Mechanical Characterization of Interfaces in SOFCs

Edgar Lara-Curzio, Amit Shyam, Rosa Trejo,
Scott Bell, Beth Armstrong, John Henry

Materials Science & Technology Division
Oak Ridge, National Laboratory
Oak Ridge, TN 37831-6062

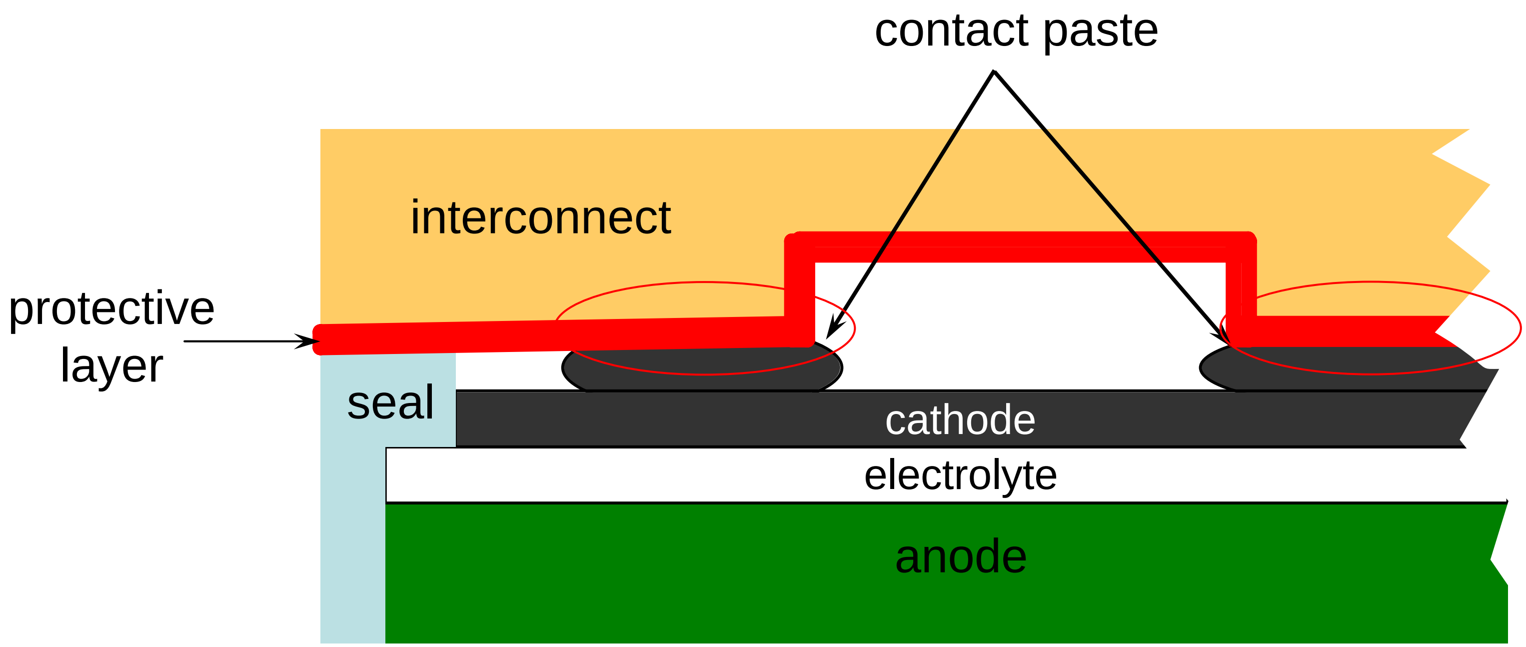
8th Annual SECA Workshop
San Antonio, Texas
August 7-9, 2007

