# *Mechanical Evaluation of Materials and Components for SOFCs*

***Edgar Lara-Curzio***
Metals & Ceramics Division
Oak Ridge National Laboratory
Oak Ridge, TN 37831-6069

**SECA Core Technology Program**
**Pittsburgh, PA.**
**November 16, 2001**

# *Outline*

- ***Objectives***
- ***Approach***
- ***Examples***
- ***Summary***

# *Objectives*

- ***To use standardized and customized test methods for the generation of mechanical and performance data of SOFC materials and components in support of the modeling efforts (Core Technology Program).***
- ***To support the Vertical Teams in establishing structure-property relationships for SOFC materials and components.***

# *Approach*

- ***Elastic constants as a function of temperature***
- ***Fracture toughness***
- ***Uniaxial and biaxial monotonic strength***
- ***Thermal shock***
- ***Thermal and mechanical fatigue***
- ***Creep***
- ***Chemical strains (compositional gradients)***
- ***Interfacial toughness in multilayered structures***
- ***Other***

# *Standard test methods*

*C 1161 Flexure Strength (Room Temp.)*
*C 1211 Flexure Strength (High Temp.)*
*C 1323 C Ring Strength*
*C 1273 Tension Strength, Room Temp.*
*C 1291 Creep, Creep Rupture*
*C 1322 Fractography*
*C 1326 Knoop Hardness*
*C 1327 Vickers Hardness*

***Elastic Moduli***

*C 1198 Continuous Excitation*
*C 1259 Impulse Excitation*

***NDE and Design***

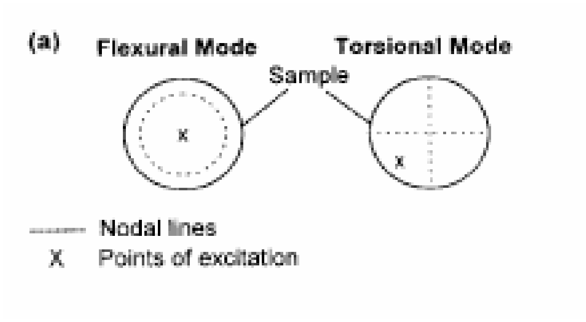
*C 1212 NDE Seeded Voids*
*C 1336 NDE Seeded Inclusions*
*C 1331 Ultrasonic Velocity*
*C 1332 Ultrasonic Attenuation*
*C 1239 Weibull Analysis*
*C 1175 NDE Guide*

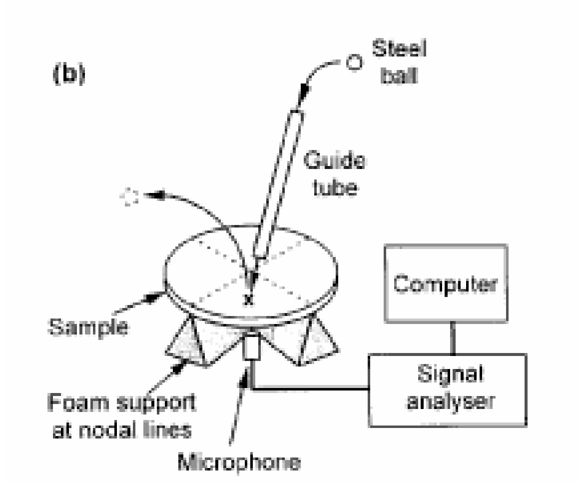
***Classification***

*C 1286 Classification*

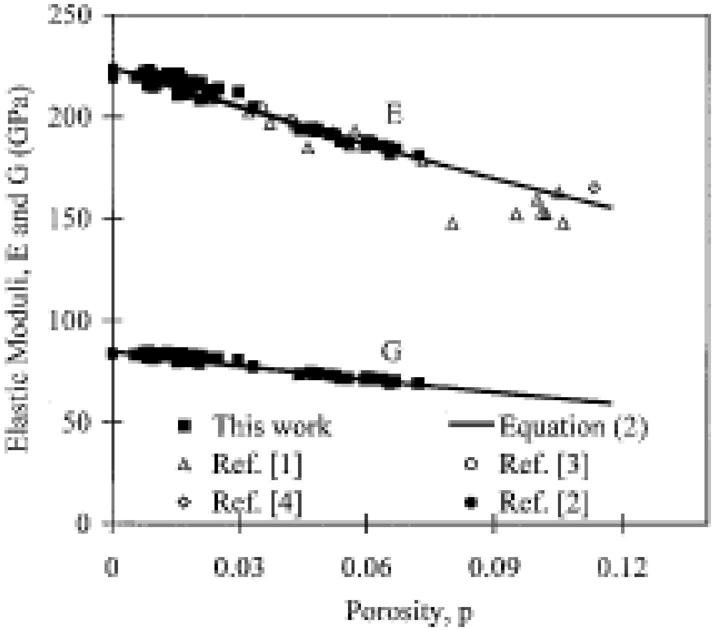
American Society for Testing and Materials

