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A systematic study on the synthesis of Ca, Gd codoped cerium oxide by combustion method

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ABSTRACT

Co-doped of CeO_2 nanopowders are ideal electrolyte materials for intermediate temperature solid oxide fuel cells. In this work, $Ce_{1-(x+y)}Gd_xCa_yO_{2-(0.5x+y)}$ nanopowders are successfully synthesized by a glycine–nitrate combustion process. Then calcination was carried out at 450, 700, 850, 950 and we found that calcined powders were single phase by room temperature X-ray diffraction (XRD) and have an average crystallite size of 45 nm (based on Scherrer formula). Scanning electron microscopy (SEM) was employed to characterize the morphology of powder. Finally we studied the effect of fuel to nitrate ratio on the properties of resulting powders.

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1. Introduction

Solid oxide fuel cell (SOFC) has attracted much attention in recent years because of its high-energy conversion efficiency and environmental friendship. In fact, solid oxide fuel cells (SOFCs) are electrochemical devices that convert the chemical energy of a fuel into electrical energy in a clean, cheap and efficient way and Consist of three parts, including anode, cathode and electrolyte [1].

Conventional SOFCs which use yttria-stabilized zirconia (YSZ) as an electrolyte are operated at around 1273 K. However, such high temperatures often lead to some problems such as solid-state reactions between the components, thermal degradation and thermal expansion mismatch. Thus, reducing the operating temperature of the SOFCs becomes increasingly important. One of the most promising methods for realizing intermediate temperature solid oxide fuel cells (ITSOFCs) operating below 1073 K is to replace YSZ with other electrolytes with higher oxygen ionic conductivity at low temperature [1].

Doped ceria is a potential electrolyte material for ITSOFCs because it shows much higher oxygen ionic conductivity than YSZ [2,3]. Ceria itself is not a good ionic conductor, but ionic conductivity increases significantly with the introduction of oxygen vacancies caused by the doping of ceria with two or more components at the same time and the research results showed that complex doping with several rare earth or/and alkali earth elements was an effective method to improve the ionic conductivity of the electrolyte [4–7].

Hurley and Hohnke [8] studied the electrical properties of solid state synthesized $Ce_{1-x}Ca_xO_{2-\delta}$ samples that were sintered at 1650 °C for 4 h. Yahiro et al. [9] reported the correlation of electrical properties and microstructures of solid state synthesized ceria alkaline earth oxide systems. Huang et al. [10] reported the hydrothermal synthesis and properties of $Ce_{1-x}Ca_xO_{2-\delta}$ solid solutions, where a sintering temperature of 1400 °C was reported for achieving 95% sintered density. Recently, Peng et al. [11] reported the synthesis of nanocrystalline $Ce_{1-x}Ca_xO_{2-\delta}$ solid solutions by nitrate citrate combustion synthesis. Rodriguez et al. [12] investigated the structural and electronic properties of $Ce_{1-x}Ca_xO_{2-\delta}$ systems. Yamashita et al. [13] and Sato et al. [14] explored the UV shielding characteristics of calcia-doped ceria systems and observed an increased UV shielding property of calcia-doped ceria systems. The results indicated that co-doping method was proved to be effective to improve the electrical property of the ceria-based electrolytes.

In the past few years, combustion synthesis of multi component ceramic oxides has been gaining reputation as a straightforward preparation process to produce homogeneous, very fine, crystalline and unagglomerated powders [15,16]. The basis of the combustion synthesis technique comes from the thermo chemical concepts used in the field of propellants and explosives [17].

In the present work, we used the glycine–nitrate solution combustion synthesis technique to obtain nanocrystalline $Ce_{1-(x+y)}Gd_xCa_yO_{2-(0.5x+y)}$ powder. Synthesized powder was then calcined to remove any traces of organic compounds. The calcined

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