Sealing Materials for Solid Oxide Fuel Cells

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- Dr. Signo Reis and Mr. Teng Zhang (UMR)

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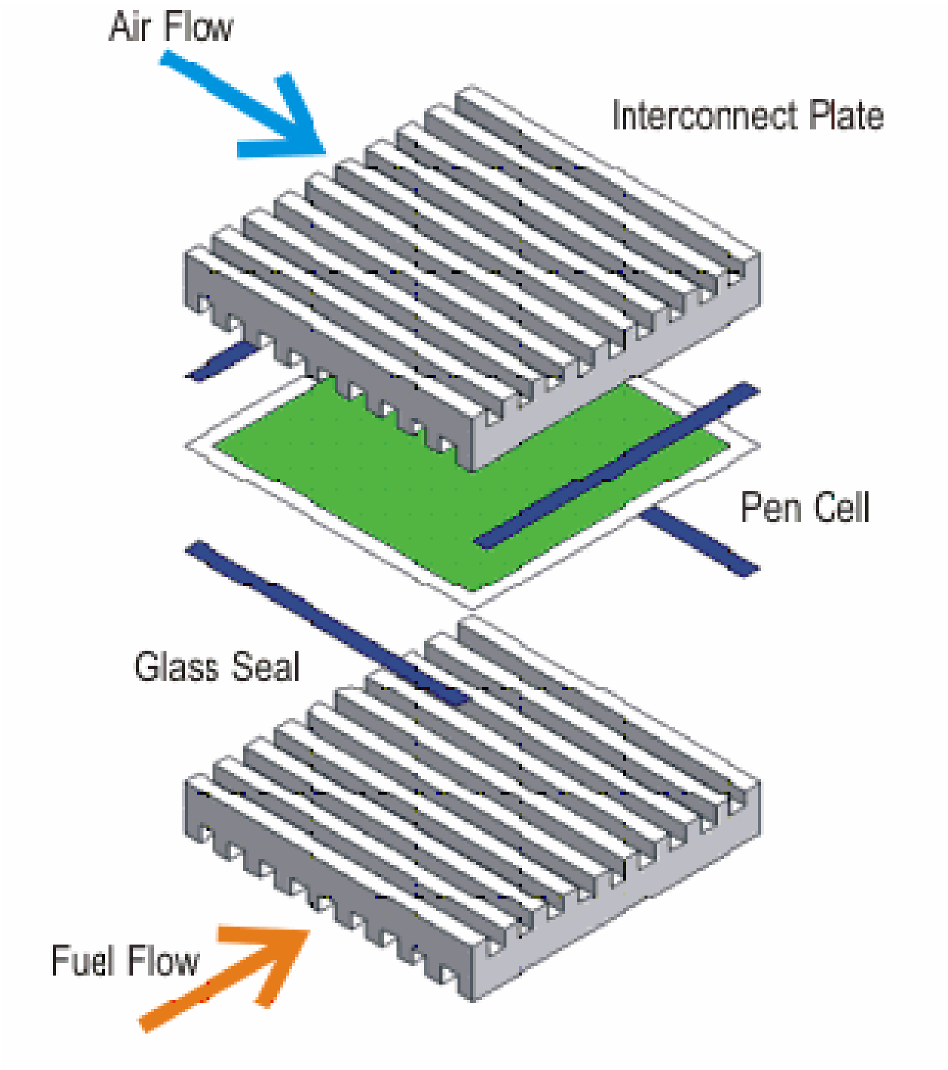
Outline

Goal: Develop stable, resilient sealing materials for SOFCs

- Reviewing the problem; initial glass development research
- Progress over the past six months
  - Glasses with greater CTE's
  - Developing composite materials
- Summarizing our program

The sealing problem is a challenge

1. Challenging compositional design problem
   - Uncommon combination of properties
   - Investigate uncommon families of glasses
2. Glass-ceramics are a likely option
   - Crystallization studies- seal processing and long-term material stability
3. Interfacial chemistry
   - Glass-metal reactions
   - Material stability/volatility
     - Thermochemical stability