OAK RIDGE
National Laboratory

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

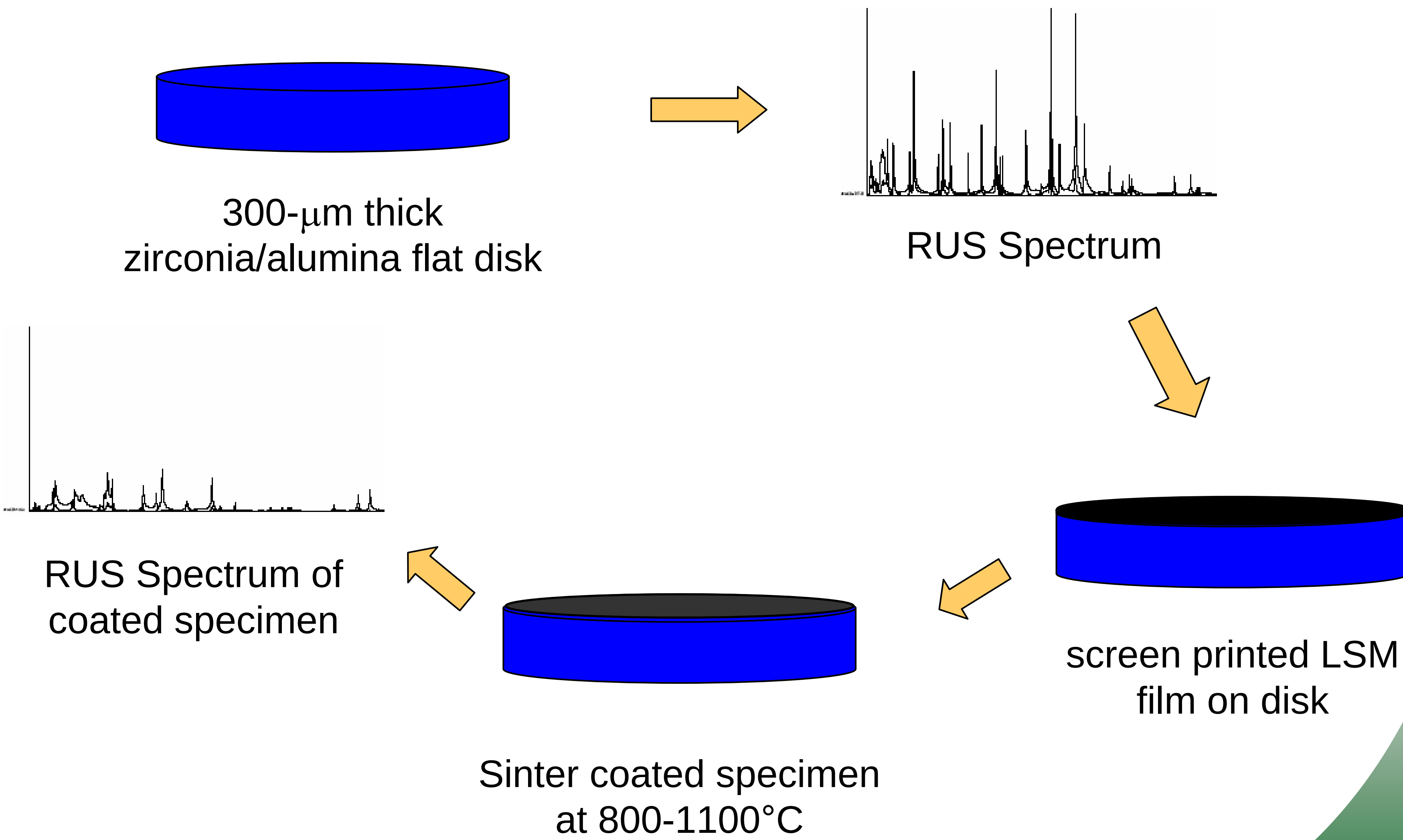
- Physical of Mechanical properties of contact paste
    - Elastic properties, thermal and electrical conductivity, thermal expansion, microstructure, uniaxial and biaxial strength as a function of processing conditions, temperature, time and thermal cycling
