Mechanical Characterization of Interfaces in SOFCs

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Outline

• Background
• Methodology
• Results
• Future Work
Background

- Residual Stresses
  - Fabrication
  - Induced by the formation of new phases
  - Changes in porosity (stiffness)
- Interfacial Electrical Resistance
Methodology

- Physical of Mechanical properties of contact paste
  - Elastic properties, thermal and electrical conductivity, thermal expansion, microstructure, uniaxial and biaxial strength as a function of processing conditions, temperature, time and thermal cycling

- Physical and Mechanical Characterization of contact paste-interconnect interface as a function of time, temperature and thermal cycling.
  - Energy Release Rate
  - Residual Stresses
Methodology

The mechanical evaluation of thin, porous structures is challenging

We are using Resonant Ultrasound Spectroscopy to determine the elastic properties of LSM contact paste
Methodology (Elastic Constants)

300-μm thick zirconia/alumina flat disk

RUS Spectrum

RUS Spectrum of coated specimen

Sinter coated specimen at 800-1100°C

Screen printed LSM film on disk
Methodology (Elastic Constants)

Optimization algorithm → Material properties, dimensions → Geometric model → Mesh → Modal Analysis

Error (match experiments)
Methodology (Elastic Constants)
Spectra of Coated/Uncoated Specimens

409 μm alumina disk; $E = 362.45$ GPa; $\nu = 0.25$; RMS error = 0.93%

Same specimen screen-printed LSM film – Dried Film

Same specimen with 24 μm LSM film – Sintered @ 1100°C – 1 hr
Position of resonant peaks change due to film sintering

- **Uncoated Al$_2$O$_3$ disk**
- **Dried LSM layer onto Al$_2$O$_3$ disk**
- **Sintered LSM layer onto Al$_2$O$_3$ disk**
• Coated+Sintered Specimen modes have a lower frequency by 0.822 %
The value obtained for the elastic modulus of sintered LSM is low ~ \textbf{1.25 GPa} but in the range of values previously reported by Adamson* (~5 GPa)

Methodology

Interfacial Characterization of Cathode Contact Paste Interconnect
Sample Preparation

- Crofer22
  - Cut and ground to either 30 or 15 mm in length and 300 µm in thickness with high values of flatness and parallelism

- Commercial LSM Paste
  - Applied by screen printing
  - Various thickness values

screen printer
Calculation of Strain Energy Release Rate

\[ G = \frac{(1 - \nu^2)}{2E} \frac{M^2}{I} \left( \frac{1}{I_2} - \frac{1}{I_c} \right) \]

\[ M = \frac{Pl}{2b} \]

\[ I_c = \frac{h_1^3}{12} + \frac{h_2^3}{12} + h_1h_2(h_1 + h_2) / 4 \]

\[ I_2 = \frac{h_2^3}{12} \]

\[ I_c = \frac{2}{3}h_2^3 + \kappa \left( \frac{1}{12}h_1^3 \right) + h_2^2h_1 + \frac{1}{2}h_1^2h_2 \]

\[ \kappa = \frac{E_1(1 - \nu_1^2)}{E_2(1 - \nu_2^2)} \]

Determination of Strain Energy Release Rate

[Graph showing load versus displacement with annotations for onset of crack propagation and load plateau]
Effect of sintering condition on Interfacial Fracture Toughness of LSM contact paste-Crofer 22
Sintered at 800°C for 1 hour

Mixed-mode cohesive/adhesive failure
Summary

• Techniques have been identified and used to determine the elastic properties of thin porous layers of LSM contact paste materials.

• A methodology was established to determine the fracture toughness of the interface between metallic interconnects and LSM contact paste.

• Fracture toughness was found to increase with sintering temperature and time.
Current and Future Work

• Working with PNNL team to characterize state-of-the-art systems
  • Spinel-coated Croffer22
  • Cathode contact paste
• Continue activities to demonstrate feasibility of determining the elastic properties of thin coatings by RUS using well-characterized substrates
• Continue generating data (thermophysical and mechanical properties) to support on-going modeling efforts
• Investigate aging and thermal cycling effects on properties