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Facile route for reactive coating of $LaCrO_3$ on high-chromium steels as protective layer for solid oxide fuel cell applications

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ABSTRACT

In this study, we present a facile route for the production of thin $LaCrO_3$ layers as a protective layer on chromium-containing steels, usually applied as a dense interconnector material for solid oxide fuel cells or porous supports for metal-supported solid oxide fuel cells. The reactive sol-gel coating method is based on dip coating in aqueous lanthanum acetate/propionate mixtures and subsequent firing. $LaCrO_3$ is formed by a reaction between lanthanum from the coating solution and chromium from the steel. The obtained layers are thin and adhere well to the sample surface. X-ray diffraction reveals the pattern of the $LaCrO_3$ phases. Thermogravimetric measurements show the improved oxidation resistance of $LaCrO_3$-coated steel. Because of the easy-to-apply nature of this method and the wide range of tailoring possibilities, the reactive coating route is a viable alternative to established nitrate- or alcoholate-based wet chemical coating technologies.

1. Introduction

In recent years, Solid oxide fuel cells (SOFCs) based on porous metal supports (metal-supported SOFC, MSC) have been demonstrated as a promising fuel cell technology for mobile power generation because of their improved thermal management in the case of rapid thermal cycling. Furthermore, MSCs are attractive because of their cost, mechanical stability, and ease of joining. [1]. Important progress was made in MSC development in close cooperation between Plansee SE (Austria) and Forschungszentrum Jülich GmbH (Germany) [2–5]. High-chromium ferritic steels are used as MSC supports and interconnect materials because of their good corrosion resistance and adapted thermal expansion coefficient. However, some challenges remain. For interconnects, chromium evaporation is a major detriment to the lifetime of a SOFC because of the poisoning of the traditional cathode materials [6–8]. For MSC supports, the interdiffusion of Fe and Cr into the anode and oxidation in humid atmospheres cause crucial long-term stability issues [9,10]. Therefore, different coating techniques were investigated to protect the interconnects [11,12] and supports [13,14]. In particular, perovskitic $LaCrO_3$ is a promising material, as it offers excellent chemical stability in oxidizing and reducing atmospheres, an adapted thermal expansion coefficient, a good electrical conductivity of $\sigma_{800^{\circ}C\ air}$ = 0.96 S/cm, a significant tolerance for lattice substitution (doping), and low Cr-bulk-diffusion rates [15–17]. In this study, a wet chemical process was developed, which is based on the reactive sol-gel coating of pre-oxidized ferritic steel by a lanthanum-acetate-based solution. A $LaCrO_3$ layer with excellent adherence was formed in-situ during subsequent thermal treatment. As a first proof-of-concept, dense and porous metal components were coated, which showed significantly improved oxidation resistances.

2. Experimental

Dense and porous intermediate temperature metal (ITM) sheets (Fe-26Cr, Mo, Ti, and Y_2O_3) were provided for use as substrates by Plansee SE (Reutte Austria). They were cut to a size of 1 × 3 cm^2 and pre-oxidized at 900 °C in Ar atmosphere. Under these conditions, a Cr_2O_3 layer approximately 100 nm thick formed. To prepare the coating solution, 0.012 Mol of lanthanum acetate hexahydrate (Sigma Aldrich) were dissolved in 40 ml propionic acid (Sigma Aldrich) and 10 ml deionized water. Additionally, in the case of the La-Cr coating solution, 0.003 Mol of chromium acetate hexahydrate (Sigma Aldrich) was dissolved. The solution was placed in an open beaker and heated to 125 °C under constant stirring in order to evaporate the water and acetic acid. After 5 h the

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