Effect on Sintering Aid on Densification and Contact Strength of Solid Oxide Fuel Cells

Y-S Matt Chou, J. F. Bonnett, and J. W. Stevenson
K2-44, Energy Processes & Materials, PNNL, Richland, WA 99354

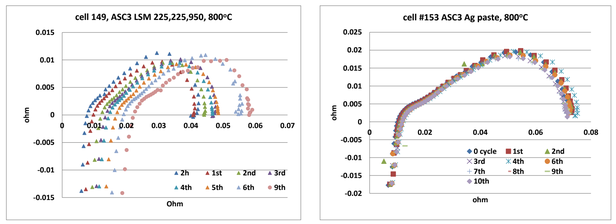
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Introduction:

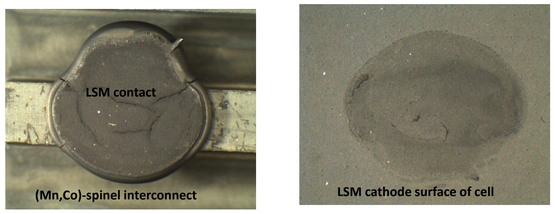
Cathode contact was identified as the weakest link in solid oxide fuel cells (SOFC) when using ceramic materials such as LSM, LSCo etc. Loss of ohmic contact was often observed in routine thermal cycling as compared to precious metal based contact (e.g., Ag). In previous work, we have proposed mechanical interlocking as means to improve cathode contact mechanical integrity, and several processing techniques were employed to create an engineered cathode surface. The concept was later validated in stack fixture test. The results was improving; however, still not as desirable as Ag-based contact. In FY16, we have proposed to enhance the contact strength by (1) sintering aid, (2) reinforcing fibers, (3) both.

The work is divided into 4 tasks: (1), densification, (2) bulk strength, (3) contact strength, and (4) validation in stack test fixture.

Problem in Routine Thermal Cycling



EIS of single cell testing with a ceramic contact (left) and a precious metal (right) shows the typical ohmic degradation from thermal cycling.

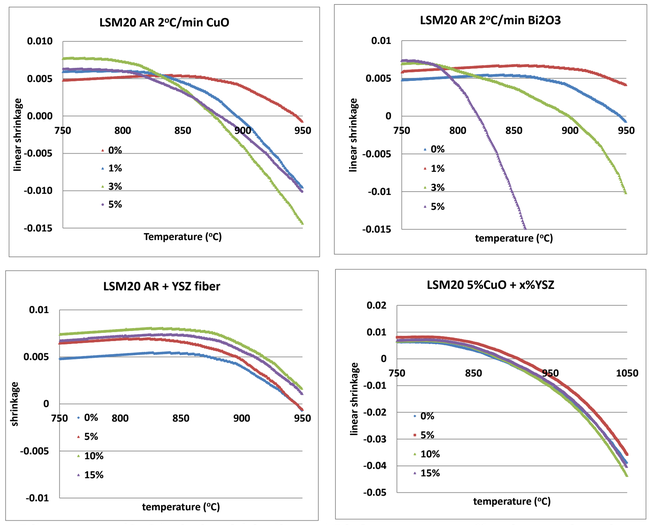


Matching fracture surface shows the weak link of LSM contact at the LSM cathode surface (right) of a cell in stack fixture test.

Experimental

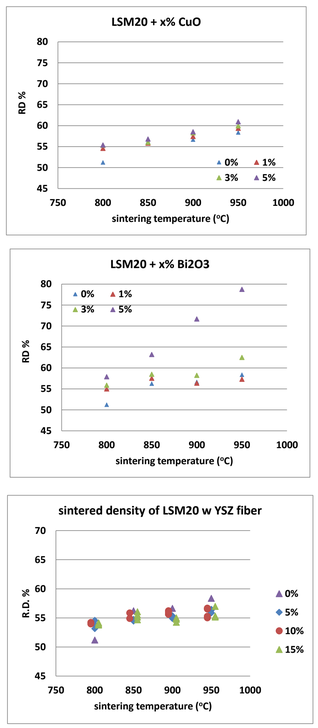
1. For sintering study, LSM20 as-received powders were mixed with 5mol% sintering aid of CuO, Bi_2O_3, or YSZ short fibers at 5, 10, and 15 v%.
2. The above powders were then di-pressed into pellets and sintered at various temperatures in air for 2h.
3. Density was determined by Archimedes.
4. Bulk strength was determined by diametral compression test at R.T.
5. 1"x1" anode supported YSZ bilayers were screen printed LSM cathode layer and sintered 1100°C2h.
6. LSM with various carbon particles (10-30 v%) was made in ink and screen printed to form cathode.
7. Engineered cathode surface was formed by depositing #35 granules of LSM20 onto wet screen printed surface.
8. Joined couples were sintered and tested tensile strength.

1. Sintering Study: Shrinkage



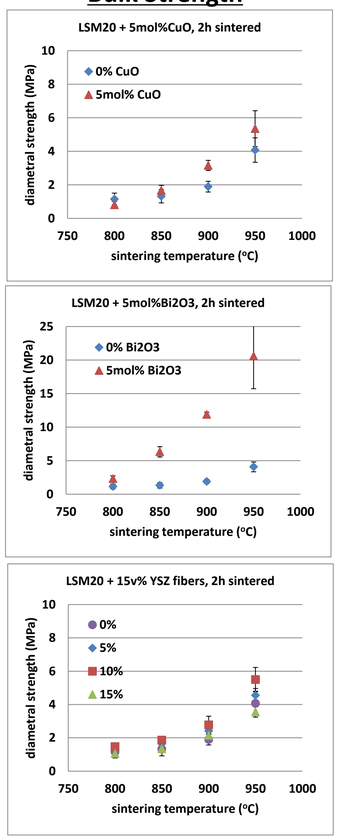
Dilatometry (2°C/min in air) indicated Bi_2O_3 was most effective as sintering aid, consistent with its low melti9ng point of 800°C. Presence of rigid YSZ fibers did not substantially alter the shrinkage behavior.