Sealing glass properties depend on composition

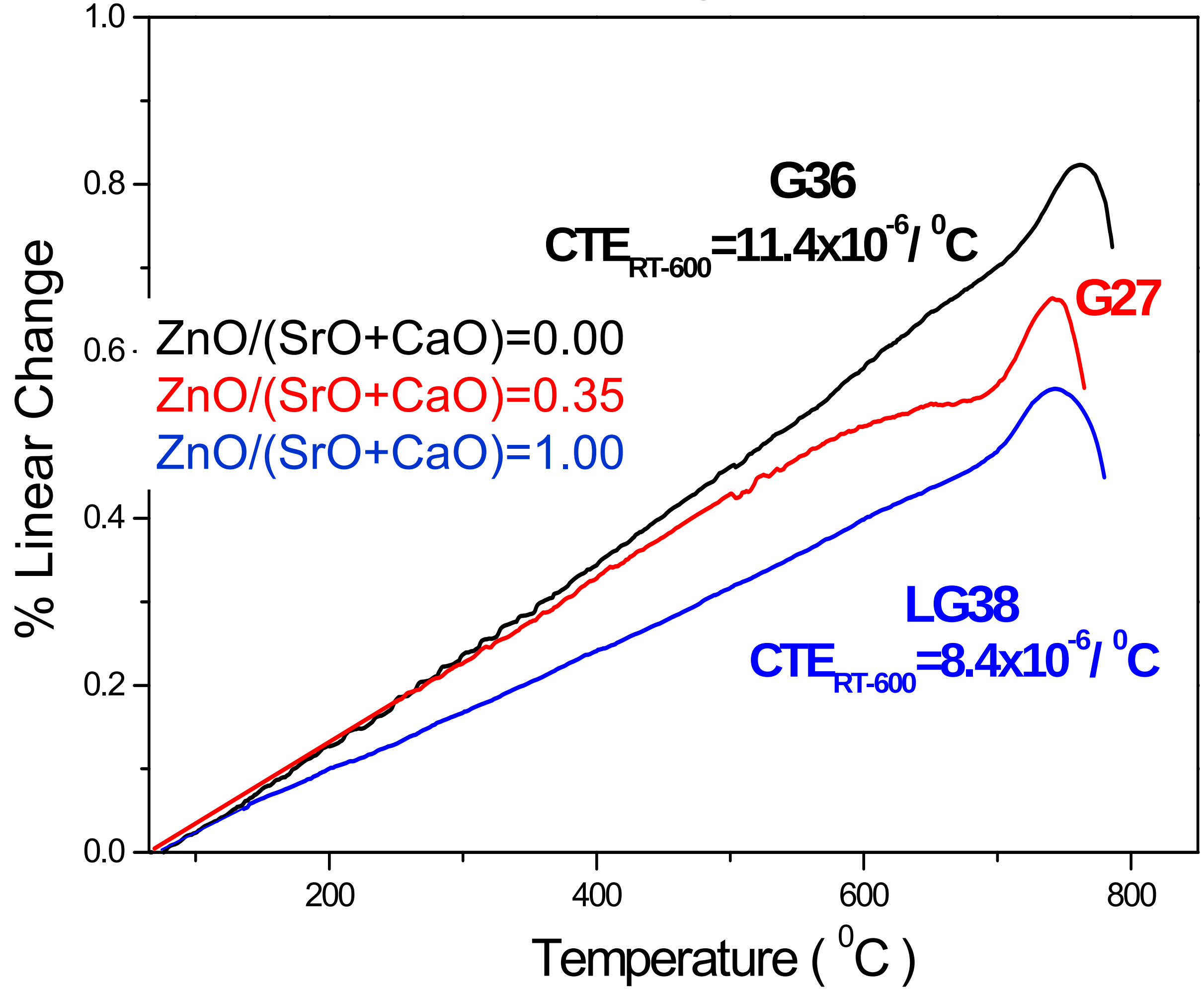
Glass forming system under study:

- Alkaline earth/zinc pyrosilicates
  - 35-50 SiO_2
  - 30-50 RO (R=Mg, Ca, Sr, Zn; no Ba)
  - 0-10 B_2O_3, Al_2O_3, TiO_2, etc.

Design targets include:

- 10<CTE<13 ppm/°C
- 800°C< T_{seal} < 900°C
- Thermochemical and thermomechanical stability

"As made glasses"



