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Enhanced ionic conductivity of scandia-ceria-stabilized-zirconia (10Sc1CeSZ) electrolyte synthesized by the microwave-assisted glycine nitrate process

Abdul Azim Jais[a], S.A. Muhammed Ali[a], Mustafa Anwar[a,b], Mahendra Rao Somalu[a,*], Andanastuti Muchtar[a,c], Wan Nor Roslam Wan Isahak[c], Chou Yong Tan[d], Ramesh Singh[d], Nigel P. Brandon[e]

[a] Fuel Cell Institute, Universiti Kebangsaan Malaysia, UKM Bangi, 43600 Selangor, Malaysia
[b] U.S-Pakistan Center for Advanced Studies in Energy, National University of Sciences and Technology, Pakistan
[c] Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, UKM Bangi, 43600 Selangor, Malaysia
[d] Centre of Advanced Manufacturing & Material Processing (AMMP), Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[e] Department of Earth Science and Engineering, Imperial College London, South Kensington Campus, London SW7 2AZ, UK

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ABSTRACT

Scandia-stabilized-zirconia is a potential zirconia-based electrolyte for intermediate temperature solid oxide fuel cells (IT-SOFCs). In this study, the properties of zirconia co-doped with 10 mol% Sc and 1 mol% Ce (scandia-ceria-stabilized-zirconia, 10Sc1CeSZ) electrolyte synthesized by the microwave-assisted glycine nitrate process (MW-GNP) were determined. The effects of microwave heating on the sintering temperature, microstructure, densification and ionic conductivity of the 10Sc1CeSZ electrolyte were evaluated. The phase identification, microstructure and specific surface area of the prepared powder were investigated using X-ray diffraction, transmission electron microscopy and the Brunauer-Emmett-Teller technique, respectively. Using microwave heating, a single cubic-phase powder was produced with nanosized crystallites (19.2 nm) and a high specific surface area (16 m^2/g). It was found that the relative density, porosity and total ionic conductivity of the 10Sc1CeSZ electrolyte are remarkably influenced by the powder processing method and the sintering temperature. The pellet sintered at 1400 °C exhibited a maximum ionic conductivity of 0.184 S/cm at 800 °C. This is the highest conductivity value of a scandia-stabilized-zirconia based electrolyte reported in the literature for this electrolyte type. The corresponding value of the activation energy of electrical conductivity was found to be 0.94 eV in the temperature range of 500–800 °C. Overall, the use of microwave heating has successfully improved the properties of the 10Sc1CeSZ electrolyte for application in an IT-SOFC.

1. Introduction

Solid oxide fuel cells (SOFC) usually operate at very high temperatures ranging from 600 to 900 °C [1]. Reduction of the operating temperature can be achieved by developing new materials and adopting thin film techniques [2]. High ionic conductivity, low thermal expansion, negligible electronic conduction and good mechanical properties are the important factors to be considered in selecting the electrolyte for intermediate temperature SOFCs (IT-SOFCs) [3]. Stabilized zirconia such as yttria-stabilized-zirconia (YSZ) has been considered the most promising solid electrolyte material for SOFC due to its high phase stability, high ionic conductivity and low electronic conductivity in both the oxidizing and reducing environment of an SOFC [4]. However, YSZ exhibits poor ionic conductivity at lower operating temperatures (< 700 °C). Therefore, wide attention has been focused on improving the ionic conductivity of the YSZ electrolyte [5]. One approach is the use of scandium oxide (Sc_2O_3) to stabilize ZrO_2 to improve the conductivity at lower operating temperatures [6,7]. The cubic fluorite-type phase of scandia-stabilized-zirconia (ScSZ) has been reported to be an excellent electrolyte material for IT-SOFC. However, ScSZ exhibits a phase transition from the highly conductive cubic phase to a low conductive rhombohedral or tetragonal phase at the IT-SOFC operating condition [8]. In previous studies, Al_2O_3 and the oxides of rare earth elements such as CeO_2, Sm_2O_3, Yb_2O_3, and Gd_2O_3 were used

* Corresponding author.
E-mail address: mahen@ukm.edu.my (M. Rao Somalu).

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