- Physical and Mechanical Characterization of contact paste-interconnect interface as a function of time, temperature and thermal cycling.
    - Energy Release Rate
    - Residual Stresses

Methodology

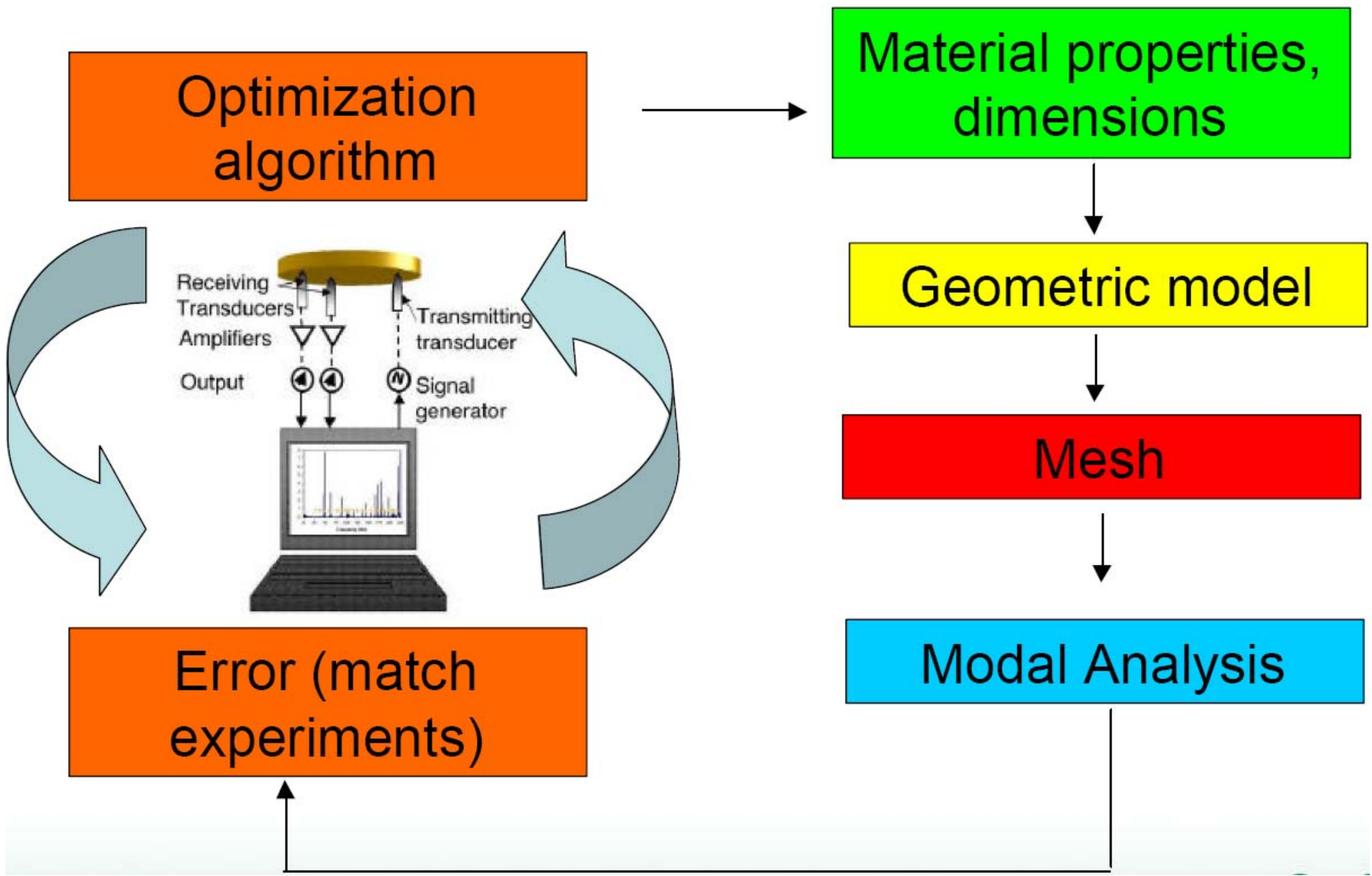
The mechanical evaluation of thin, porous structures is challenging

