

## Electron Microscopy Study of Novel Ru Doped $\text{La}_{0.8}\text{Sr}_{0.2}\text{CrO}_3$ as Anode Materials for Solid Oxide Fuel Cells (SOFCs)

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Solid Oxide Fuel Cells (SOFCs) have been the center of research activities with the goal of improving energy efficiency and reducing air pollution. There has been great interest in incorporating nanostructures into SOFCs to yield improved electrolyte and electrode performance [1,2]. For instance, small amounts of electrocatalyst nanoparticles have been introduced into ceramic anodes to improve the electrochemical characteristics. However, these nanoparticles are prone to coarsening at the fairly high firing temperature used during fabrication. In this study, a new method was shown to produce metal nanoparticles on anode surfaces after these high temperature processing. Electron microscopy study was carried out to characterize the new anode materials.

Ruthenium was dissolved into lanthanum chromate through a solid state reaction to form  $\text{La}_{0.8}\text{Sr}_{0.2}\text{Cr}_{0.82}\text{Ru}_{0.18}\text{O}_3$  (LSCR) as an anode material for SOFCs. Instead of being added separately, Ru nanoparticles precipitate onto the surface of the anode upon heating in hydrogen at the start of SOFC operation. FIG. 1 shows the electrical performance versus time after the onset of testing in humidified  $\text{H}_2$  at  $800^\circ\text{C}$  for a typical SOFC with an LSCR-GDC anode. The power density of the cell increased rapidly with time and stabilized after reaching a maximum. Even after 311 hours of operation, the cell still maintained its performance.

As-prepared LSCR powders were annealed under SOFC operation conditions (humidified  $\text{H}_2$  at  $800^\circ\text{C}$ ) for various times. TEM studies of these powder samples were then carried out to investigate how the surface and bulk of LSCR changed under high temperature reducing conditions and furthermore to explain why the LSCR anode exhibited such properties as indicated in FIG. 1. From our study, as prepared LSCR shows a single phase cubic perovskite structure. After only 15 minutes annealing, Ru nanoparticles were formed on the surface. The surface density of these nanoparticles began to level off after around 3 hours of annealing and didn't change noticeably even after 311 hours. At the same time, the bulk LSCR didn't show any sign of phase transformation after Ru precipitation. The appearance and stability of Ru nanoparticles could then be directly linked to the electrochemical performance of LSCR anode. Our further TEM studies also explored the Ru formation mechanism and suggested that the present strategy, i.e., substituting a small amount of a suitable catalyst element for one of the cations in an oxide, could be employed to further improve on other anode oxide materials.

### References

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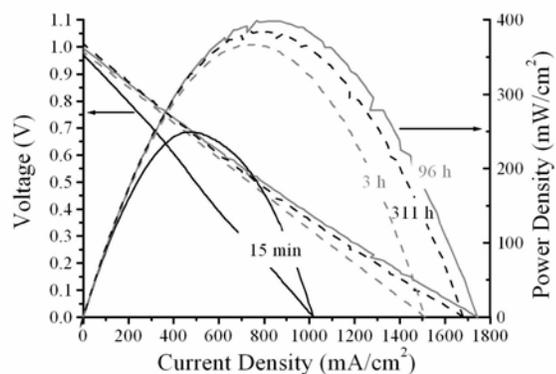


FIG. 1. Voltage and power density versus current density, measured at various times after the cell reached 800°C and humidified H<sub>2</sub> was introduced to the anode, for a typical cell with an LSCR-GDC (Gadolinium Doped Ceria) anode.

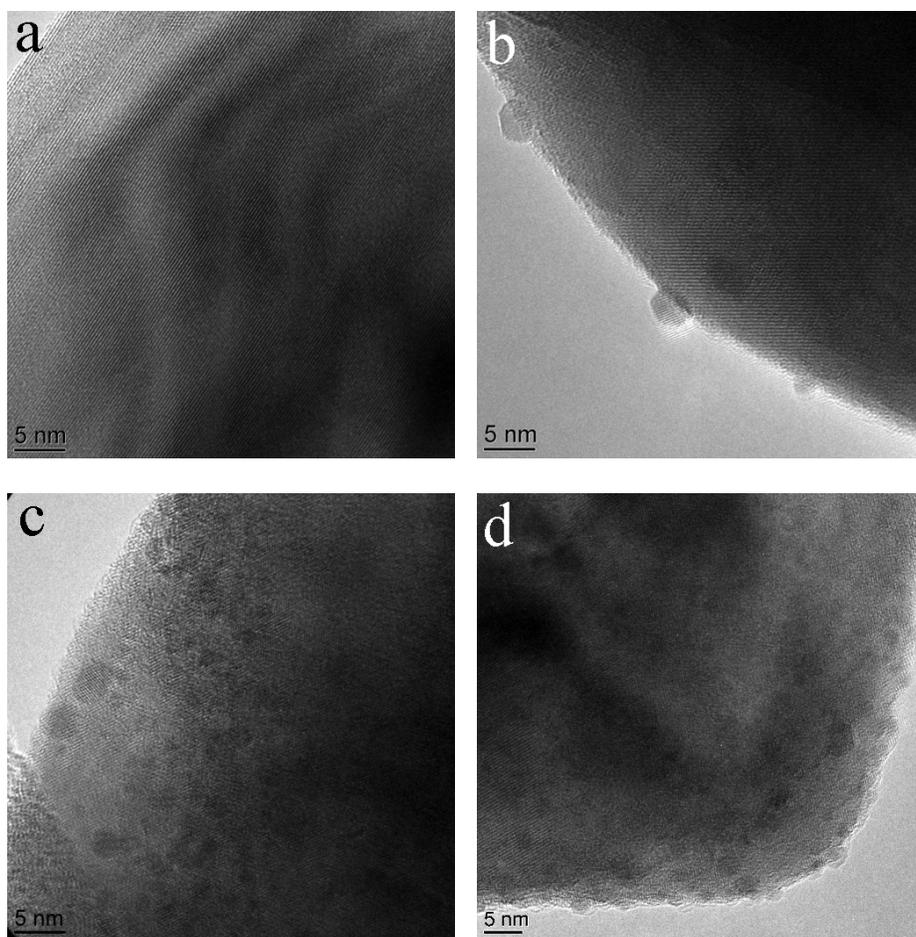


FIG. 2. High resolution TEM images of La<sub>0.8</sub>Sr<sub>0.2</sub>Cr<sub>0.82</sub>Ru<sub>0.18</sub>O<sub>3</sub> particle surfaces after reduction in H<sub>2</sub> for (a) 0 h, (b) 0.25 h (c) 3 h and (d) 311 h, showing Ru nanoparticles on the surface of LSCR after annealing.