Available online at www.sciencedirect.com

ScienceDirect

Ceramics International 40 (2014) 10901–10906

CERAMICS INTERNATIONAL

www.elsevier.com/locate/ceramint

Enhanced ionic conductivity of co-doped ceria solid solutions and applications in IT-SOFCs

Monika Srivastava, Kuldeep Kumar*, Nandini Jaiswal, Nitish Kumar Singh, Devendra Kumar, Om Parkash*

Department of Ceramic Engineering, Indian Institute of Technology, Banaras Hindu University, Varanasi, Uttar Pradesh 221005, India

Received 16 January 2014; received in revised form 21 February 2014; accepted 17 March 2014
Available online 26 March 2014

Abstract

Co-doping effect of Sm^{3+} and Ca^{2+} ions in ceria has been studied using the microwave assisted synthesis (MAS) technique. Thermal response of the prepared compositions was studied using differential thermal and thermo-gravimetric techniques (DTA/TG). Structural studies were performed using X-ray diffraction (XRD) and fourier transform infrared spectroscopy (FT-IR). The impedance analyses were performed over a wide range of temperatures (200–500 °C) and frequency (100 Hz to 1 MHz). The conductivity data show that 10% doping of both Sm^{3+} and Ca^{2+} in ceria provides a significant rise in the conductivity value of pure ceria.

Keywords: B. CeO_2; C. Impedance spectroscopy; C. Ionic conductivity; E. Fuel cells

1. Introduction

Solid oxide fuel cells (SOFCs) have attracted a great attention as promising systems for electrical power generation because of their high efficiency of chemical energy to electric power conversion. Ceria based solid electrolytes ($Ce(M)O_{2-\delta}$, M: rare-earth or alkaline-earth cations) are of considerable interest for potential use in SOFCs due to their higher ionic conductivity and lower cost as compared to stabilized zirconia and lanthanum gallate based phases respectively [1–5]. The main drawback of ceria-based electrolytes, complicating their commercial application is their increased electronic conduction which is caused by the reduction of Ce^{4+} to Ce^{3+} [3,6] under low oxygen partial pressure (below 10^{-10} atm) at 800 °C. It has been reported that the reduction of ceria is negligible at temperatures around 600–700 °C. However, such low temperatures are not suitable for single ion doped ceria as an electrolyte in SOFC due to its high electrical resistance [7]. Herle et all [8] found that ceria doped with two and more cations shows significantly higher ionic conductivity than the pure form.

Among ceria based ionic conductors, the highest level of ion conductivity is the characteristic of Sm^{3+} and Gd^{3+} doped solid solutions – $Ce_{1-x}M_xO_{2-\delta}$, where $M=Gd^{3+}$ or Sm^{3+}, $x=0.10–0.20$ [9–13]. Some ternary systems involving CeO_2–Gd_2O_3 or CeO_2–Sm_2O_3, the third components being Pr_2O_3 [14], Y_2O_3 [15], Tb_2O_3 [16], MgO [17], CaO [18] have been

Table 1
Abbreviation and lattice parameters of CeO_2 and compositions of system $Ce_{0.80}Sm_{0.20-x}Ca_xO_{2-\delta}$.

Composition	Abbreviation	Lattice parameter
$\mathbf{CeO_2}$	C	5.400
$\mathbf{Ce_{0.8}Sm_{0.2}O_{2-\delta}}$	CS20	5.415
$\mathbf{Ce_{0.8}Sm_{0.15}Ca_{0.05}O_{2-\delta}}$	CS15C5	5.416
$\mathbf{Ce_{0.8}Sm_{0.10}Ca_{0.10}O_{2-\delta}}$	CS10C10	5.403
$\mathbf{Ce_{0.8}Sm_{0.05}Ca_{0.15}O_{2-\delta}}$	CS15C15	5.412
$\mathbf{Ce_{0.8}Ca_{0.20}O_{2-\delta}}$	CC20	5.398

*Corresponding authors. Tel.: +91 542 6701791; fax: +91 542 2368428.
E-mail addresses: k86.kuldeep@gmail.com (K. Kumar), oprakash.cer@itbhu.ac.in (O. Parkash).

http://dx.doi.org/10.1016/j.ceramint.2014.03.086
0272-8842/

studied from the viewpoint of structure and electrical conductivity. These materials when co-stabilized with Sm_2O_3 or Gd_2O_3 and other trivalent cations, depending on their chemical composition have generally improved ionic conductivities, although in some cases deterioration of the ionic conductivity or increased electronic conductivity was observed [19].