We are using Resonant Ultrasound Spectroscopy to determine the elastic properties of LSM contact paste

Methodology (Elastic Constants)



Methodology (Elastic Constants)

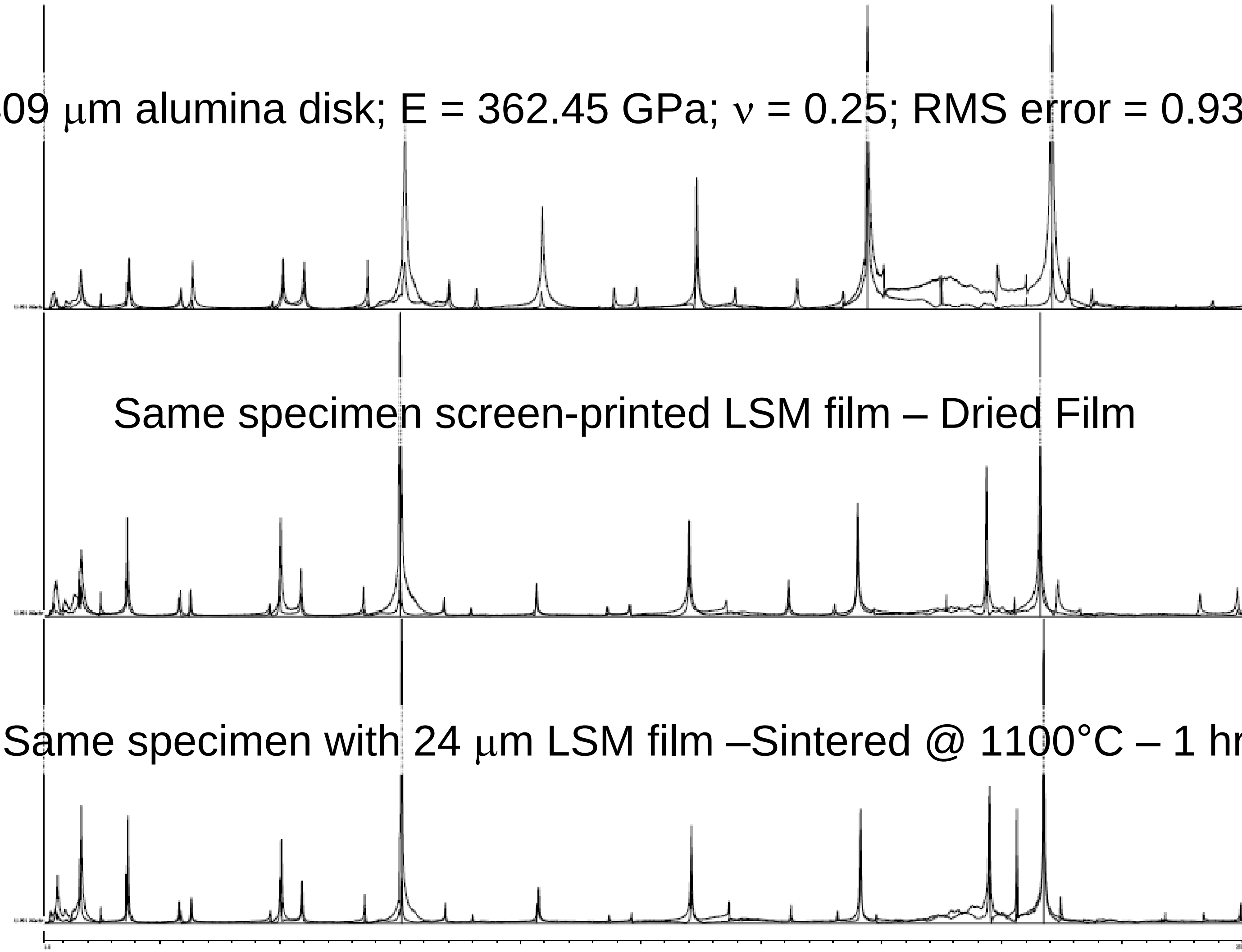


Methodology (Elastic Constants)

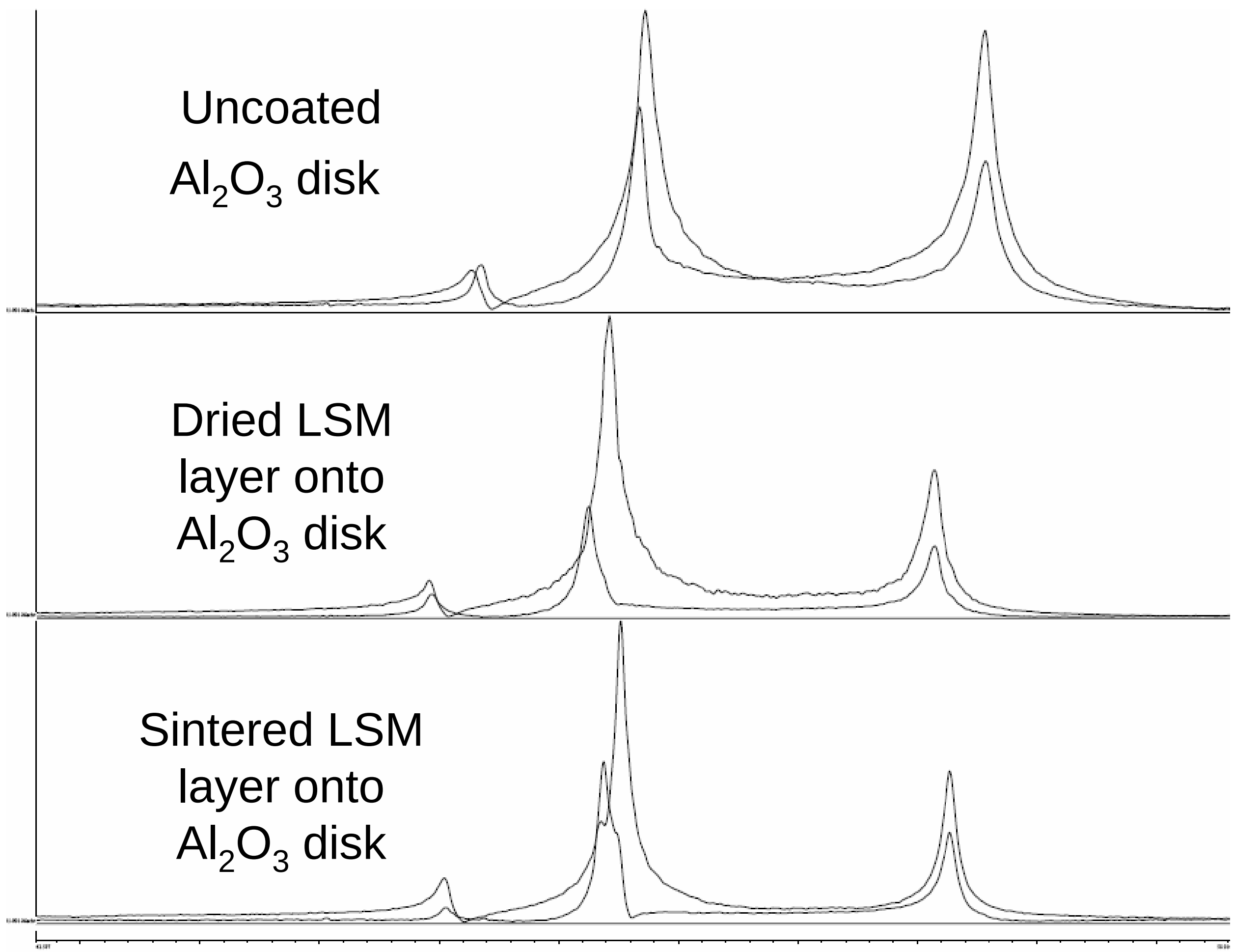
QuickTime™ and a
Microsoft Video 1 decompressor
are needed to see this picture.