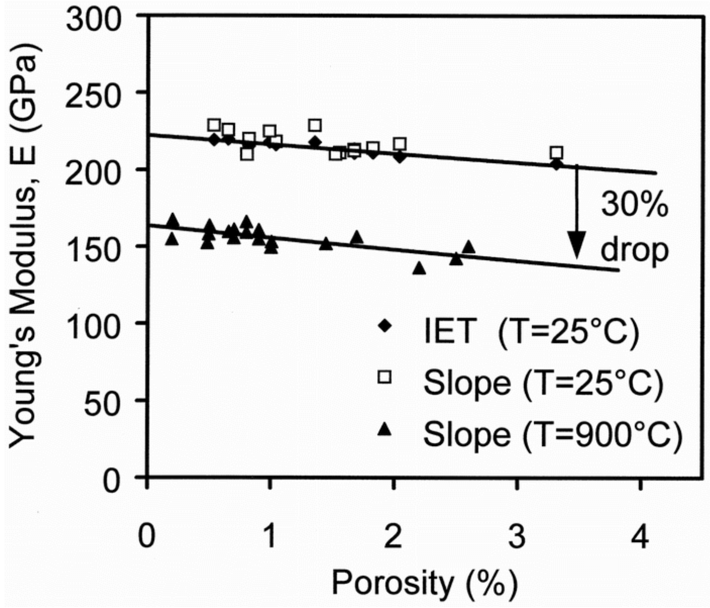
# *Elastic Properties*



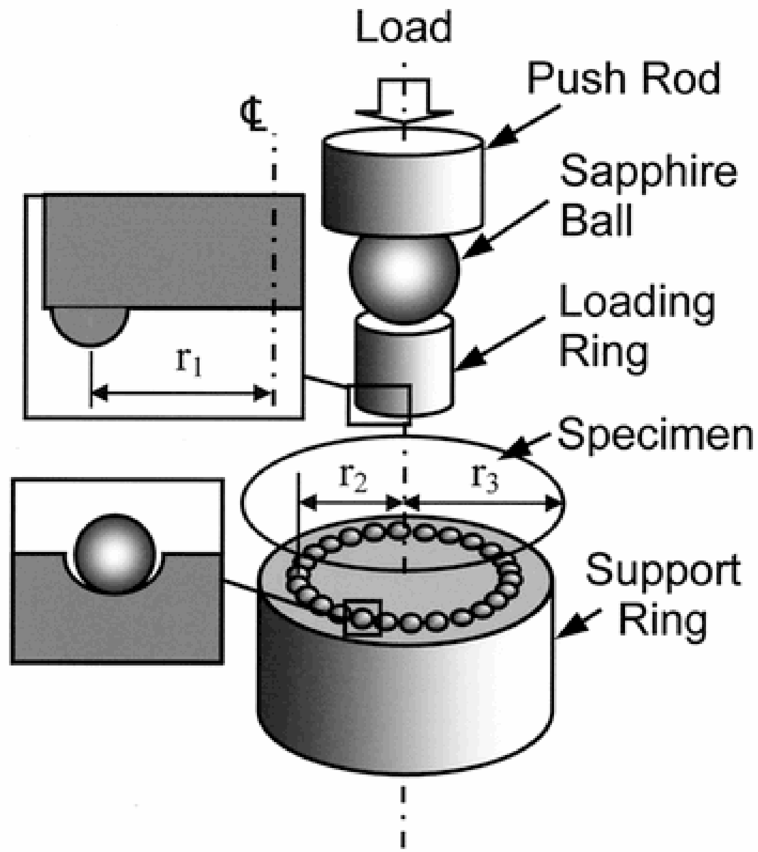
# *Elastic Properties*



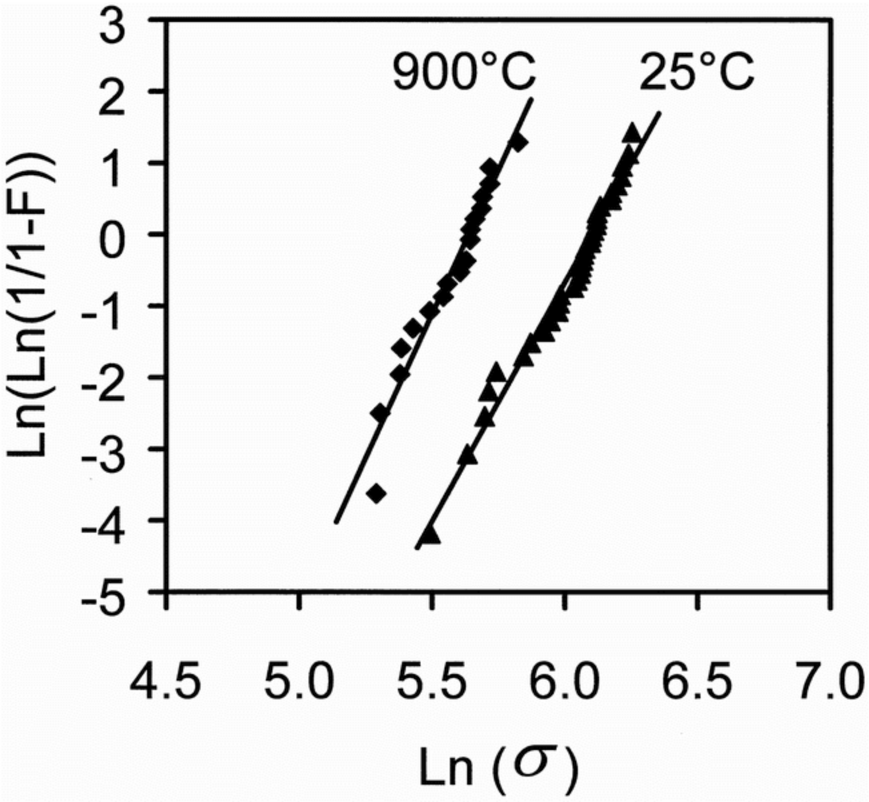




A. Atkinson, A.Selcuk, *Solid State Ionics*, **134** (2000) pp. 59–66

# *Biaxial Strength*



# *Biaxial Strength*

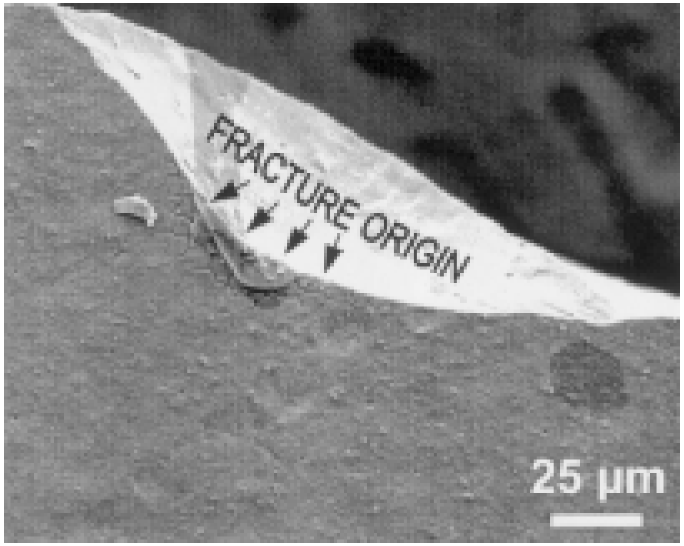