In this article, we have reported the synthesis of pure and co-doped ceria solid solutions via a newly developed route of

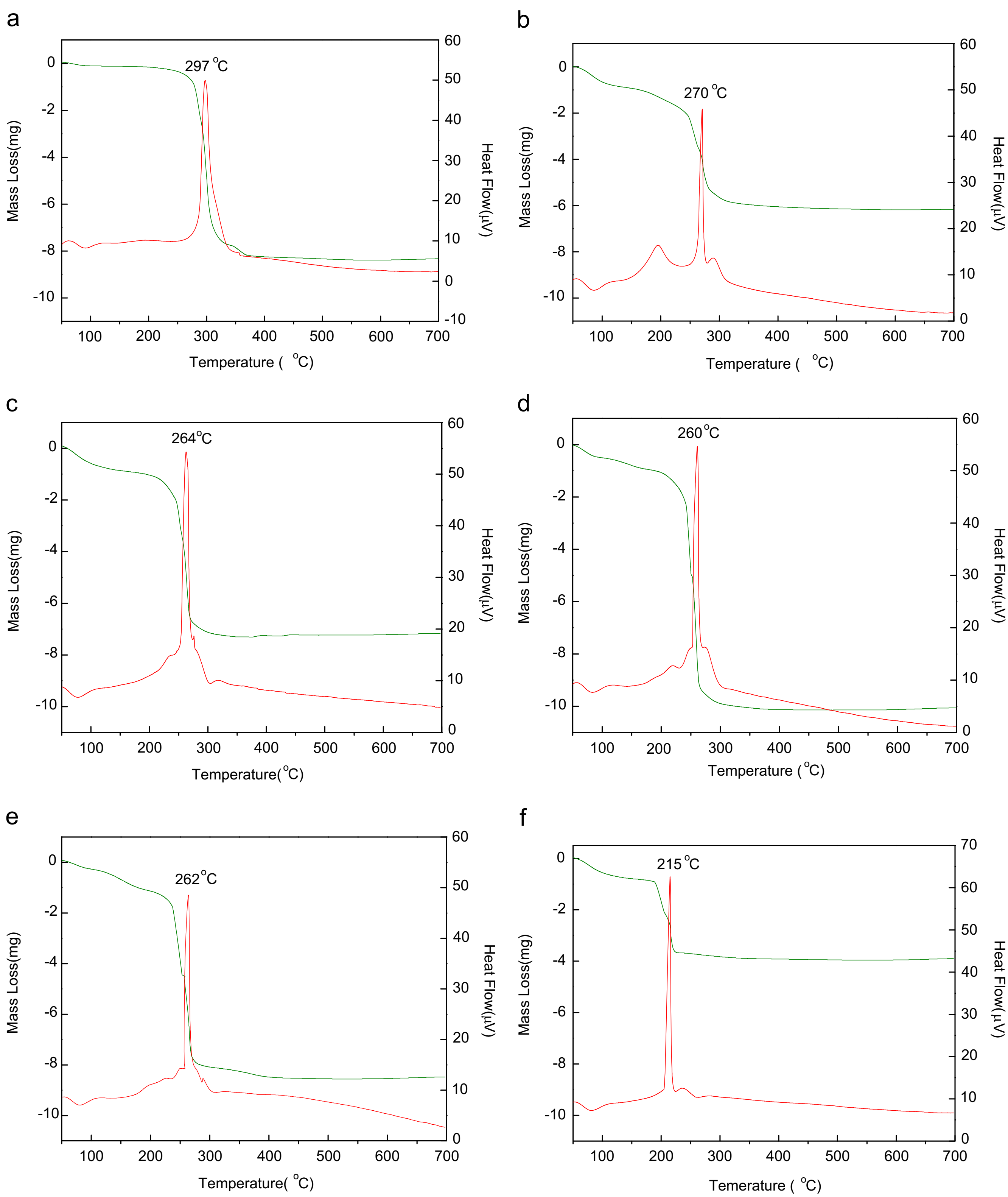

Fig. 1. DTA/TG plots of as prepared (a) C, (b) CS20, (c) CS15C5, (d) CS10C10, (e) CS5C15 and (f) CC20 compositions.