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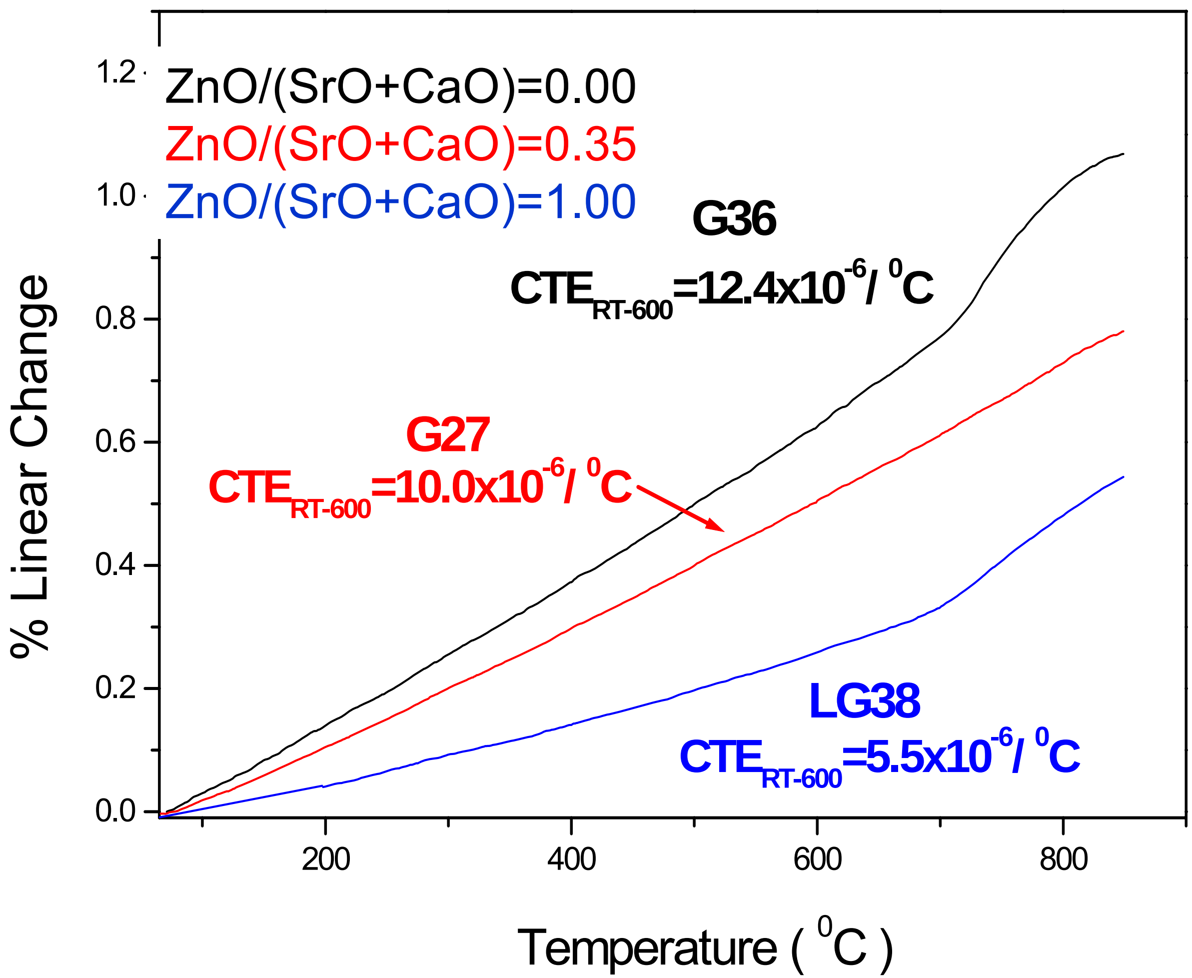

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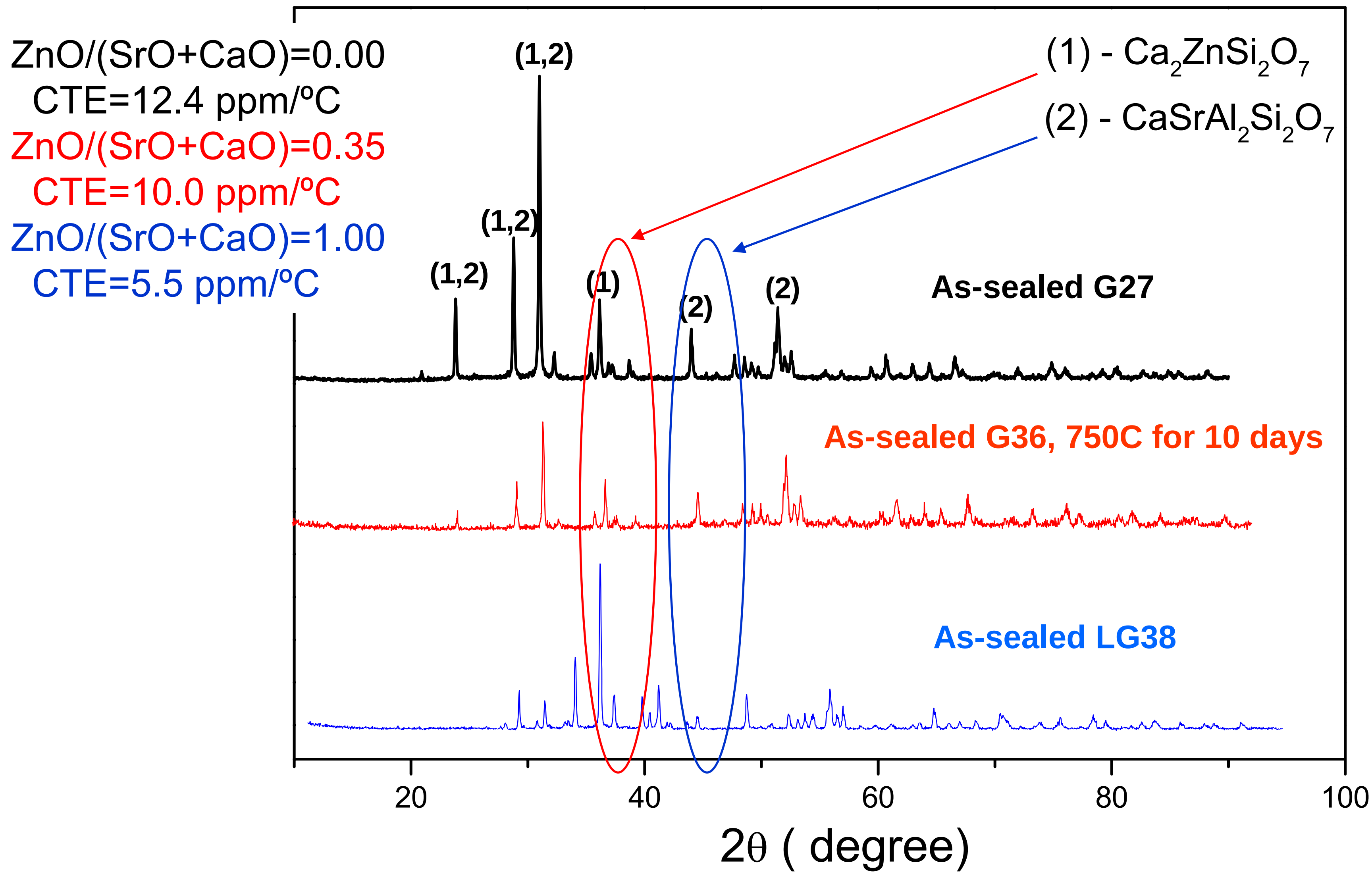
Thermal properties of sealing glasses are controlled by the ZnO/RO ratio



