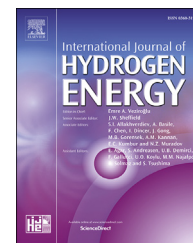


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Nickel foam anode-supported solid oxide fuel cells with composite electrolytes

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ABSTRACT

In this paper, three composite electrolytes ($\text{Ce}_{0.8}\text{Sm}_{0.2}\text{O}_{1.9}/\text{Na}_2\text{CO}_3$) SDC, ($\text{Ce}_{0.8}\text{Gd}_{0.2}\text{O}_{1.9}/\text{Na}_2\text{CO}_3$) GDC and ($\text{La}_{0.8}\text{Sr}_{0.2}\text{Ga}_{0.8}\text{Mg}_{0.2}\text{O}_{3-\delta}/\text{Na}_2\text{CO}_3$) LSGM have been studied to review the effect of Na_2CO_3 , present as second phase, and effect of Ni support, sintering and pressure for dry pressing for fuel cell performance. The electrolytes were prepared through a co-precipitation method. Different techniques were used to characterize the prepared electrolytes. The crystal structures were determined using x-ray diffraction (XRD) and structural morphologies were analyzed through scanning electron microscopy (SEM). The four-probe dc conductivity and two probe AC impedance analysis were carried out in open air. The fuel cell performance was determined with and without Ni support on anode side which resulted in a considerable difference in obtained peak power densities. It is suggested that prepared electrolytes can find potential applications in low temperatures Solid Oxide Fuel Cells (LT-SOFCs).

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Introduction

Solid Oxide Fuel Cells (SOFCs) have acquired considerable attention in recent years due to their clean conversion of chemical energy into electrical energy with a comparatively high efficiency. A considerable work is being done to lower the operating temperature of SOFC which will result in the reduced cost of materials with less degradation problems and longer life. Due to their high ionic conductivity and better

performance in the temperature range of 450–650 °C, low temperature SOFCs (LT-SOFCs) based on ceria with suitable dopants have been studied in detail [1–4]. Electrolytes are considered to be an important part of SOFCs due to their significant role in ionic conduction mechanism. Electrolytes based on Yttria stabilized Zirconia (YSZ) have widely been used but the problem linked with such electrolytes is their high operating temperature (1000 °C) resulting in rapid degradation and ultimately a shorter life span [5,6]. Hence, to address these problems, electrolytes with better ionic

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conduction and performance at low temperature ($\sim 650^\circ\text{C}$) are highly desired.

In recent years, nanocomposite materials based on ceria salts have emerged as promising electrolytes for LT-SOFCs offering a better ionic conductivity as well as fuel cell performance [7–12]. These materials are usually made up of two phases which include a carbonate phase and ceria based oxide phase. These nanocomposite materials exhibited a high ionic conduction (10^{-2} to 1 S/cm) with a superb fuel cell performance in the temperature range of $400\text{--}650^\circ\text{C}$ [13–15]. Hence, the fabrication of such nanocomposite materials has opened a window of new horizon in research field of LT-SOFCs.

The factors which have precluded the commercialization of SOFC technology include materials high cost, rapid cell degradation due to their operation at high temperature, mechanical shocks, anode oxidation, manufacturing issues etc. To address these problems, new designs of SOFCs with Ni support have acquired considerable attention in recent years due to added advantages like low cost materials, ability to absorb mechanical stress, ruggedness and high performance at low temperature associated with them [16]. Many researchers have tested Ni foam as anode substrate, as diffusion layer of gas on fuel side and in tabular SOFC assembly, the support between the tubes [17]. Following this, Yan et al., [2014], obtained a notable performance of 1.04 Wcm^{-2} at 650°C using Ni-Fe alloy supported SOFCs [18]. Similarly, Jin et al., [2015], prepared anode supported SOFCs and obtained notable performance by getting OCV over 1 V but at high temperature of 800°C [19].

In the present study, nanocomposite electrolytes based on samarium doped ceria (SDC), gadolinium doped ceria (GDC) and strontium, magnesium-doped lanthanum gallate (LSGM) have been prepared through co-precipitation method with Na_2CO_3 as second phase to review the effect of Na_2CO_3 and then the effect of compaction pressure, sintering and Ni support on fuel cell performance is discussed in the last portion.

