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Journal of Power Sources 151 (2005) 85–92
JOURNAL OF POWER SOURCES
www.elsevier.com/locate/jpowsour

Properties of zirconia thin layers elaborated by high voltage anodisation in view of SOFC application

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Accepted 4 February 2005
Available online 25 May 2005

Abstract

In order to adapt the anodisation technique to SOFC application, zirconium and zirconium–niobium alloys were tested in various electrolytic media and applied potentials (up to 420 V). The elaborated ZrO_2 insulating layers were characterised in situ by electrochemical impedance spectroscopy and their thicknesses were determined as ranging up to 1 μm. The effect of thermal annealing treatment of layers prepared in various experimental conditions was investigated by X-ray diffraction (XRD) and solid-state electrochemical impedance spectroscopy in a planar configuration. The effect of the growing conditions on significant parameters such as zirconia crystallite size, zirconia conductivity and activation energy were deduced up to 800 °C. The possibility of using the anodisation process for fuel cell devices is discussed. This study demonstrates that it surely requires the use of more efficient dopants, such as yttria.

Keywords: Anodisation; Zirconia; Nb-doped zirconia; Impedance spectroscopy; Solid oxide fuel cells

1. Introduction

Although the feasibility of solid oxide fuel cells (SOFC) has been clearly demonstrated, the present working temperature, above 800–850 °C, requires the use of expensive ceramics for the interconnection plates (i.e. $LaCrO_3$) and provokes the premature ageing process of the different components: anode, cathode and bipolar plates. The decrease in the working temperature of this electrochemical device is probably the main target in order to obtain reliable prototypes and to reach the commercial market. Nevertheless, decreasing the temperature down to 600–700 °C in order to increase SOFC lifetime conduces to an insufficient ionic conductivity of oxide ions through the electrolyte. Therefore, one of the most promising means to solve this problem is to reduce the electrolyte thickness and, consequently, to limit its ionic resistance [1]. The aim of the present work is to elaborate zirconia and doped zirconia-based thin layers by a cheap electrochemical method allowing to obtain dense and homogeneous layers: high voltage anodisation. Elaboration of zirconia by this technique has already been realised in the literature [2–9]; however, our purpose here is to optimise the zirconia synthesis parameters, to initiate the work on doped zirconia (i.e. with niobium) and analyse the electrical properties of these materials at high temperature. The basis of the method is to start from metallic zirconia and to oxidise this metal electrochemically in an appropriate electrolytic solution. Depending upon the pH of the solution, the global reaction can be written as:

$$Zr + 2H_2O \rightarrow ZrO_2 + 4H^+ + 4e^- \quad (1)$$

$$Zr + 4OH^- \rightarrow ZrO_2 + 2H_2O + 4e^- \quad (2)$$

Synthesis of zirconia and doped zirconia was realised at different experimental conditions, including: the applied

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doi:10.1016/j.jpowsour.2005.02.086