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Investigation of nozzle shape effect on $Sm_{0.1}Ce_{0.9}O_{1.95}$ thin film prepared by electrostatic spray deposition

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Abstract

Dense samarium doped ceria (SDC) thin films are deposited using electrostatic spray deposition (ESD) technique. The influences of nozzle shape on the distribution of liquid jet at the nozzle tip and the morphology of the deposited SDC films are elucidated. Geometries of three nozzles employed are flat, sawtooth and wedge tips. From the observation of jet formation, the nozzle in flat shape gives the highest distribution of emitted droplets. The deposited films are characterized using a combination of XRD, SEM and AFM techniques. XRD results reveal that the single-phase fluorite structure forms at a relatively low deposition temperature of 400 °C. The flat spray tip provides the most uniform and smooth thin films, and also presents the lowest agglomeration of particles on thin-film surface.

Keywords: Samarium doped ceria; Electrostatic spray deposition; Thin film; Solid oxide fuel cells

1. Introduction

Recently, solid oxide fuel cells (SOFCs) have attracted a great deal of attention because they can produce electricity directly by electrochemical combination of a gaseous fuel with an oxidant in an efficient energy-conversion and environmental friendly technology. While several researchers emphasize on the development of SOFCs for operating at extremely high temperatures (900–1000 °C), it becomes increasingly important to reduce the operation temperature of the fuel cell to the intermediate range of 500–800 °C to increase the operational life and reduce the thermal mismatch between cell components [1–3]. Consequently, great efforts have recently been taken to decrease the operating temperature of SOFCs. Two approaches are widely used to decrease the resistance of dense electrolyte thin films, either by reducing the thickness of the traditional yttria-stabilized zirconia (YSZ) electrolyte or employing the alternative electrolytes of higher ionic conductivity at lower temperature. Doped ceria is considered to be one of the most promising electrolytes for SOFCs operating at intermediate temperature range due to cheaper materials, less thermal mismatch, and lower degradation problems [4–8].

Various thin-film fabrications, such as chemical vapor deposition [9], rf magnetron sputtering [10], laser deposition [11], plasma coating [12] or flame-assisted vapor deposition [13], have been used to prepare the components of SOFCs. In the past few years, a novel spray pyrolysis technique, electrostatic spray deposition (ESD), was employed to produce thin films of many oxide materials. This technique is superior to other film formation methods due to its simplicity, non-vacuum deposition condition and an economical and effective deposition with simple setup and inexpensive and non-toxic precursors [14–16].

In principle, dense and thin ceramic films are needed for SOFC electrolytes. Therefore, the preparation of dense and thin SDC films appears to be a valuable means to achieve such a challenge. In this contribution, the application of electrostatic spray deposition to fabricate dense SDC thin films was investigated. The shape of nozzle requires a special attention resulting in the homogeneous thin film and the control of deposition area. Therefore, the effect of nozzle shapes on the distribution of liquid jet at the nozzle tip and the morphology of the deposited SDC

