

Microstructure of Surface Functionalized Powder for SOFC Cathodes

Bahareh Deljoo¹, Nick M. Sbrockey², Gary S. Tompa², Mark Aindow¹

¹. Dept. of Materials Science and Engineering, University of Connecticut, Storrs, CT 06269, USA

². Structured Materials Industries, Inc., Piscataway, New Jersey 08854, USA

Solid oxide fuel cells (SOFCs) exhibit an attractive combination of high energy efficiency and fuel flexibility. However, the main drawbacks to SOFCs are limited durability and high cost of the cells. Much of the cost arises from the special materials required due to the high operating temperatures of SOFCs. Lanthanum strontium manganese oxide (LSM) is an SOFC cathode material that has high stability and catalytic activity for oxygen reduction at high temperatures and good compatibility with yttrium-stabilized zirconia (YSZ) electrolytes. However, attempts to reduce the cost of SOFCs by lowering the operating temperature have had negative effects on LSM cathode efficiency due to decreases in electronic and ionic conductivity [1]. A popular alternative for LSM is lanthanum strontium cobalt ferrite (LSCF), which has shown superior electronic and oxygen ion conductivity to LSM at lower temperatures. The main drawbacks for LSCF are large thermal expansion coefficients and high reactivity with electrolyte.

Recent studies have shown that the properties of LSCF can be enhanced by using catalytically active coatings. Additionally, it has been shown that adsorption of oxygen on the surface of this catalyst is the controlling factor of oxygen reduction kinetics in SOFCs. These two important outcomes suggest that the total surface area and the chemical composition of the cathode are essential in selecting suitable materials to achieve high efficiency [2][3]. One proposed system is LSM-coated LSCF cathode. There are two common methods to fabricate this combination: atomic layer deposition (ALD) and chemical vapor deposition (CVD). In our work, we explored the use of fluidized bed chemical vapor deposition (FBCVD) to produce LSM-coated LSCF. The advantage of FBCVD over CVD or ALD is that it is easily scalable and the surface of cathode powder precursor is functionalized before sintering [4].

In this study, we used electron microscopy to characterize LSM-coated LSCF cathode powders. Figure 1(a) shows different powder particle morphologies, which are classified as: 1) rough surface particles ranging from 0.1-0.5 μm , 2) smooth surface particles ranging from 0.5 μm to 10s of μm , and 3) large agglomerates in the range of 10s of μm . BF-TEM investigation of LSM-coated LSCF powder particles, shown in figure 1(b), suggests that these particles are polycrystalline in nature, as confirmed by the ring pattern observed in SADP (fig. 1(c)). Furthermore, a FIB lift-out obtained from a powder particle was investigated to better understand the surface functionalization mechanism of the cathode. Figure 2(a) shows a BF-TEM image of the smooth surface particle cross-section obtained from the lift-out. The corresponding HRTEM image and SADP, in Fig 2 (b) and (c), confirm that it is in fact a single crystal. Moreover, Fig. 3(b-g) are composition maps that verify the distribution of La, Sr, Fe, and Co in the single crystal particle, and Mn in the form of separate islands on the particle surface. Since Mn can only be added to the complex in the form of LSM particles, it is implied that the FBCVD process will result in the segregation of Mn in the form of manganese oxide. This forms a discontinuous thin film on the surface of the LSCF particle, which ultimately results in the improved electrochemical performance of these intermediate-temperature SOFCs.

References:

[1] Z. Shao, et al, *Nature*, vol. 431, pp. 170-173, 2004.

- [2] P. Leone, et al, *Journal of Power Sources*, vol. 177, pp. 111-122, 2008.
 [3] Z. Liu, et al, *Journal of Energy Chemistry*, vol. 22, No. 4, pp. 555-559, 2013.
 [4] N. M. Sbrockey, et al, *ECS Transactions*, vol. 78, No. 1, pp. 817-825, 2017.

