SOFCs), the processes occurring during electrolysis are less well understood. In-situ characterization will greatly simplify and assist the development of novel electrode and electrolyte materials and structures.

The majority of characterization currently takes place ex situ and is often destructive to the cell, for example SEM. Whilst in situ electrochemical characterization (impedance spectroscopy) can give some information about cell performance, in situ vibrational spectroscopy and imaging have potential to provide detailed understanding of the mechanisms occurring under real operating conditions.

As part of the UK-wide £5.7m 4CU project (A Comprehensive, Coordinated Programme for Carbon Capture and Utilisation Research) we are developing a suite of in-situ characterization techniques for high temperature SOC operation. In this paper we discuss the use of thermal imaging, Raman spectroscopy and diffuse reflectance infrared fourier transform spectroscopy (DRIFTS) to probe both the reactions occurring during operation and any associated changes within the structure of the electrodes and electrolyte.

One of the major challenges of in-situ characterization is the design of experimental apparatus suitable for high temperature operation with optical spectroscopic access to the areas of the SOC that are of interest. In particular, issues with sealing, temperature gradients, signal strength and cell configuration will be discussed and final, commissioned rig designs will be presented. Preliminary results obtained during co-electrolysis operation will also be presented.