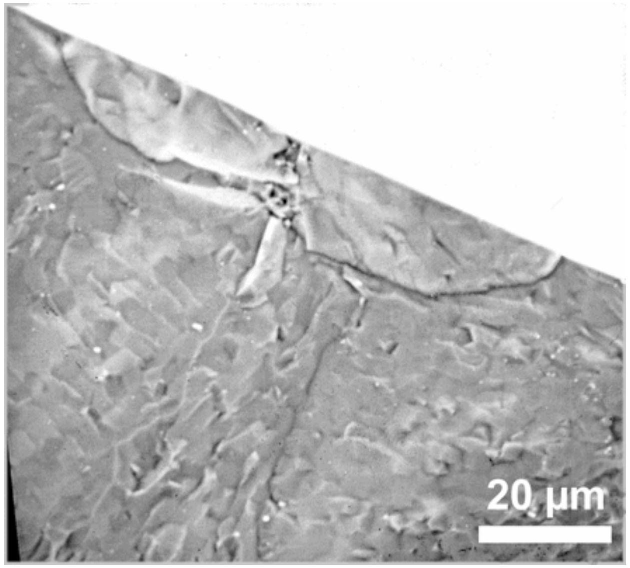

**Weibull plot of biaxial flexural strength of tape-cast YSZ**

| | 25°C | 900°C |
|---|---|---|
| $\sigma_{avg}$ | 416 ± 70 MPa | 265 ± 39 MPa |
| $\sigma_o$ | 446 MPa | 282 MPa |
| m | 6.7 | 8.0 |

Selcuk and Atkinson, *J. Am. Ceram. Soc.*, **83** [8] 2029–35 (2000)

