

Microstructure and Electrical Properties of Nanocrystalline, Mesoporous LSCF/GDC Thin Films for Micro-SOFC.

Guillaume Muller^{1,2}, Armelle Ringuedé², Christel Laberty-Robert¹

¹LCMCP, Laboratoire Chimie de la Matière Condensée de Paris, UMR UPMC-CNRS 7574, Université Pierre et Marie Curie (Paris VI), Collège de France, 11 place Marcelin Berthelot, 75231, Paris, France

²LECIME, Laboratoire d'Electrochimie, Chimie des Interfaces et Modélisation pour l'Energie, UMR 7575 CNRS, Chimie ParisTech, 11 rue Pierre et Marie Curie, F-75231, Paris Cedex 05, France.

Micro-solid oxide fuel cells (micro-SOFC) are predicted to have high energy density and are potential power sources for portable electronic devices.¹ Derived ceria based composite nanoarchitectures are synthesized through the sol–gel approach combined with template and one-step thermal processing.^{2, 3} The 3-D network of this cathode consists of non-agglomerated nanoparticles with sizes of 5 to 7 nm for 70%vol. of LSCF at 700 °C. In this arrangement, nanoscale particles retain the presence of three mixed phases, LSCF, GDC and pores. The microstructure obtained depends strongly on the temperature and the LSCF content in the thin film. Densification of the porous thin film cathode is influenced by temperature and LSCF composition, which affect the particle size of LSCF and CGO in the film. As the film becomes more dense, porosity collapses due to the increase in grain size. However, a nanostructured microstructure is maintained at temperatures between 500

and 700 °C, regardless of the composition of the cathode.

In addition to microstructural changes, the electrical properties of LSCF/GDC composite thin films are affected by processing conditions. We show that a minimum crystallite size of ~ 9 nm, obtained at 500 °C and 600 °C for LSCF80%/GDC20% and pure LSCF mesoporous thin films, is required for predominantly electronic conduction in these films. A conductivity of $2.3 \cdot 10^3$ S/m at 400 °C and $2.8 \cdot 10^3$ S/m at 700 °C was measured for 500 nm thick porous films of pure LSCF. These films exhibit activation energy of 0.07 eV. Moreover, we show that the content of LSCF in films of ~ 120 nm must be higher than 80% in volume to retain its interesting electrical properties (Figure 1d). Higher electrical conductivity is obtained upon increasing the thickness of the films.

In summary, his study provides insight into the relationships existing between the microstructure and electrical properties by following, in-situ, the changes in the microstructure as a function the temperature and LSCF growth in mesoporous thin films to be applied in micro-SOFC systems.

1. Bieberle-Hutter, A. et al. A micro-solid oxide fuel cell system as battery replacement. *J. Power Sources*, 2008, **177**, pp. 123-130.
2. G. Muller, C. Boissiere, D. Grosso, A. Ringuede, C. Laberty-Robert and C. Sanchez, *J. Mater. Chem.*, 2012, **22**, 9368-9373.
3. J. Hierso, O. Sel, A. Ringuede, C. Laberty-Robert, L. Bianchi, D. Grosso and C. Sanchez, *Chem. Mat.*, 2009, **21**, 2184-21.

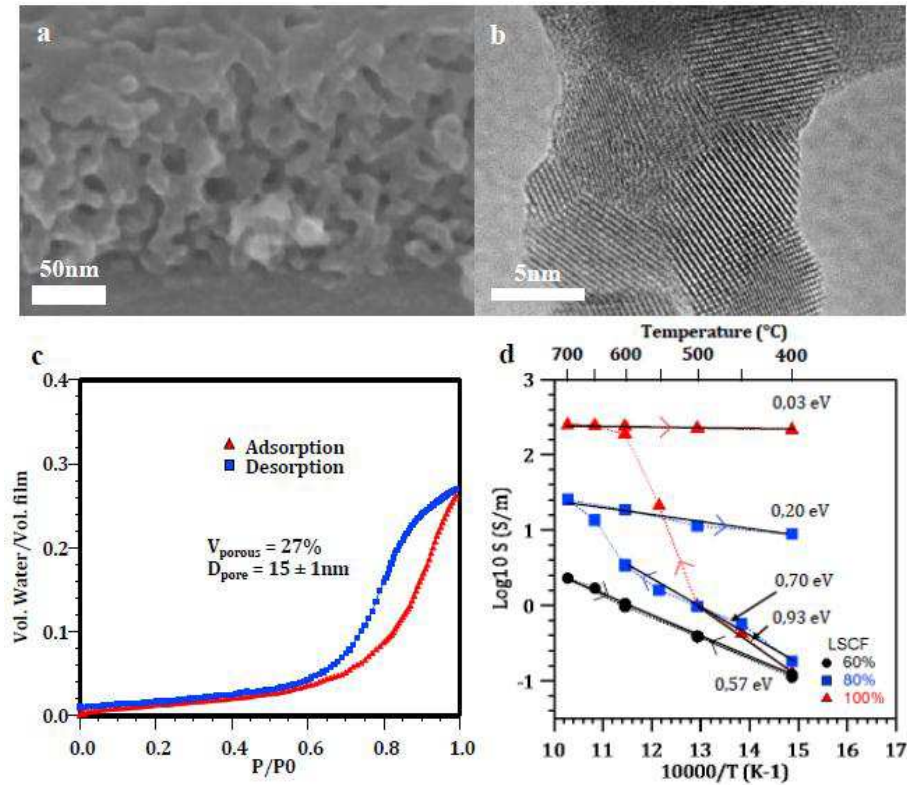


Fig.1: (a) Cross section FE–SEM and (b) TEM images for mesoporous LSCF70%/GDC30% thin films calcined at 700°C (1°C.min⁻¹/h) in air. (c) Water adsorption-desorption isotherms of mesoporous LSCF70%/GDC30% thin films calcined at 700°C (1°C.min⁻¹/h) in air. (d) Conductivity plots as a function of temperature during crystallization of mesoporous composite and pur thin films with different content of LSCF in air and with 120 nm of thickness.