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Comparative investigation on the functional properties of alkaline earth metal (Ca, Ba, Sr) doped $Nd_2NiO_{4+\delta}$ oxygen electrode material for SOFC applications

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Functional properties of $Nd_2NiO_{4+\delta}$ based materials doped with different alkaline earth metal ions for SOFC applications is studied extensively and compared in this article. Phase pure powders of $Nd_2NiO_{4+\delta}$ and $Nd_{1.7}A_{0.3}NiO_{4+\delta}$ (A=Ca, Sr and Ba) were synthesized by solid state route at 1250 °C from the constituent precursor oxides and carbonates. Good compatibility of these cathode materials with GDC electrolyte is confirmed through XRD analysis of the composite powder heat treated at 1250 °C. Electrical conductivity of undoped $Nd_2NiO_{4+\delta}$ is found to attain a maximum at ~470 °C and then decreases noticeably with increase in temperature. The decrease in conductivity at higher temperatures is not significant for alkaline earth metal ion doped systems. In the lower temperature range, electrical conductivity decreases with alkaline earth metal ion doping and this decrement is more as the size of the dopant cation increases with an exception for Sr doped samples. However, at the operating temperature of the fuel cell (say 800 °C) electrical conductivity of Ca and Sr doped $Nd_2NiO_{4+\delta}$ are higher than the undoped material. Polarization resistance of the cathode materials are evaluated from the measured impedance spectra of symmetric cells and activation energy for oxygen reduction reaction is calculated from the Arrhenius plot of polarization resistance. Activation energy decreases with alkaline earth metal ion doping and this decrease is more in case of Ca doping followed by Sr and Ba doping. Electrolyte supported button cells fabricated under identical processing conditions were tested at 800 °C; highest power density of 188 mW cm^{-2} is obtained for the cell having Ca doped $Nd_2NiO_{4+\delta}$ as oxygen electrode.

1. Introduction

The journey towards energy sustainability is closely associated with solid oxide fuel cells (SOFCs) having great potential to convert chemical energy of fuel (e.g. hydrogen) to electrical energy in an efficient and environment friendly manner [1,2]. The main advantages of solid oxide fuel cells are absence of costly catalyst, internal reforming of fossil fuels, higher electrical efficiency, high quality waste heat for cogeneration, low activation over-potential and negligible pollution. SOFCs offer better performance at high temperature due to higher kinetics. However, the issues associated with the high temperature operation like stability of materials-of-construction (mechanical and chemical), compatibility of cell components, inter-diffusion of chemical species, and usefulness of sealing limit its performance [3,4]. Thrust has been given by various research groups around the globe to develop high performance SOFCs' operating in the intermediate temperature range. More emphasis is given on the development of new materials with significant improvement on the functional properties. Many mixed ionic and electronic conductors (MIEC) shows good performance as the three-phase boundary responsible for the electrochemical reaction is not limited to the electrode-electrolyte interface only for these materials. The reaction site is extended away from the electrode-electrolyte interface to few microns. A wide variety of materials have been reported for use as oxygen electrode and these materials are largely perovskite based. Few cathode compositions like $Ba_{0.5}Pr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$, $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (BSCF), $Sm_{0.5}Sr_{0.5}CoO_{3-\delta}$, $SrNb_{0.1}Co_{0.9}O_{3-\delta}$ and $SrSc_{0.2}Co_{0.8}O_{3-\delta}$ have proven as candidate cathode materials for IT-SOFC applications [5–9]. Though there are lots of advantages in using

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