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# Performance of solid oxide electrolysis cells based on scandia stabilised zirconia

M.A. Laguna-Bercero*, S.J. Skinner, J.A. Kilner

*Department of Materials, Imperial College London, Prince Consort Road, SW7 2BP London, UK*

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ABSTRACT

Zirconia doped with scandia and ceria (10Sc1CeSZ) is presented as an electrolyte in solid oxide electrolysis cells (SOECs) for hydrogen production at intermediate temperatures. At 700 °C, the conductivity of the 10Sc1CeSZ is 0.057 S cm$^{-1}$ and the ohmic resistance at OCV is 0.27 Ω cm$^2$. The electrolysis tests using Pt electrodes show that the oxygen ion conduction in the electrolyte produces high current densities when operating as a SOEC. The performance of cells with Ni-YSZ (yttria stabilised zirconia) cathodes are also tested under external potential load at temperatures between 600 °C and 900 °C. These preliminary results demonstrate the suitability of 10Sc1CeSZ as an electrolyte for SOECs although further work is required to develop suitable electrodes.



## 1. Introduction

One of the major concerns in research related to future energy sources is the production and storage of hydrogen. In order to achieve zero-emission hydrogen production the hydrogen must be produced from non-hydrocarbon sources, such as the electrolysis of water [1].

At present the state-of-the-art technologies in electrolysis are low temperature alkaline and proton exchange membrane (PEM) electrolysers. The problem with these low temperature technologies is that >2/3 of the cost of electrolysis is due to electricity demand. By increasing the cell operating temperature electrical energy demand is significantly reduced [2]. In this field, solid oxide electrolysers (SOEs) offer significant power, and hence cost, savings over conventional low temperature electrolysers. Nuclear power, renewable energy and waste heat from high temperature industrial processes could be used to supply the heat and power needed for electrolysis. According to the studies of Mogensen et al. [3] SOE technology has the potential for the production of fuel from renewable energy sources or with excess energy from the primary and secondary control of existing power station capacity.

In a SOE, water is supplied to the cathode side of the cell, oxygen ions are transported to the anode through the electrolyte, and the hydrogen is produced at the cathode side. The reactions in the anode and cathode are:

$$H_2O + 2e^- \rightarrow H_2(g) + O^{2-} \quad \text{(cathode)} \tag{1}$$

$$O^{2-} \rightarrow ½O_2(g) + 2e^- \quad \text{(anode)} \tag{2}$$

Another advantage of SOEs is that they can operate reversibly as solid oxide fuel cells (SOFC) producing electricity with high efficiency by consuming the stored hydrogen. Where a fuel cell is capable of being used as an electrolyser cell it is referred to as a solid oxide regenerative fuel cell (SORFC) [2].

To date there have been relatively few investigations of ceramic electrolysers with the majority of studies focussing on the low temperature polymer based systems. Most of the ceramic electrolysers studied have been based on the high temperature yttria stabilised zirconia (YSZ) system [4,5] operating at temperatures of about 1000 °C. In order to reduce the cell operating temperature, electrolytes based on ceria have been recently studied. Zhu et al. [6] tested samarium doped ceria (SDC)-carbonate composite based SOEs and they found that both $H^+$ and $O^{2-}$ transport is significant in the ceria-based composite electrolytes resulting in satisfactory electrolysis effects/processes. At 650 °C, they obtained current densities of −125 mA cm$^{-2}$ at 1.5 V under water saturated air atmosphere.

Several efforts have been also made in order to optimise the performance of the electrodes. Wang et al. [7] tested different composite electrodes of yttria-stabilised zirconia (YSZ) with $La_{0.8}Sr_{0.2}MnO_3$ (LSM), $La_{0.8}Sr_{0.2}FeO_3$ (LSF), and $La_{0.8}Sr_{0.2}CoO_3$ (LSCo) as SOE anodes. LSF-YSZ and LSCo-YSZ composites exhibit impedances that are essentially independent of current and the same under anodic and cathodic polarization. Because LSM-YSZ composites show good performance only after cathodic activation and because this activated state is lost during operation as an SOE, LSM-based electrodes do not appear to be optimal. Marina et al. [8] also studied a wide range of electrodes. As negative electrode compositions they studied a nickel/zirconia cermet (Ni/YSZ) and lanthanum-substituted strontium titanate/ceria composite, whereas positive electrode compositions examined included mixed

* Corresponding author.
*E-mail address:* m.laguna-bercero@imperial.ac.uk (M.A. Laguna-Bercero).

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