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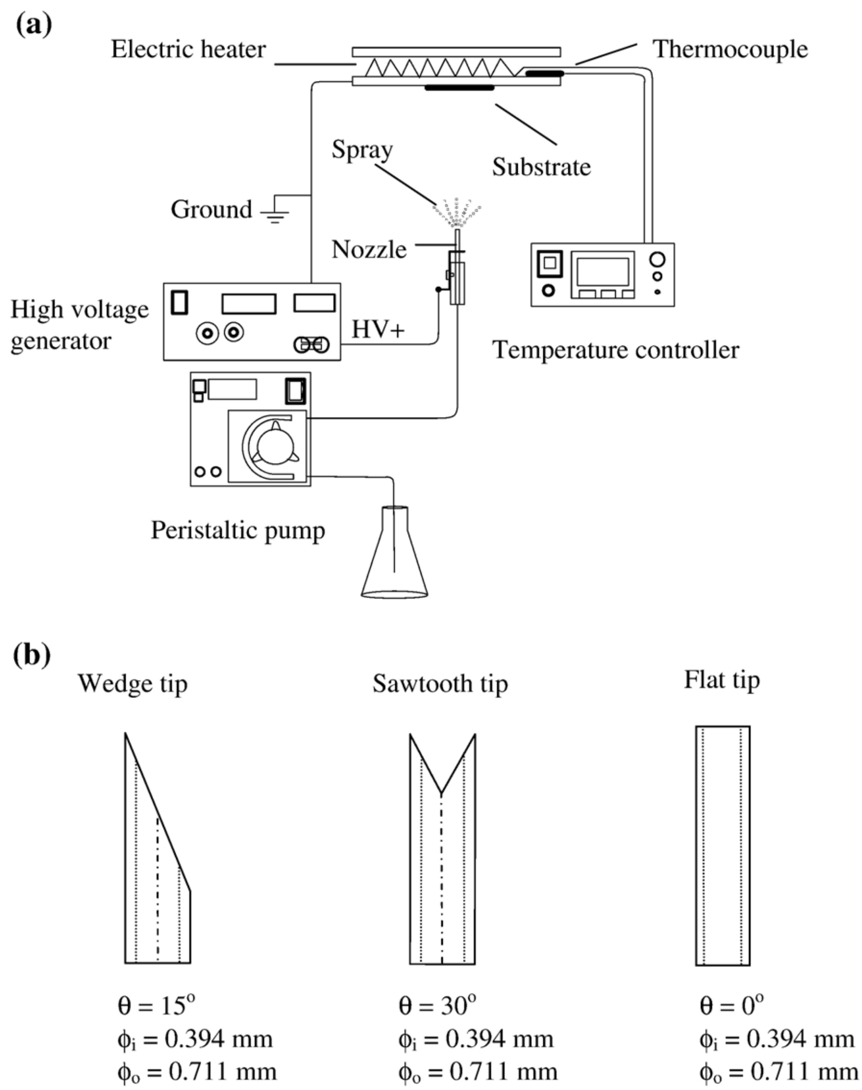

Fig. 1. (a) Schematic diagram of electrostatic spray deposition setup, (b) geometry of three nozzles for the feeding of precursor solution. (θ = tip angle, ϕ_i = inner diameter and ϕ_o = outer diameter).

films were discussed. Furthermore, the effect of calcination temperature on the crystallinity of the films was also elucidated.

2. Experimental

2.1. Electrostatic spray deposition (ESD) setup

The configuration of ESD setup employed to deposit SDC thin films was schematically demonstrated in Fig. 1(a). It consists of a precursor feeding unit, a power supply unit and a temperature control unit. Precursor solution was pumped towards a spraying nozzle by means of a peristaltic pump (Watson Marlow, 101U/R). When high positive voltage was applied on the precursor solution, electrostatic field was established between metal capillary nozzle and grounded substrate. Owing to electrostatic force generated, precursor solution was atomized into charged droplets. These charged droplets were attracted to the heated substrate, and then deposited on the substrate to form a thin solid layer.

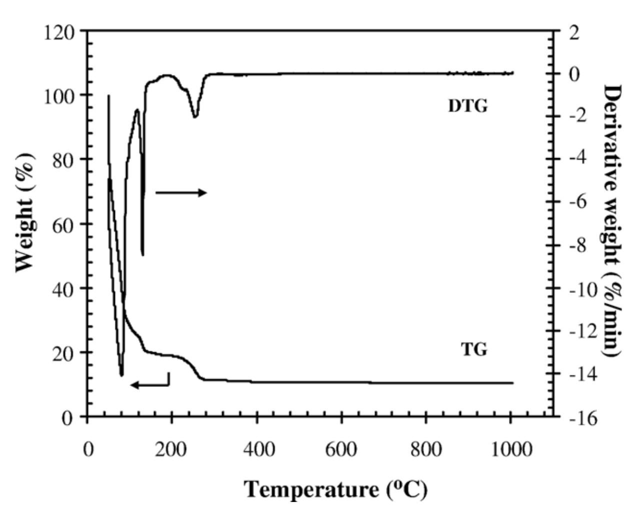

Fig. 2. TG-DTG thermograms of precursor solution.