# *Fractography*

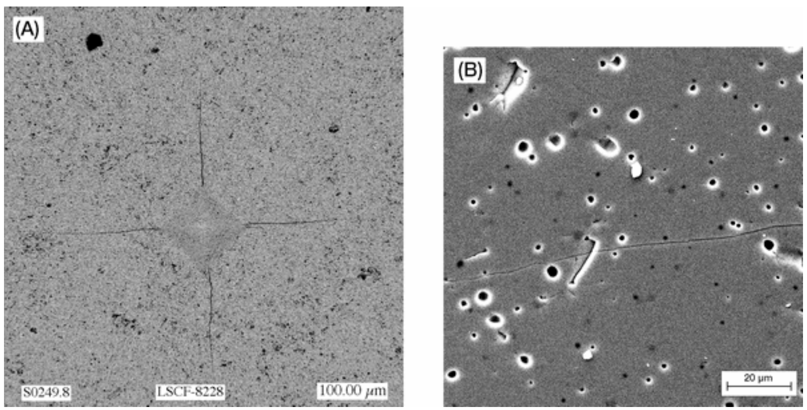


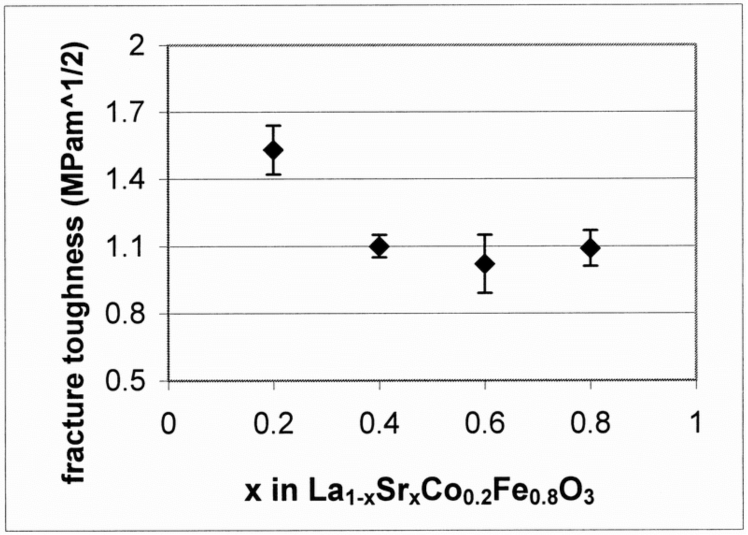




Selcuk and Atkinson, *J. Am. Ceram. Soc.*, **83** [8] 2029–35 (2000)

# *Fracture Toughness*

*Indentation fracture toughness as function of strontium content, x, in* $La_{1-x}Sr_xCo_{0.2}Fe_{0.8O3}$.



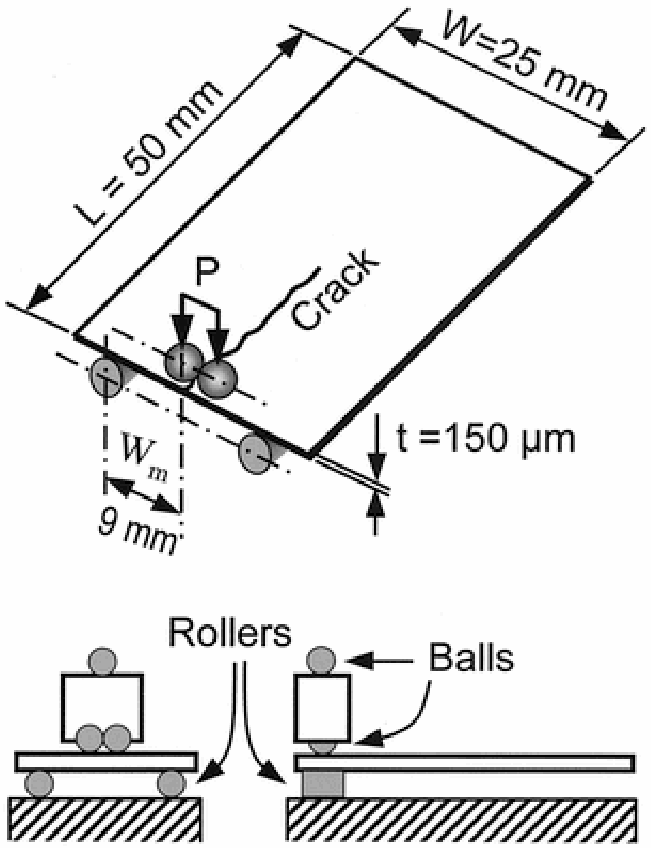





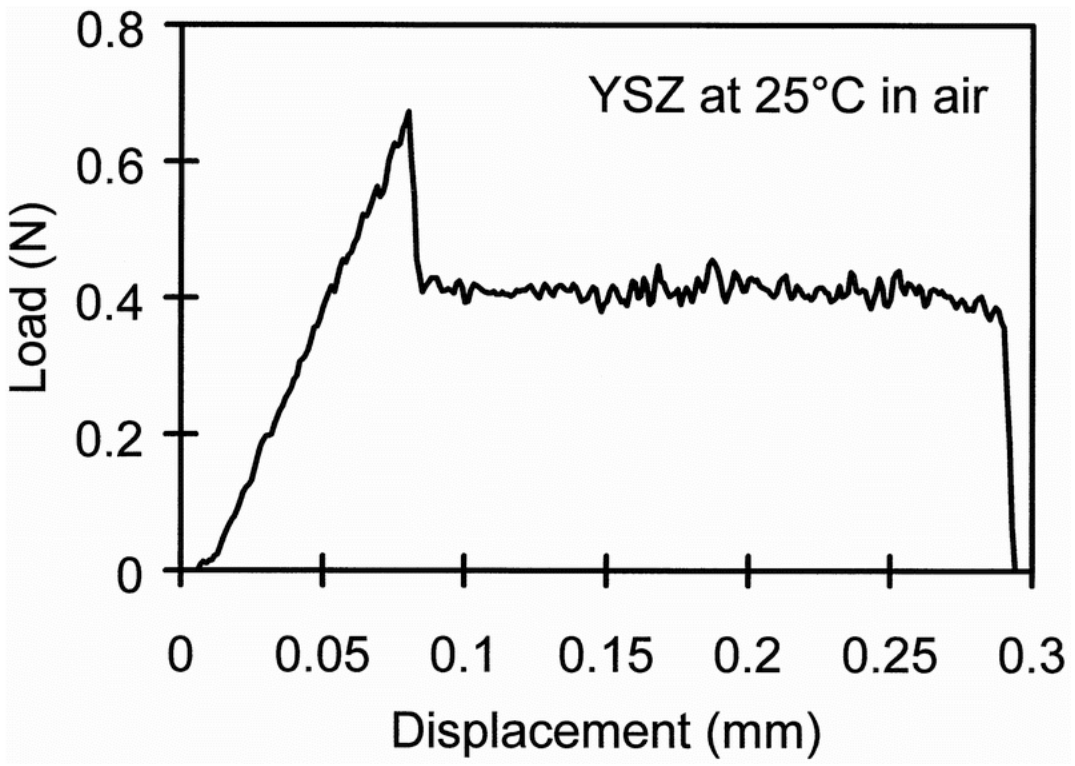
Y.-S. Chou, J. W. Stevenson, T. R. Armstrong, and L. R. Pederson,
*J. Amer. Ceram. Soc.*, **83**, No. 6, June 2000