QuickTime™ and a
Microsoft Video 1 decompressor
are needed to see this picture.

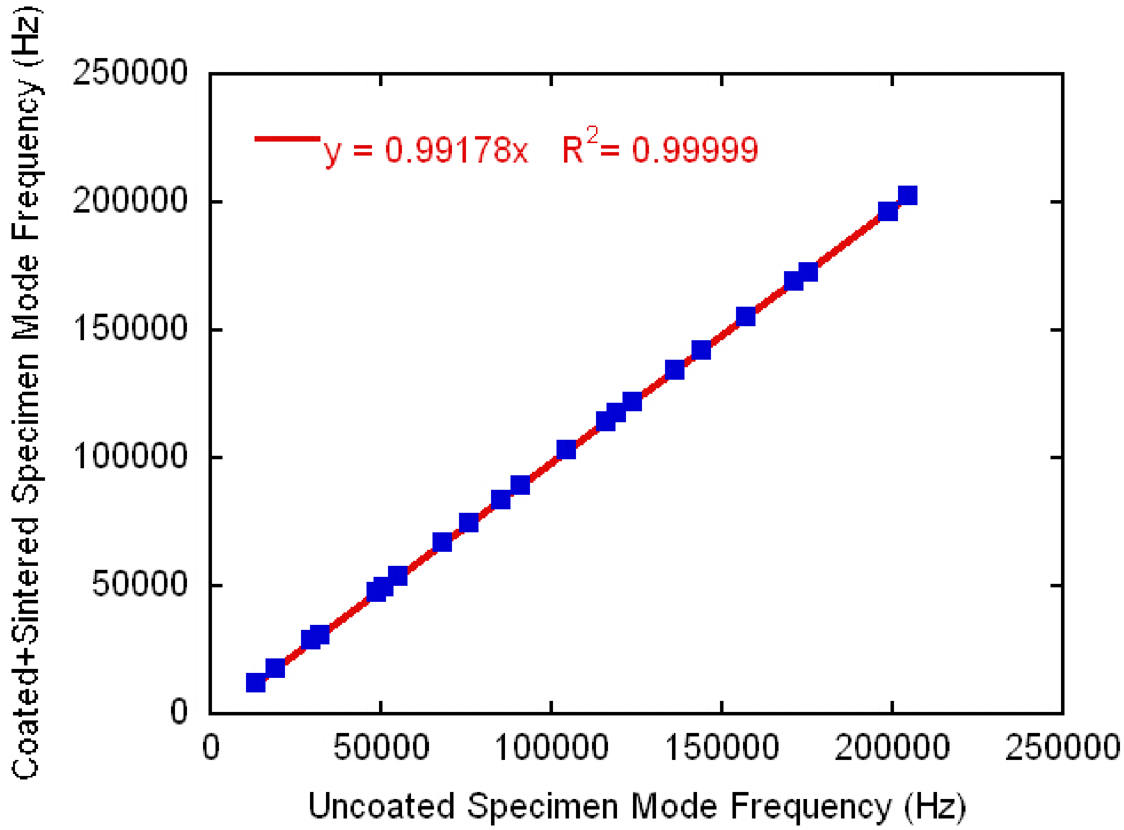
Spectra of Coated/Uncoated Specimens



Position of resonant peaks change due to film sintering



Mode Frequency Comparison



- Coated+Sintered Specimen modes have a lower frequency by 0.822 %

Optimization reveals low value of LSM Elastic Modulus

- Optimization was performed using ANSYS™

Iteration #	Range of E for Optimization	Range of ν	Optimized E	Optimized ν	RMS Error
1	10-50 GPa	0.20-0.40	10.00 GPa	0.258	1.49%
2	0.1-10.0 GPa	0.20-0.40	1.25 GPa	0.39	1.39%
3	0.1-10.0 GPa	0.25	1.28 GPa	0.25	1.39%

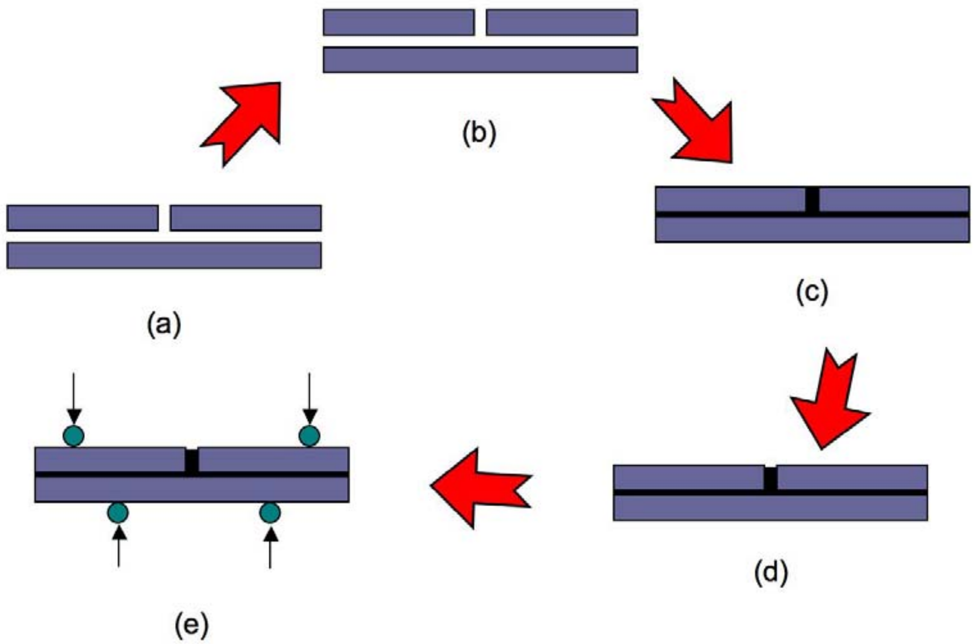
The value obtained for the elastic modulus of sintered LSM is low ~ **1.25 GPa** but in the range of values previously reported by Adamson* (~5 GPa)