Experimental

Sample preparation

In this study, SDC/ Na_2CO_3 , GDC/ Na_2CO_3 , LSGM/ Na_2CO_3 nanocomposite electrolytes having general formulae, $\text{Ce}_{0.8}\text{Sm}_{0.2}\text{O}_{2-\delta}$, $\text{Ce}_{0.8}\text{Gd}_{0.2}\text{O}_{2-\delta}$ and $\text{La}_{0.8}\text{Sr}_{0.2}\text{Ga}_{0.8}\text{Mg}_{0.2}\text{O}_{3-\delta}$ were prepared through co-precipitating route. The stoichiometric amount of cerium nitrate [$\text{Ce}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$], samarium nitrate [$\text{Sm}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$], gadolinium nitrate [$\text{Gd}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$], lanthanum nitrate [$\text{La}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$], strontium nitrate [$\text{Sr}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$], gallium nitrate [$\text{Ga}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$], magnesium nitrate [$\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$] and sodium carbonate (Na_2CO_3) (purchased from Sigma Aldrich with purity of $\geq 99\%$) were taken as raw materials. The sodium carbonate (NC) was used as a precipitating agent. The MNs and NC were first dissolved in de-ionized water separately and then mixed together to form a homogeneous solution. The solution was allowed to stir for 30 min, producing white precipitates. The precipitates were filtered, dried in an oven at 120°C , grounded with mortar and pestle and then sintered at 880°C for 4 h in an air

atmosphere. The sintered powders were then compressed into pellets using CARVER hydraulic press for further analysis.

Sample characterization

Structural analysis was carried out using X-ray diffractometer (Bruker, D8-Advanced) utilized with CuK_α radiations ($\lambda = 1.5406\text{ \AA}$) operated at 40 mA and 40 kV. The microstructures were examined with Nova NanoSEM scanning electron microscope. The four probe dc conductivity measurement of pellets (pure materials) having diameter of $\sim 13\text{ mm}$ and thickness $\sim 2\text{ mm}$ coated by silver paint on both sides was carried out using Keithley 2450 Source Meter. The two probe ac conductivity was measured through PARSTAT 4000 Potentiostat/Galvanostat Impedance Analyzer. The fuel cell performance was determined using hydrogen as a fuel.

Results and discussions

Crystal structure

Fig. 1 shows the XRD diffraction spectra of nanocomposite electrolytes. XRD pattern of SDC nanocomposite electrolyte shows the formation of single phase cubic fluorite type structure which matched well with JCPD card # 01-075-0158. The lattice constant value came out to be 5.456 \AA . For GDC nanocomposite electrolyte, a single-phase face centered cubic structure was confirmed with lattice constant value of 5.438 \AA . All the observed peaks correspond to the JCPD card #01-075-0162. The calculated lattice constant values were higher than pure ceria showing agreement with Vegard's rule [20]. The XRD pattern of LSGM was also determined by indexing all the peaks to a cubic structure with lattice constant equal to 3.91 \AA , matched with reference JCPD card # 00-520-022.

Microstructure analysis

Fig. 2 (a–c) depicts the structural morphologies of prepared nanocomposite electrolytes obtained by scanning electron microscope (SEM). Fig. 2(a) represents the SEM micrograph for

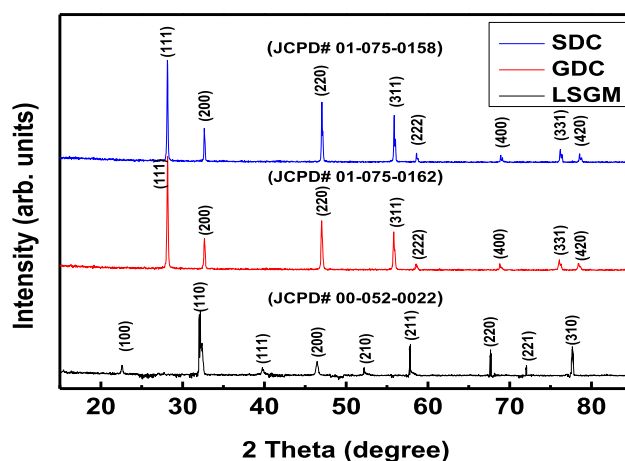


Fig. 1 – XRD pattern for SDC, GDC and LSGM nanocomposite electrolytes.

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