# *Fracture Toughness (cont.)*

***Double-torsion test***

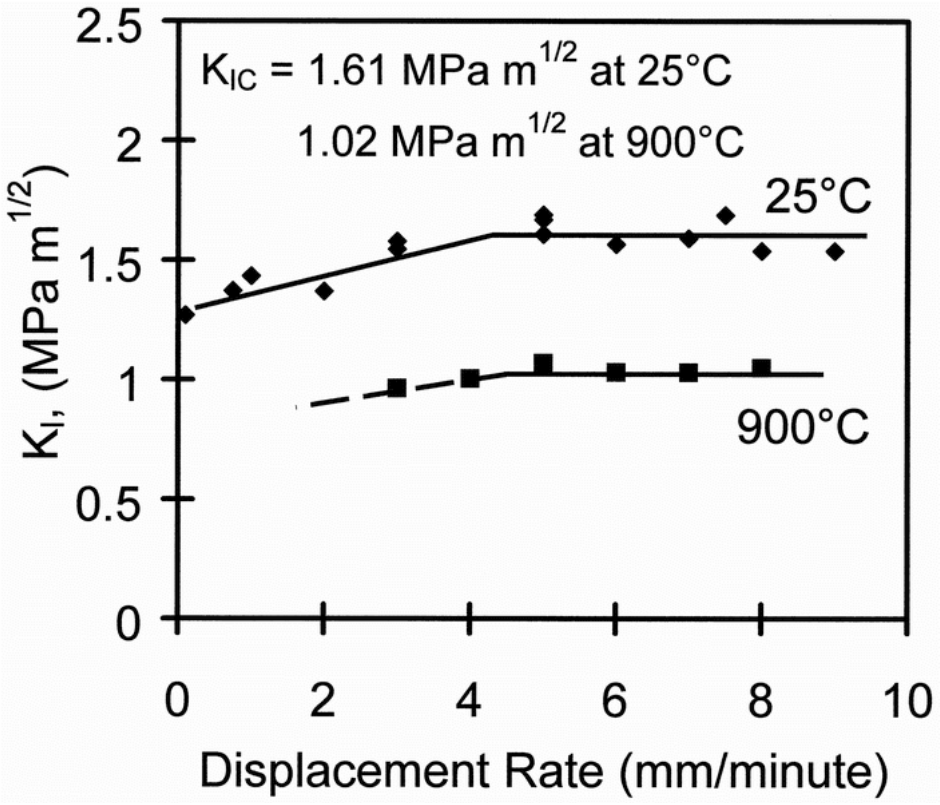


# *Fracture Toughness (cont.)*



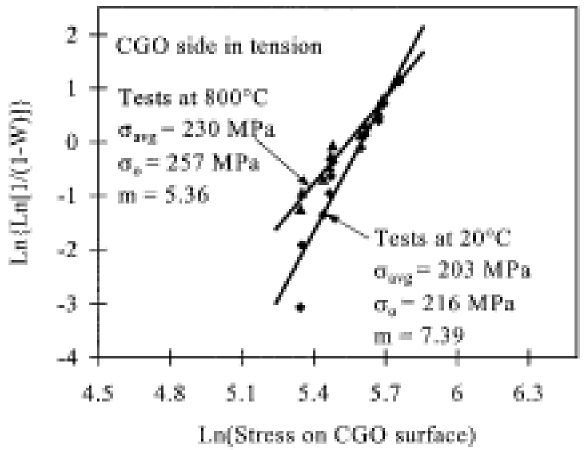
# *Fracture Toughness (cont.)*

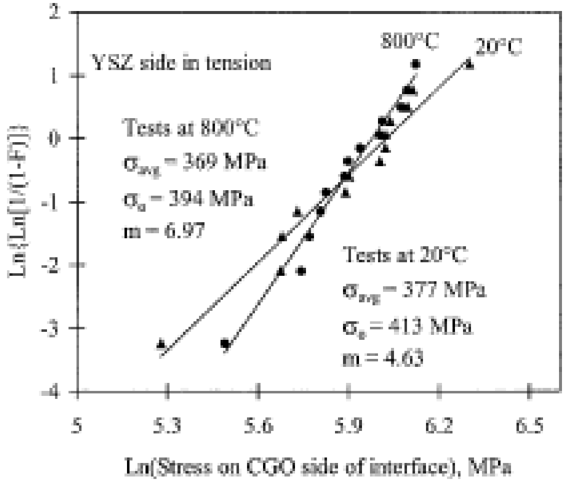
*Stress intensity for crack extension of YSZ at constant-displacement rate*