1. Sintering Study: Density

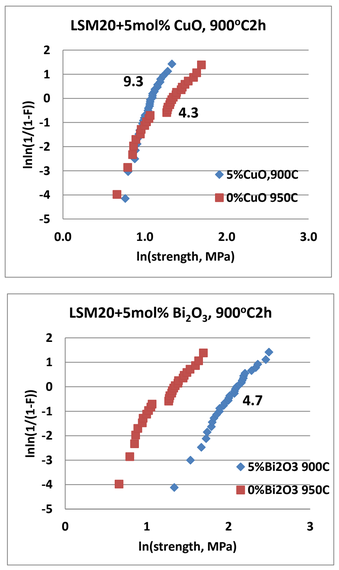


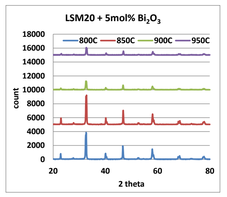
Sintered density showed substantial increase for Bi_2O_3 at 5% while minute improvement was observed for CuO, retardation by rigid inclusion of YSZ fibers.

2. Mechanical Property Bulk Strength

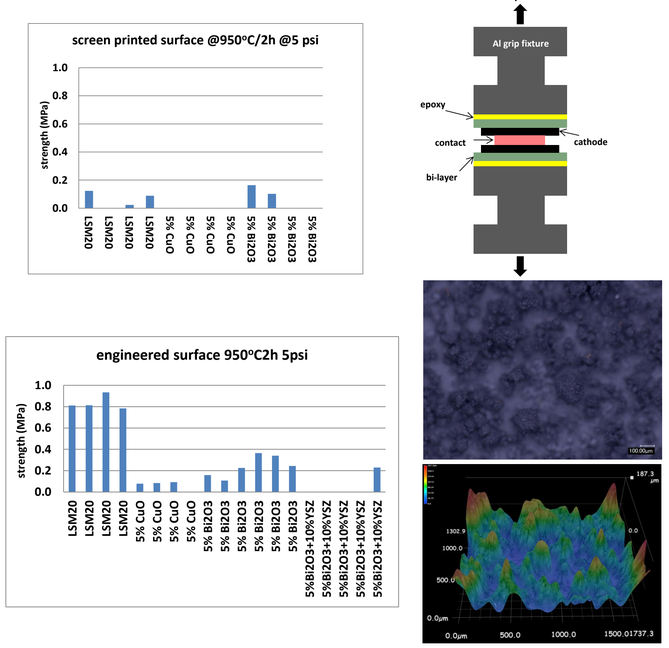


2. Mechanical Property Weibull Modulus

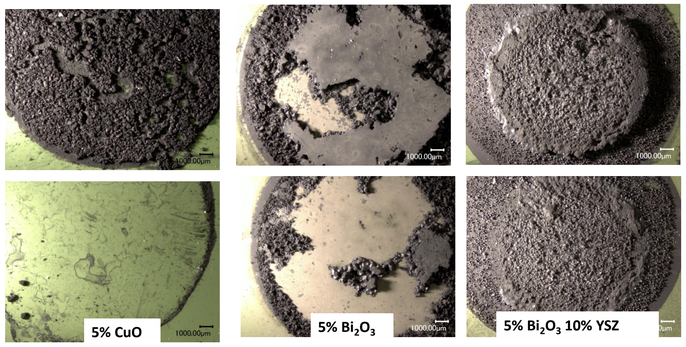




3. Contact Strength of Joined Couples



Matching Fracture Surface



Summary and Conclusion

1. Sintering study indicated Bi_2O_3 is more effective to enhance densification than CuO, while YSZ fibers appeared no effect.
2. Strength results showed most increase by Bi_2O_3 and less by CuO for LSM20 contact. Strength of LSM20 with both Bi_2O_3 and 5% YSZ fibers was less than LSM20+Bi_2O_3, but was doubled compared to plain LSM20.
3. XRD showed good chemical compatibility of LSM20 with CuO or Bi_2O_3 as sintering aid.
4. Contact strength test with screen printed surface showed no bonding at all for CuO (5%) and YSZ fibers (5-15%). Samples with Bi_2O_3 were bonded; however, no substantial strengthening was observed.
5. Fractography showed all fracture occurred along contact/electrode interface, consistent with constrained sintering.
6. Contact strength test with engineered surface showed improved bonding as compared to screen printed surface; however, no strengthening was observed for CuO, Bi_2O_3, or Bi_2O_3+10%YSZ as compared to plain LSM20 contact.

Presented at the 17th Annual Solid Oxide Fuel Cell (SOFC) Project Review Meeting, July 19-21, 2016, Pittsburgh, PA

U.S. DEPARTMENT OF ENERGY

ACKNOWLEDGEMENT

The authors wish to thank S. Vora, B. White, J. Stoffa, R. Burke, and T. Schultz for their valuable discussions. and Allegheny Ludlum, who provided some treated AISI441 samples. This work was funded by the U.S. Department of Energy's Solid-State Energy Conversion Alliance (SECA) Core Technology Program.