Surface Modified LSCF Powders for SOFC Cathodes

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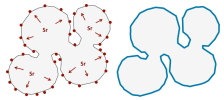
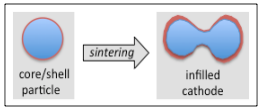
Introduction

Improvements are needed to mitigate effect of cathode degradation on long-term SOFC performance

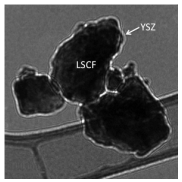
- Sr migration to surface of perovskite cathode materials appears to be linked to decreased cell performance at elevated temperature
- Post-sintering infill approaches have shown promise for improved short and long-term performance
- Surface modified powder is an alternate, potentially cost-effective route to improved long-term performance



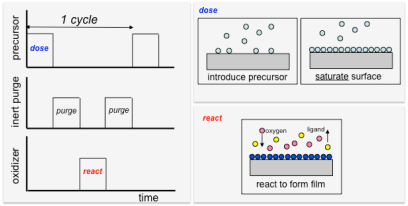
Idealized process route for surface modified cathode powder



Pre-demonstration of ALD coating of LSCF: YSZ via Atomic Layer Deposition (ALD) TEM micrograph



Core – Shell Approach



ALD's highly self-regulating process enables precise control of surface modification

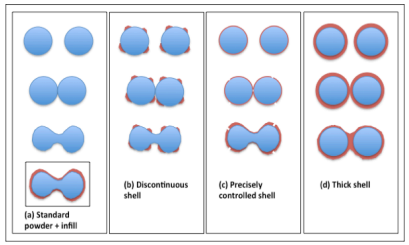
- Thickness of coating
- Morphology of coating

Examples of surface modification of particles via ALD

Particle	Coating
ZrO_2	Al_2O_3 [1]
BN	Al_2O_3 [2]
$Li[Li_{0.20}Mn_{0.54}Ni_{0.13}Co_{0.13}]O_2$	Al_2O_3 [3]
Polymers	W [4]

[1] J.A. McCormick, B.L. Cloutier, W. Weimer, and S.M. George, "Rotary reactor for atomic layer deposition on large quantities of nanoparticles," J. Vac. Sci. Technol. A 25 (2007) 67.
[2] J.R. Wank, S.M. George, and A.W. Weimer, "Nanocoating individual cohesive boron nitride particles in a fluidized bed by ALD," Powder Tech. 142 (2004) 59.
[3] Y.S. Jung, A.S. Cavanagh, Y. Yan, S.M. George, and A. Manthiram, J. Electrochem. Soc. 158 (2011) A1298.
[4] C.A. Wilson, J.A. McCormick, A.S. Cavanagh, D.N. Goldstein, A.W. Weimer, and S.M. George, "Tungsten atomic layer deposition on polymers," Thin Solid Films 516 (2008) 6175.

Potential sintering routes of surface modified particles (post-sintered infill process at left)



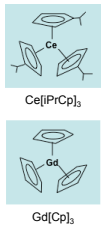
Choice of Shell Material

Desired attributes of shell material:

- Conductive
- Strong blocking potential for Sr migration to surface
- Non-interfering with sintering
- Non-reactive with cathode
- Long term stability

Infill material	Attributes
Pd, Ag	catalyst
La, Sr manganate (LSM)	Triple phase boundaries
Sm-doped ceria (SDC)	Expensive compared to Gd
La, Ca ceria (LCC)	Three component
Sm, Sr cobaltate (SSC)	Barrier properties unknown
Gd-doped ceria (GDC)	Existing barrier in SOFC
Y-doped ceria (YDC)	Lower conductivity than GDC
Pr-doped ceria (PDC)	Expensive compared to GDC
ZrO_2	Non-conductive

GDC ALD Process

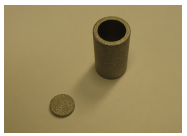


Cyclopentadienyl based chemistry:

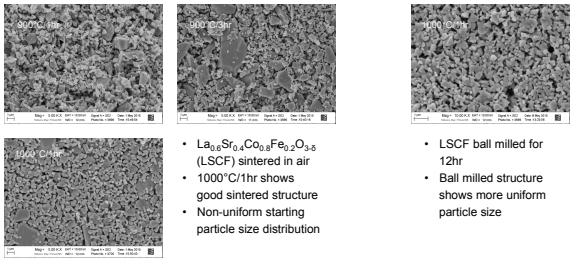
- Volatile
- Thermally stable
- Highly reactive with water as oxidizing agent

GDC films targeting 10mol% Gd have been deposited on LSCF at 230-240°C

- Loosely packed bed in porous cup
- 20 cycles
- 60 cycles
- 196 cycles



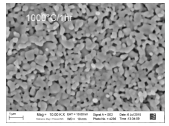
Sintering Behavior



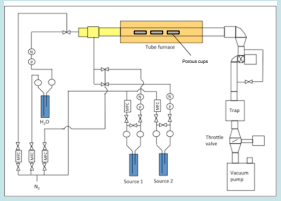
- $La_{0.6}Sr_{0.4}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (LSCF) sintered in air
- 1000°C/1hr shows good sintered structure
- Non-uniform starting particle size distribution

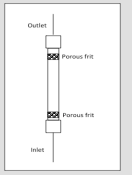
- LSCF ball milled for 12hr
- Ball milled structure shows more uniform particle size

- LSCF with 60 cycles GDC (240°C)
- Minimal impact of coating on sintering

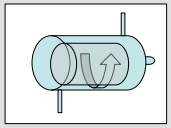


Manufacturing Scale Up





Fluidized bed



Rotating reactor

Novel reactor

Acknowledgements

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