Selcuk and Atkinson, *J. Am. Ceram. Soc.*, **83** [8] 2029–35 (2000)

# Properties of Structures




A . Atkinson , A . Selcuk, *Solid State Ionics* **134** (2000) pp. 59– 66

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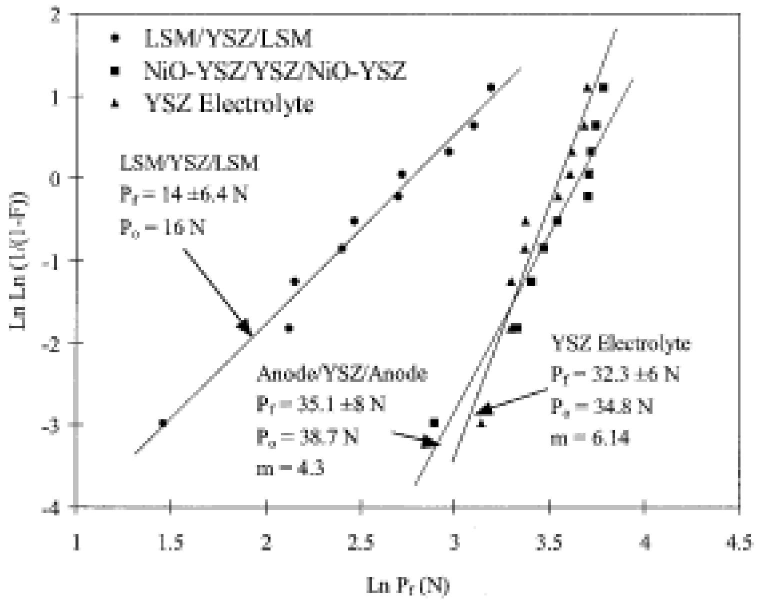


A . Atkinson , A . Selcuk, *Solid State Ionics* **134** (2000) pp. 59– 66

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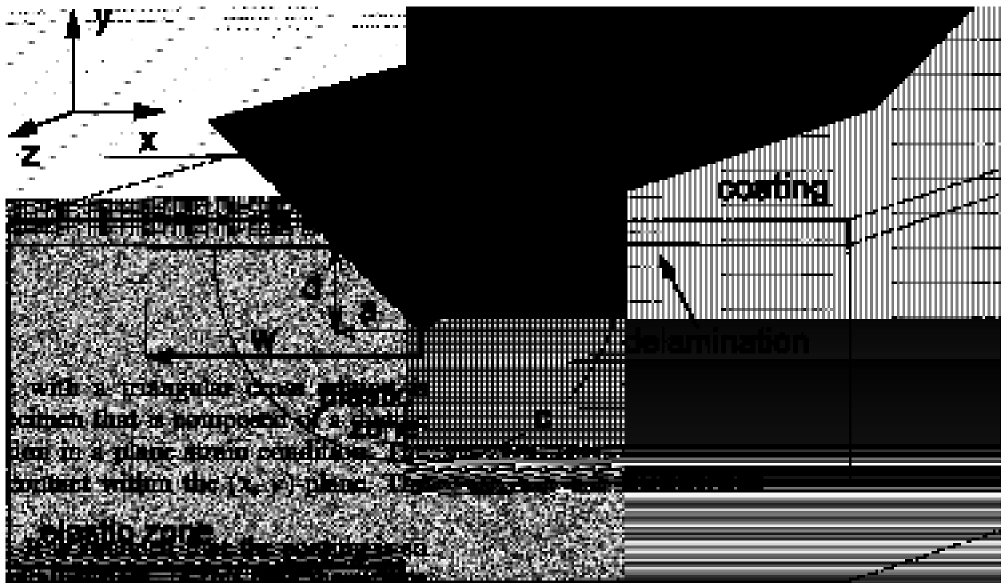
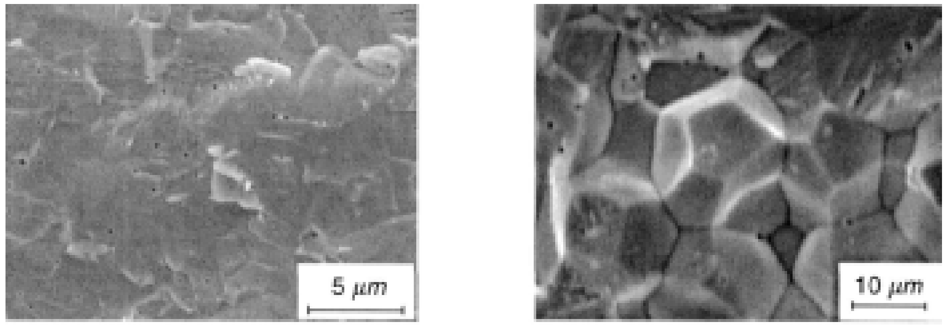
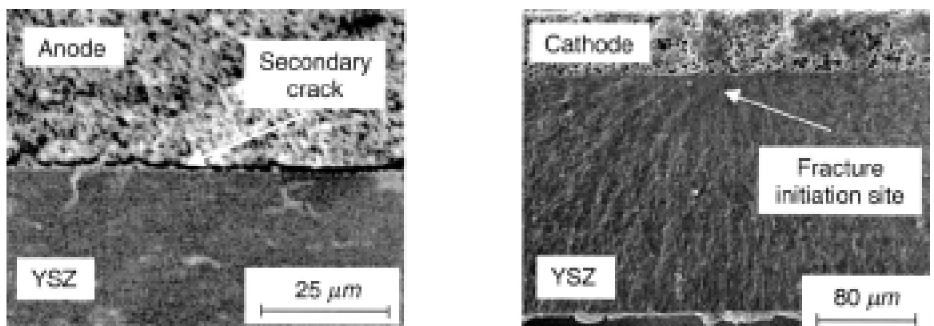