* M. T, Adamson, Ph.D. Thesis, University of London (1997)

Methodology

Interfacial Characterization of Cathode Contact Paste Interconnect

Sample Preparation



screen printer

- 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

Calculation of Strain Energy Release Rate

$$G = \frac{(1-\nu^2)\, M^2}{2E}\left(\frac{1}{I_2} - \frac{1}{I_c}\right)$$

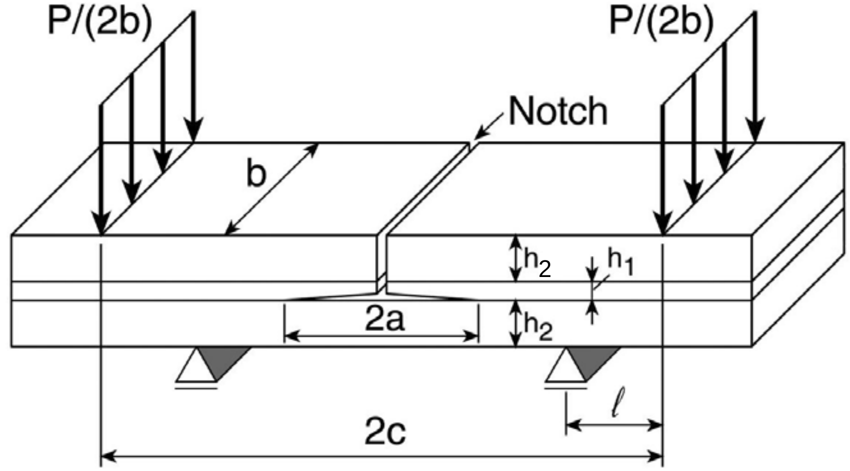
$$M = Pl/2b$$

$$I_c = h_1^3/12 + h_2^3/12 + h_1 h_2 (h_1 + h_2)/4$$

$$I_2 = h_2^3/12$$

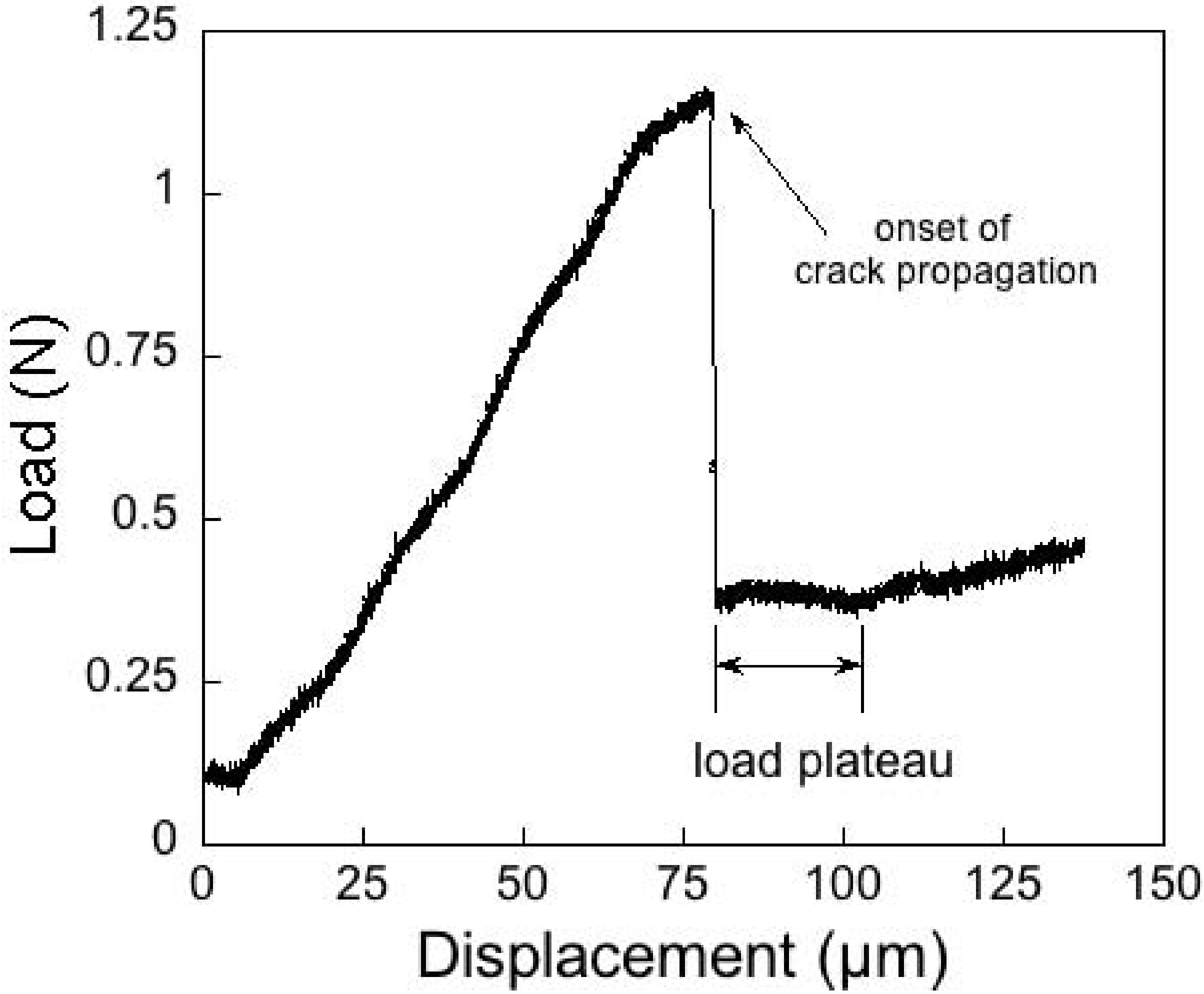
$$I_c = \tfrac{2}{3}h_2^3 + \kappa(\tfrac{1}{12}h_1^3) + h_2^2 h_1 + \tfrac{1}{2}h_1^2 h_2$$