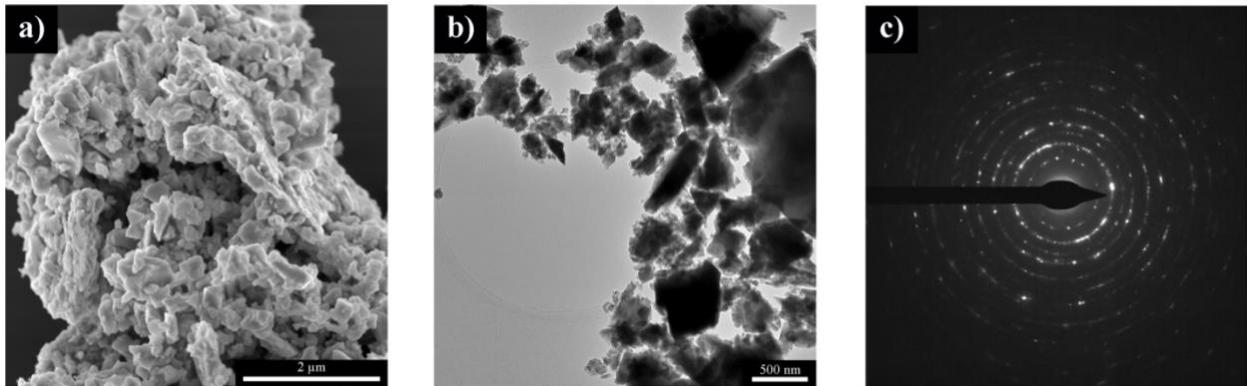


Figure 1. (a) SEM, (b) BF-TEM image, (c) selected area diffraction pattern of LSM-coated LSCF powder.

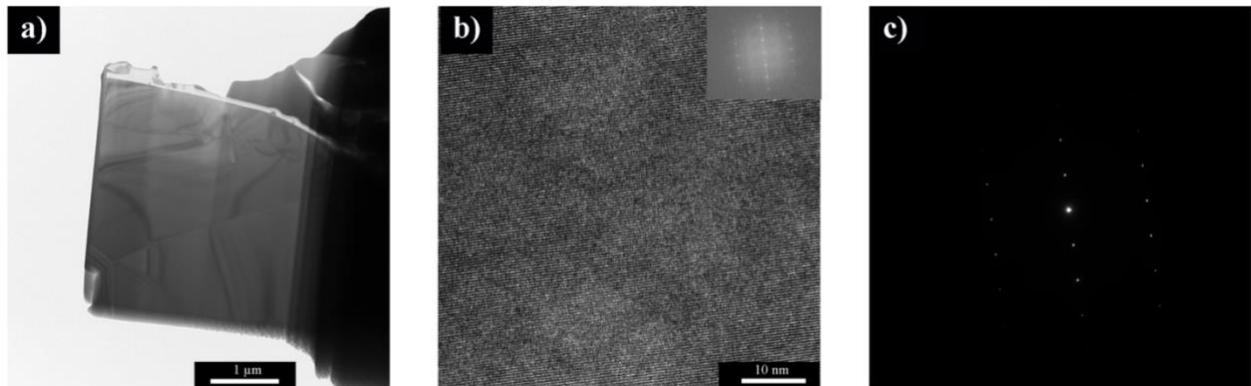


Figure 2. (a) BF-TEM image, (b) HRTEM image, (c) SADP of the LSM-coated LSCF powder.

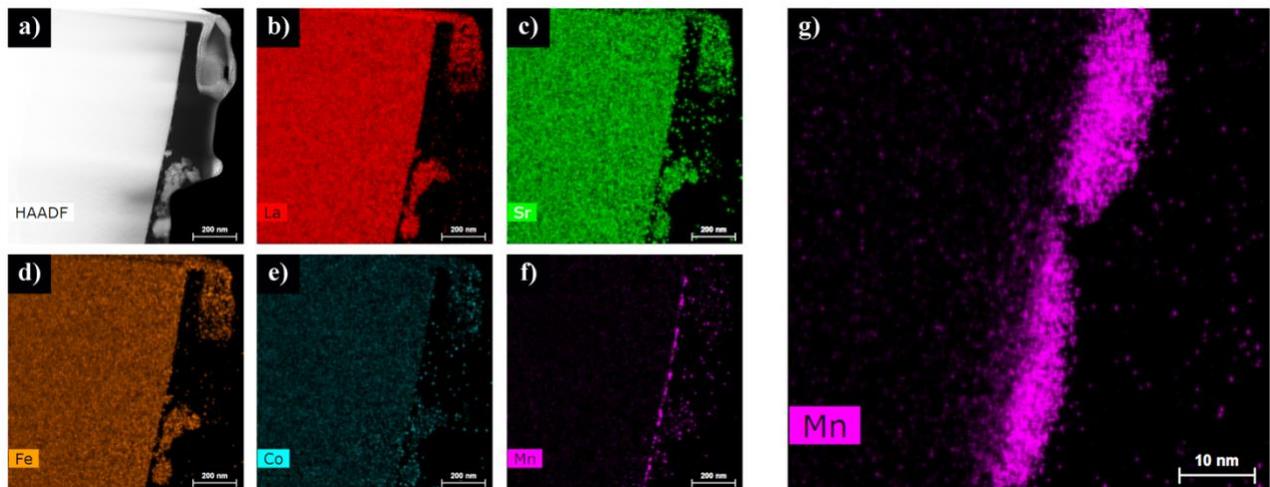


Figure 3. Chemical map data obtained from a FIB-cut cross section of LSM-coated LSCF by FBCVD.