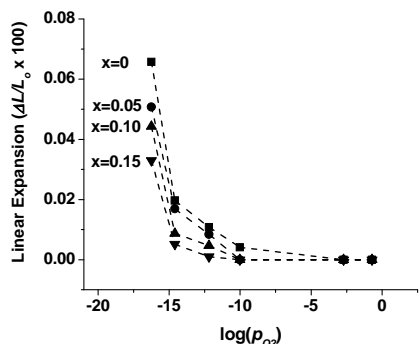


## Calcium- and Nickel-Doped Yttrium Chromite as an Advanced Ceramic Interconnect Material for Solid Oxide Fuel Cells (SOFCs)

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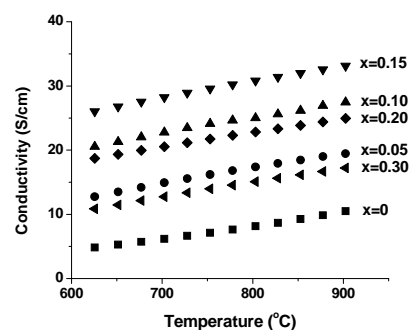
Ceramic interconnects are required for high temperature solid oxide fuel cell (SOFC) stack operation because metallic interconnects are not stable in oxidizing atmosphere above 800°C [1]. Currently, donor-doped lanthanum chromite is the state-of-the-art ceramic interconnect material, and the major challenges are their inferior sintering behavior [2] and the chemical reaction with the YSZ electrolyte at high temperatures [3]. Yttrium chromite-based materials are considered to be one of the promising alternatives because it is more stable in SOFC operating conditions and the formation of impurity phases can be effectively avoided [4]. In this work, calcium- and nickel-doped yttrium chromites were synthesized using the glycine nitrate method, and a comprehensive study on their thermal and electrical properties was performed.

The room temperature and high temperature X-ray diffraction (XRD) study on  $Y_{0.8}Ca_{0.2}Cr_{1-x}Ni_xO_{3\pm\delta}$  ( $x=0\sim 0.3$ ) showed the single orthorhombic phase between 25 and 1200°C up to  $x=0.15$ , and secondary phase peaks such as NiO and  $Y_2O_3$  were observed when  $x\geq 0.2$ . Sintering behavior was remarkably enhanced with nickel doping up to  $x=0.15$ , resulting in 94% of theoretical density at 1400°C with  $x=0.15$ . Thermal expansion coefficient (TEC) increased from  $9.7\times 10^{-6} K^{-1}$  to  $11.5\times 10^{-6} K^{-1}$  with increasing nickel content from  $x=0$  to  $x=0.15$ , and closely matched to that of 8 mol% yttrium-stabilized zirconia (YSZ) when  $x$  was between 0.05 and 0.15. The chemical expansion in reducing atmosphere, which can cause warping and cracking due to the internal stresses, was effectively reduced by Ni doping as shown in Figure 1, and it suggests that Ni doping improves the stability of yttrium chromite toward reduction.

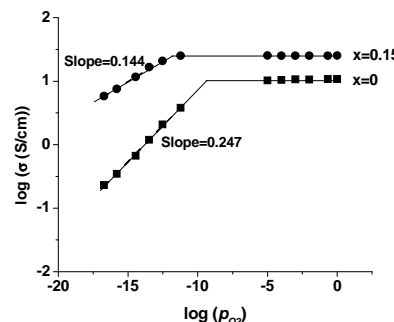


**Figure 1.** Isothermal linear expansion of  $Y_{0.8}Ca_{0.2}Cr_{1-x}Ni_xO_{3\pm\delta}$  ( $x=0\sim 0.15$ ) as a function of  $p_{O_2}$  at 900°C.

Nickel doping leads to a substantial increase in electrical conductivity in air up to  $x=0.15$  as shown in Figure 2. In Figure 3, the plot of  $\log(\sigma)$  versus  $\log(p_{O_2})$  for  $Y_{0.8}Ca_{0.2}Cr_{0.85}Ni_{0.15}O_{3\pm\delta}$  shows  $p_{O_2}^{1/4}$  dependence in reducing environment which implies complete ionic charge compensation, and nickel doping ( $x=0.15$ ) stabilizes the defect structure and suppresses the oxygen vacancy formation in reducing atmosphere resulting in higher electrical conductivity. The electrical conductivity of  $Y_{0.8}Ca_{0.2}Cr_{0.85}Ni_{0.15}O_{3\pm\delta}$  at 900°C in reducing atmosphere ( $p_{O_2}\sim 10^{-17}$ ) is 5.8 S/cm, which is more than an order of magnitude higher than that of  $Y_{0.8}Ca_{0.2}CrO_{3\pm\delta}$  (0.2 S/cm).

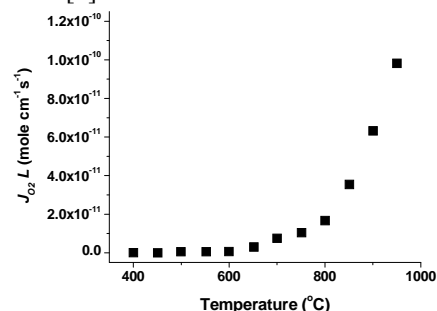


**Figure 2.** Electrical conductivity of  $Y_{0.8}Ca_{0.2}Cr_{1-x}Ni_xO_{3\pm\delta}$  ( $x=0\sim 0.3$ ) between 600 and 900°C in air.



**Figure 3.** Electrical conductivity of  $Y_{0.8}Ca_{0.2}Cr_{1-x}Ni_xO_{3\pm\delta}$  ( $x=0$ , and 0.15) as a function of oxygen partial pressure and linear fits at 900°C.

The electrochemical oxygen permeation through dense  $Y_{0.8}Ca_{0.2}Cr_{0.85}Ni_{0.15}O_{3\pm\delta}$  disc between oxidizing ( $p_{O_2}=0.21$ ) and reducing ( $p_{O_2}\sim 10^{-20}$ ) atmospheres was measured as shown in Figure 4, and the leaking current density is calculated to be 3.2 mA/cm<sup>2</sup> for 20μm thick interconnect, which is considered to be acceptable in practical use [5].



**Figure 4.** Oxygen flux through  $Y_{0.8}Ca_{0.2}Cr_{0.85}Ni_{0.15}O_{3\pm\delta}$  normalized by the sample thickness as a function of temperature.

The chemical compatibility study between  $Y_{0.8}Ca_{0.2}Cr_{0.85}Ni_{0.15}O_{3\pm\delta}$  and 8 mol% YSZ indicated no reaction product up to 1400°C. Based on the results presented in this work, yttrium chromite with ~20% calcium on A-site and 10~15% nickel on B-site is considered to be a promising candidate for the interconnect applications in high temperature SOFCs.

## References

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