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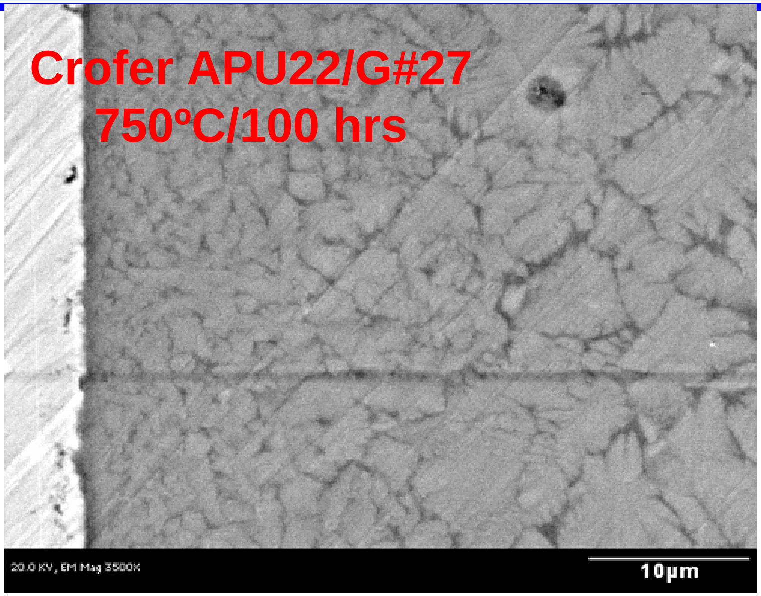
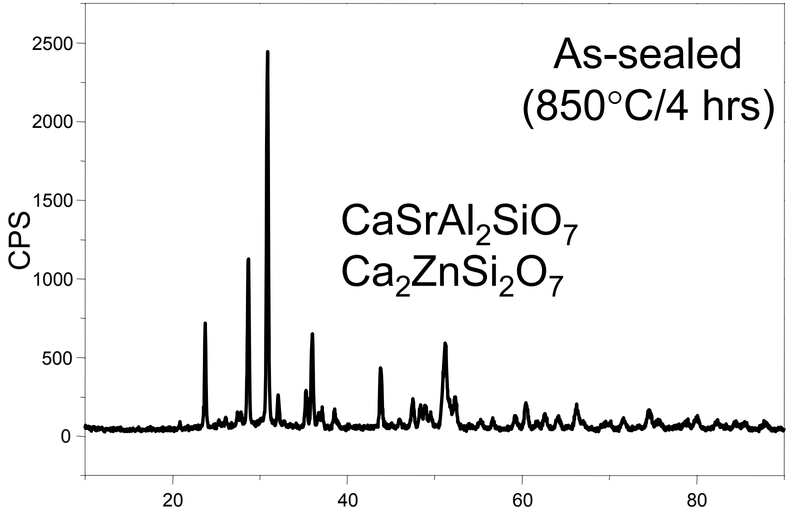
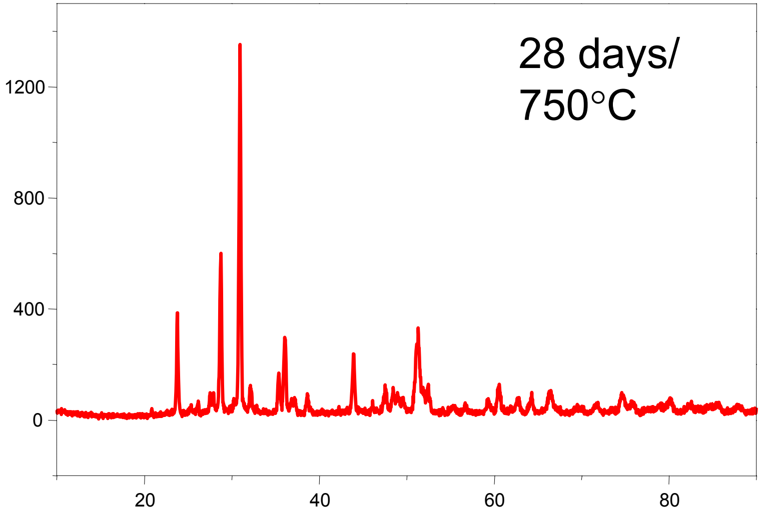
Representative crystalline phases in the UMR glass-ceramics

