Oxidation Properties of Fe-25Cr Steel Coated with Thick $(La,Ca)CrO_3$ Film for SOFC Application

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To construct the planar-type high-temperature solid oxide fuel cells (SOFC) proposed for the modern automobile, the metallic bipolar-plate (interconnect) is one of the important components, which is currently developed from the high-chromia ferritic steels (1,2).

Since the Fe-Cr steels are exposed to both air and reducing (H_2/H_2O or CH_4/H_2O) atmosphere at predicting SOFC operation temperature of about 1073 K, their surface modification is required in order to improve the electrical conductivity of Cr_2O_3 scale, having high resistance against high temperature corrosion (3-5). Coating of some conducting perovskite materials on the Fe–Cr steels is of particular interest (3-5). Considering the chemical stability, thermal expansion match and electrical conductivity, Ca-doped lanthanum chromite $(La,Ca)CrO_3$ has been used, at present (1).

To understand the mechanism of the electrical improvement of the ceramic/composite materials in SOFC operation conditions it is necessary to get information on the microstructure of the interaction product of the coating material with metallic substrate, which is the key issue of the steel application as interconnector in SOFCs.

In this work, the development of the microstructure of the conducting multilayer resulting from the interaction between the thick $La_{0.8}Ca_{0.2}CrO_3$ film and the Fe–25Cr steel substrate after oxidation process has been investigated using XRD, SEM-EDS and TEM-SAD analysis.

The thick film of $La_{0.8}Ca_{0.2}CrO_3$ compound with the thickness range of 20-60 μm, coated on Fe–25Cr steel substrates, was obtained by screen-printing method from the paste composed of the fine $(La,Ca)CrO_3$ powder prepared by the sol-gel route. The oxidation of the coated $(La,Ca)CrO_3$ film on Fe-25Cr steel was conducted in air at 1073 K for 200 hrs.

A cross-sectional microstructure of the $(La,Ca)CrO_3$/Fe-25Cr composite material indicates that the porous film has good adhession to the substrate. Moreover, a thin, about 2 μm thick continuous layer between the film and the metallic core has been developed.

The main outer part of the coating was composed of $La_{0.8}Ca_{0.2}CrO_3$ oval-like particles of about 400 nm in diameter, and identified by electron diffraction as single crystals of Ca-doped $LaCrO_3$ with an orthorhombic structure (space group Pnma). The crystalline particles of $(La,Ca)CrO_3$ containing some dislocations were connected with each other by “bridges”.

The SEM-EDS analysis of the boundary region indicated that the bottom portion of the intermediate layer directly neighbouring the metal substrate is enriched with Cr, O and Fe, Mn. The accumulation of the above elements in the continuous area is the evidence of the reaction zone composed of $(Fe,Mn)Cr_2O_4$ spinel due to the diffusion process of Fe and Mn from the steel to the film/substrate boundary. The existence of the spinel layer was confirmed by the XRD and TEM-SAD analysis. At the upper part of the $(Fe,Mn)Cr_2O_4$ spinel layer, the formation of an intermediate conducting $LaCrO_3$ compound as a result of the partial decomposition of the $(La,Ca)CrO_3$ film during high temperature oxidation was observed.

The influence of the formation of $LaCrO_3/(Fe,Mn)Cr_2O_4$ multilayer reaction products in SOFC cathode operating conditions on the electrical properties of the Fe-25Cr steel covered with the $(La,Ca)CrO_3$ film, measured by impedance spectroscopy is presented and discussed in terms of the applicability of the composite material for construction of the interconnector used in SOFC.

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