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# Application of doped $CeO_2$ nanopowders as anode catalysts in Intermediate Temperature Solid Oxide Fuel Cells using hydrocarbon fuels

S. Song[1], R. O. Fuentes[1,2], R. T. Baker[1]*

(1) School of Chemistry, University of St. Andrews, North Haugh, St. Andrews, Fife, KY16 9ST, United Kingdom. rtb5@st-andrews.ac.uk
(2) now at: CINSO (Centro de Investigaciones en Sólidos), CITEDEF-CONICET, J.B. de La Salle 4397, 1603 Villa Martelli, Buenos Aires, Argentina.
* Corresponding author.

**Abstract** – Nanopowders of several compositions of doped ceria were prepared by a high purity, low temperature chemical method. These powders were incorporated into the fuel electrodes of electrochemical test cells and impedance studies were carried out with a view to their application in Intermediate Temperature (IT-) SOFCs. The electrochemical performance of these materials in hydrogen and in hydrocarbon gas atmosperes was very encouraging and was comparable and sometimes better than that observed for existing IT-SOFC anode materials, depending on the exact composition of the materials.

A low temperature chemical method was employed to prepare a compositional range of doped ceria-based mixed oxide nanopowders of high purity, high crystallinity and very small average particle size (5-10 nm, Fig. 1(a)). These materials were characterized by XRD and by scanning and high resolution transmission electron microscopy (SEM, HRTEM). The nanopowders - with a number of compositions - were incorporated in the electrodes of symmetric electrochemical cells (Fig. 1(b)) and were exposed to hydrogen and to methane fuel atmospheres at a range of operating temperatures. The composition of the electrolyte of the cells was Gadolinium-doped ceria (GDC). Impedance spectroscopy studies of these cells – working in the symmetrical configuration - were performed with a view to their application in intermediate temperature solid oxide fuel cells (IT-SOFCs) using hydrocarbon fuels. A significant increase in catalytic activity and thermal stability was achieved in a number of the doped cerias compared with the pure ceria electrode, which was also studied to provide a comparator. The polarization resistances of the best compositions were only 0.17 and 4.52 $\Omega$ $cm^2$ at 700 °C in humidified 5% $H_2$ and humidified 5% $CH_4$, respectively. These values were about half of those for the pure ceria electrode. The anode performance of these new electrodes compares very favourably with the currently most promising candidate anode materials applied in SOFCs for use with hydrocarbon fuels such as Cu(Ni)-ceria -based anodes and $La_{0.75}Sr_{0.25}Cr_{0.5}Mn_{0.5}O_3$ (LSCM) -based anodes, giving superior results in some cases. The impedance spectra were analysed in terms of a double fractal finite length Gerischer impedance model. The model parameters indicated that the anode activity was enhanced by doping of the $CeO_2$. This was attributed to an improvement in surface diffusion of oxygen species to the three-phase boundary. The activity for the oxygen exchange reaction showed just the opposite trend but the electrode process was found to be rate limited by the surface diffusion of oxygen species. The relationship between the exact composition and the electrochemical performance of these materials will be discussed in detail on the basis of the electrochemical results and the physicochemical characterization of the materials.

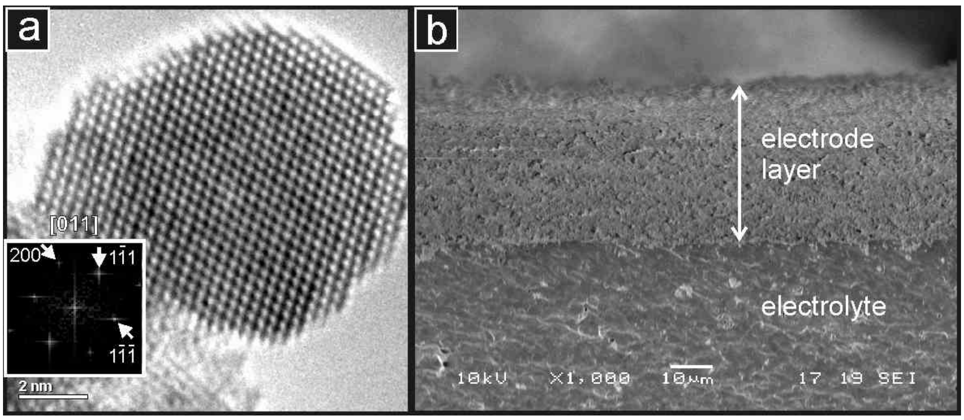


Figure 1.(a) HRTEM image of an 8 nm diameter doped ceria nanoparticle with inset Digital Diffraction Pattern; (b) SEM image of cross-section of the electrochemical cell used for impedance studies showing porous electrode layer and dense electrolyte.