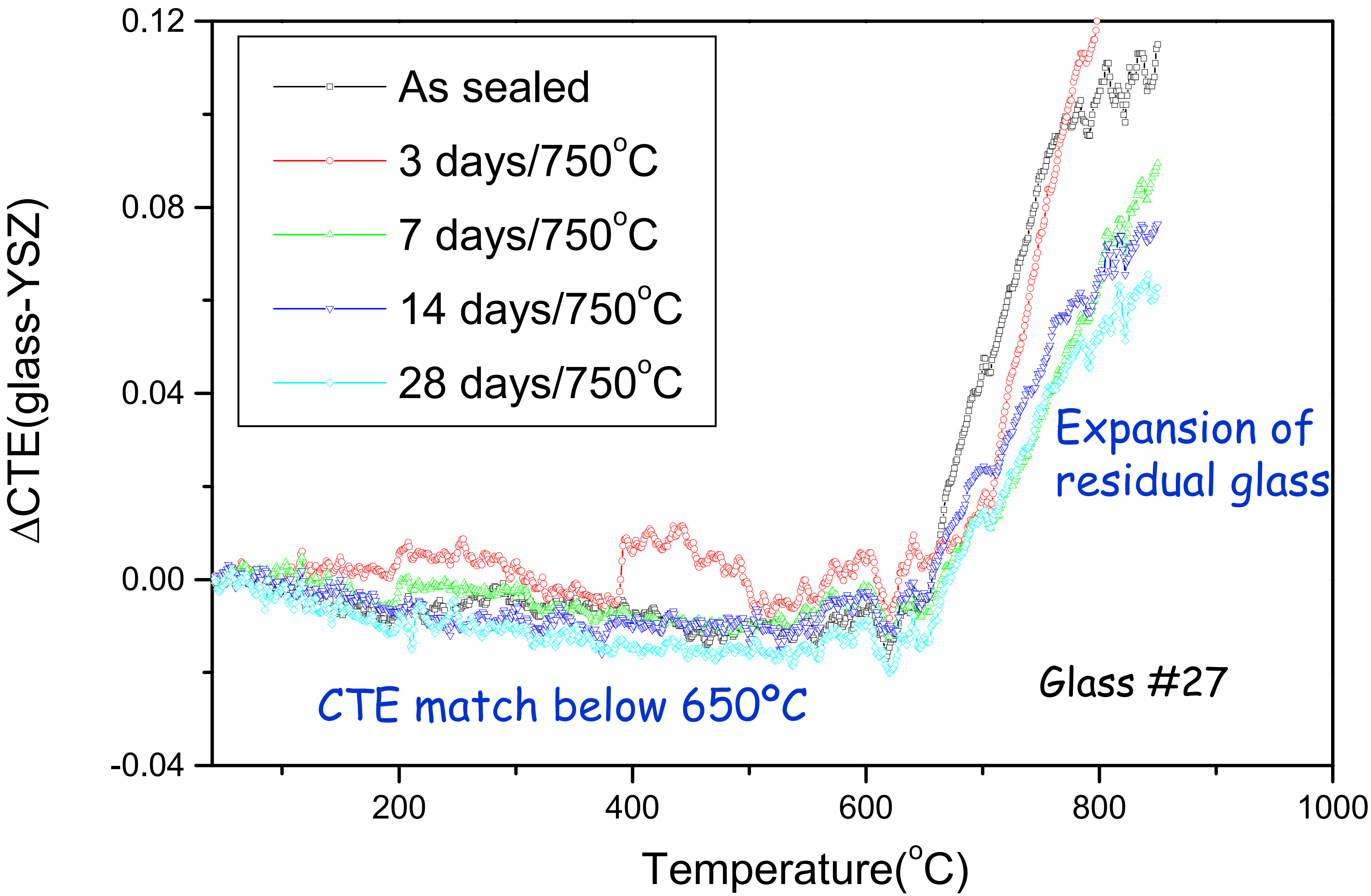
- **Pyrosilicates**
  - $CaSrAl_2SiO_7$, $Ca_2ZnSi_2O_7$
- **Orthosilicates**
  - Sr_2SiO_4, Zn_2SiO_4
- Composition is most important parameter for final phase distribution.