# *Thermal Shock*




(a) (b)




(a) (b)

Busso, E. P., Tkache, Y., and Travis, R. P., *Phi. Mag. A*, **81**, 8 (2001) pp. 1979-95

# *Approach*

- ***Elastic constants as a function of temperature***
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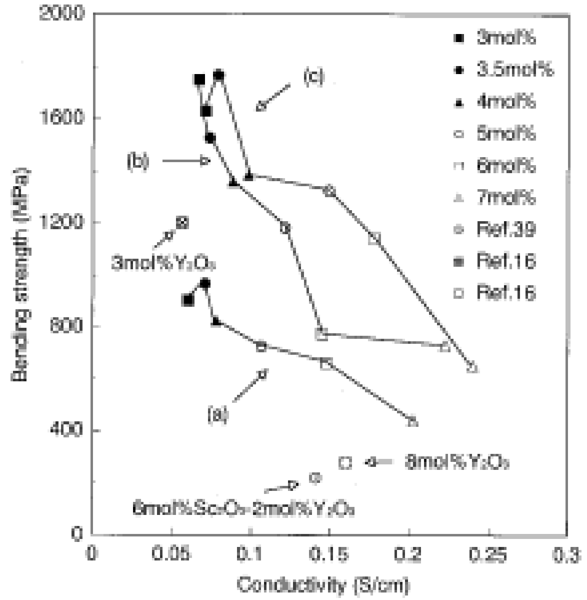
- ***Chemical strains (compositional gradients)***
- ***Other***