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

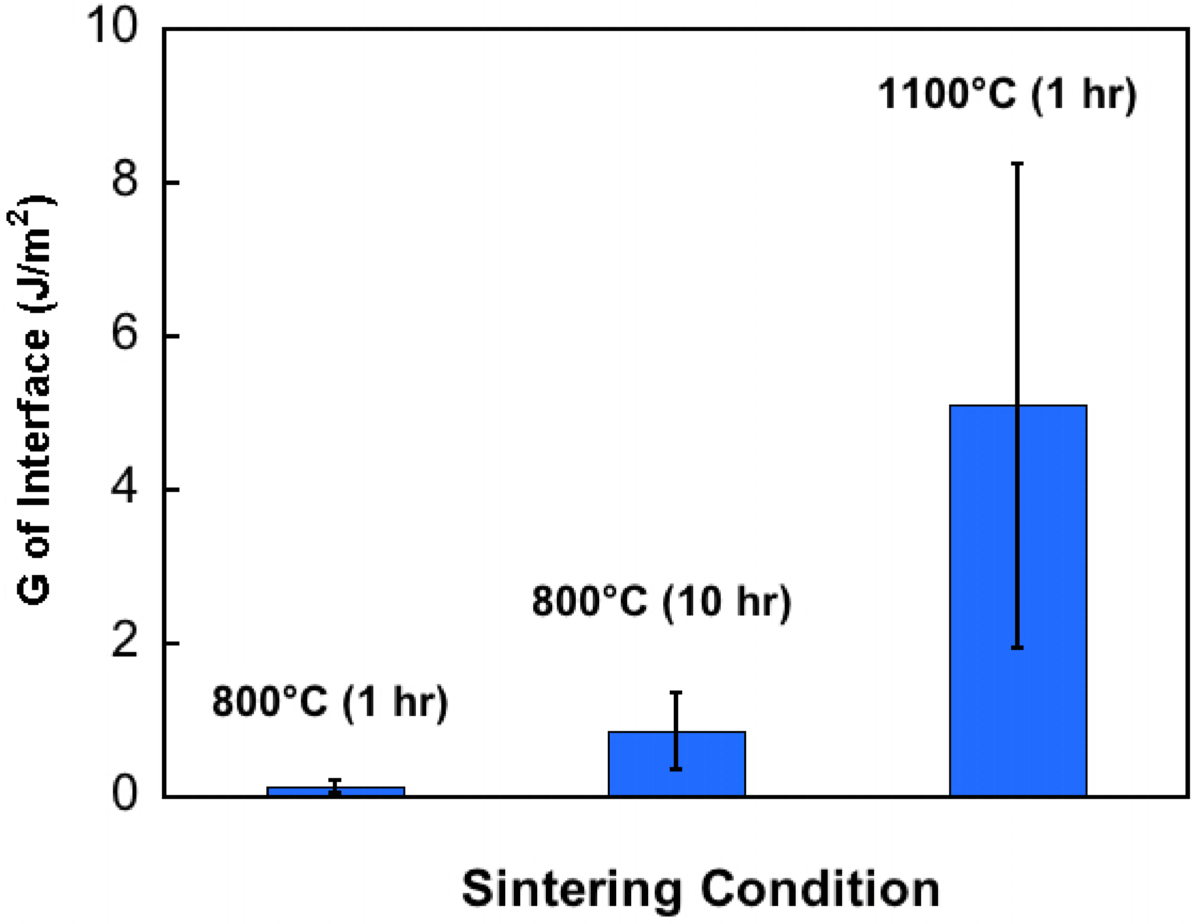


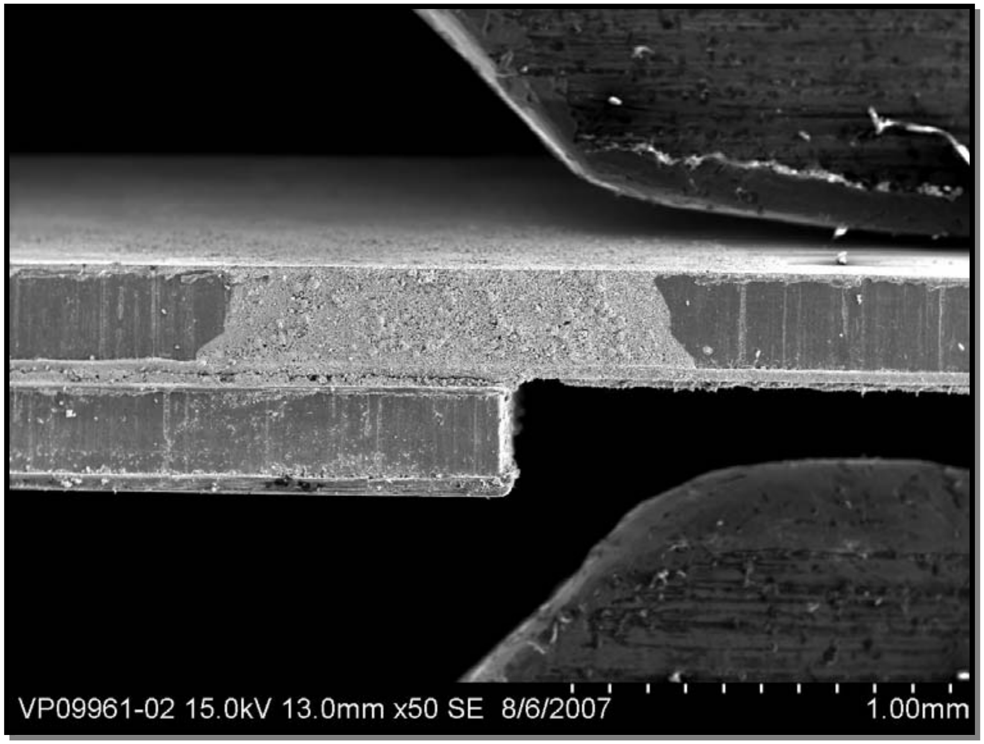
Hofinger *et al*., International Journal of Fracture **92**: 213-220, 1998.

Determination of Strain Energy Release Rate

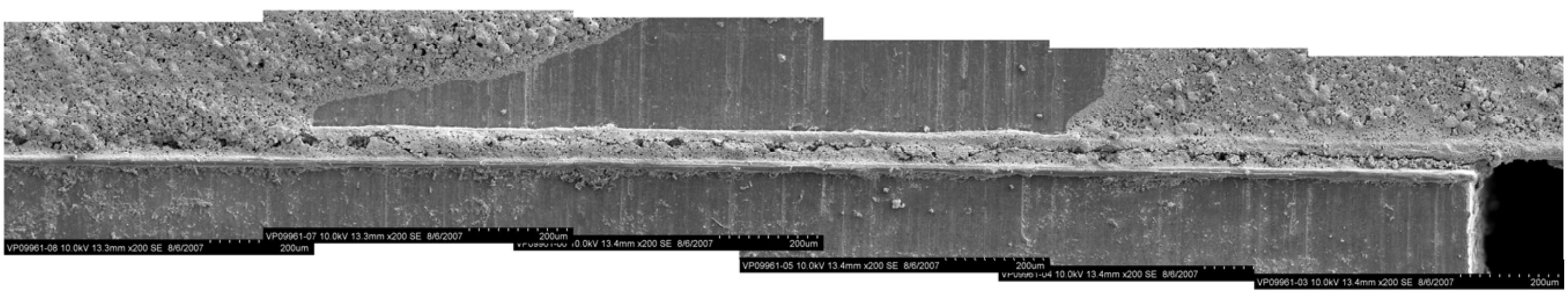


Effect of sintering condition on Interfacial Fracture Toughness of LSM contact paste-Crofer 22





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 the fracture toughness of the interface between metallic interconnects and LSM contact paste.
- Fracture toughness was found to increase with sintering temperature and time.

Oak Ridge National Laboratory

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