Glass#27 possesses a good CTE-match with YSZ



Greater CTE's are needed for some SOFC designs

- Compositional modifications include
  - Replacing ZnO with CaO and SrO
  - Reducing Al_2O_3 content
  - Modifying relative SiO_2 and B_2O_3 contents
- About fifteen new compositions prepared this past reporting period

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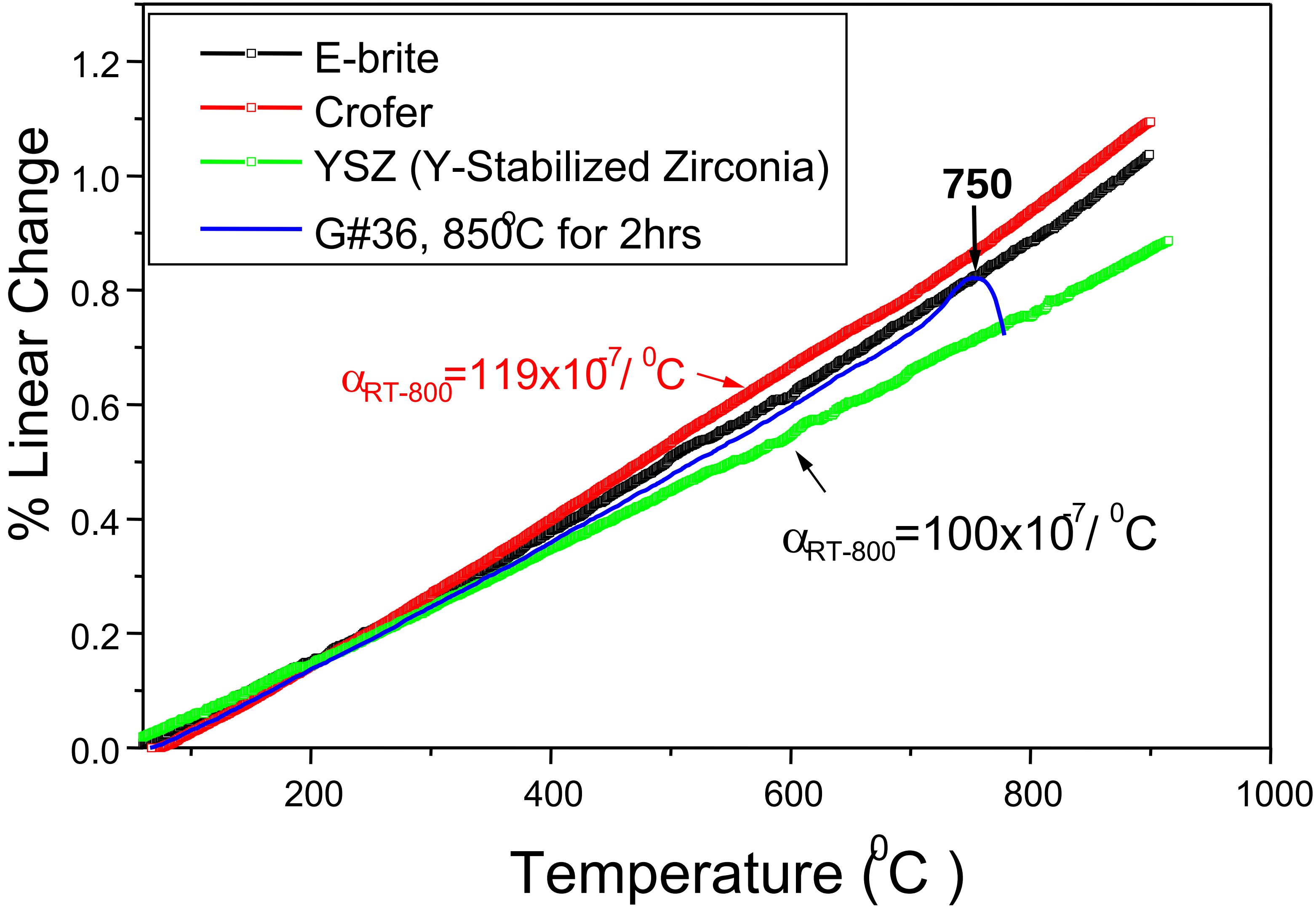
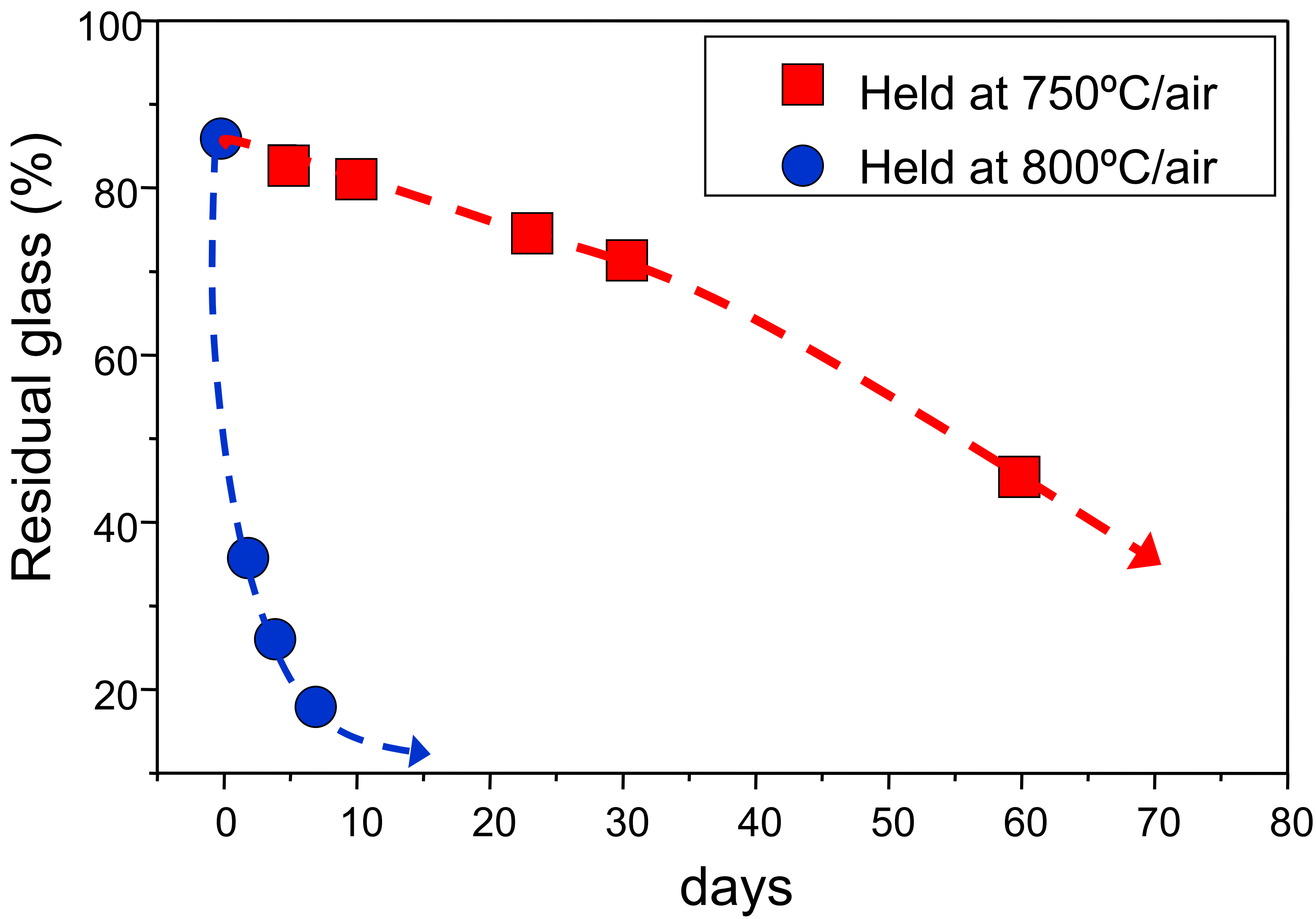
Glass #36 may be more appropriate for some SOFC designs