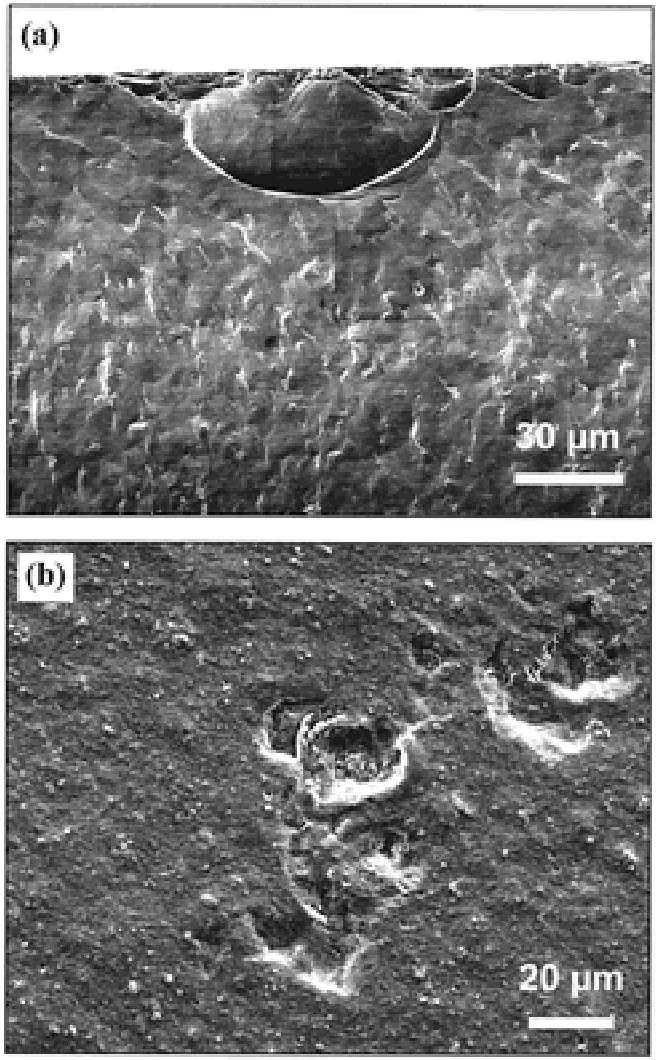
# *Summary*

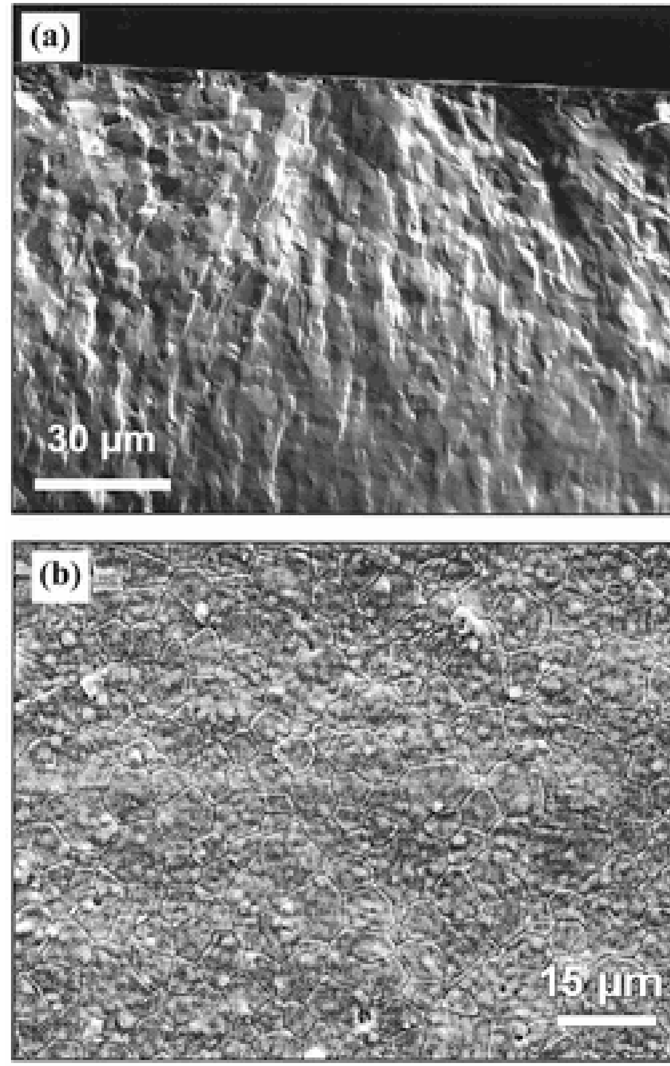
- ***Supporting role in modeling effort.***
- ***Standardized and customized test methods to evaluate properties and performance.***
- ***Identify structure-property/performance relations.***
- ***Support vertical teams in material/component development characterization.***

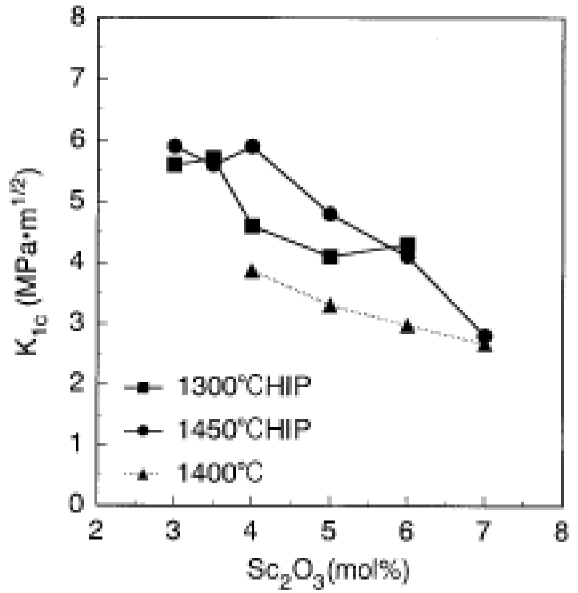



Relationship between bending strength and electric conductivity at 1000°C for ScO-doped zirconia polycrystals (a) sintered at 1300°C, (b) HIPed at 1300°C, and (c) HIPed at 1450°C

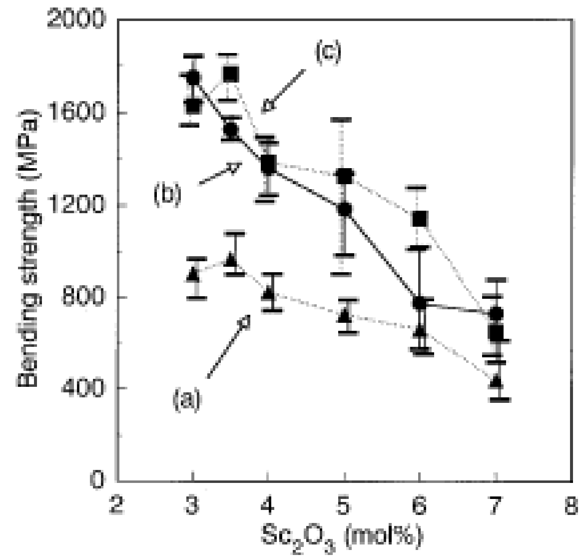
Ahmet Selçuk and Alan Atkinson, *J. Am. Ceram. Soc.*, Vol. **83**, No. 8, August 2000






Fracture toughness of ScO-doped zirconia polycrystals sintered at 1400°C [18], and HIPed at 1300° and 1450°C versus ScO content.




Bending strength of ScO-doped zirconia polycrystals sintered at 1400°C [18], and HIPed at 1300° and 1450°C versus ScO content.

M.Hirano et al./*Solid State Ionics*,133 (2000) pp.1–9