Crystallization Kinetics of Glass#36/DTA Analyses



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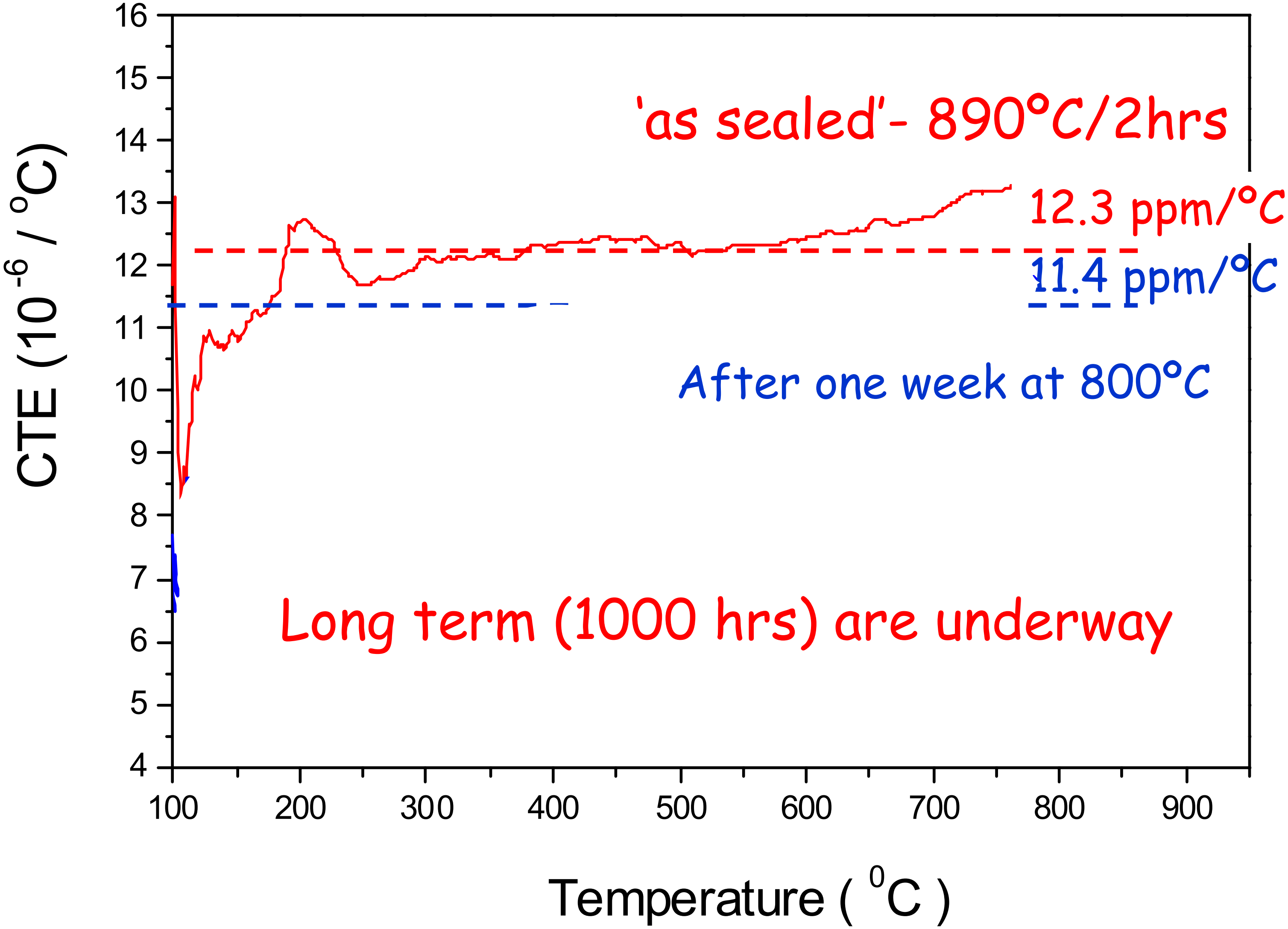
The CTE of glass#36 changes at 800°C



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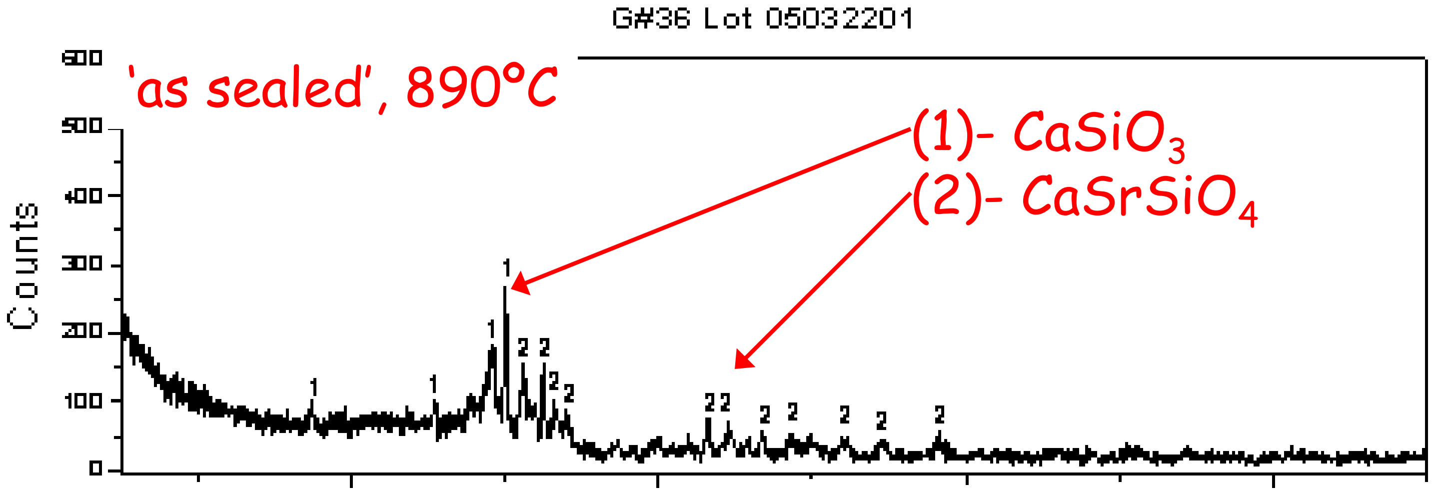
Ca-silicate phases form on crystallization



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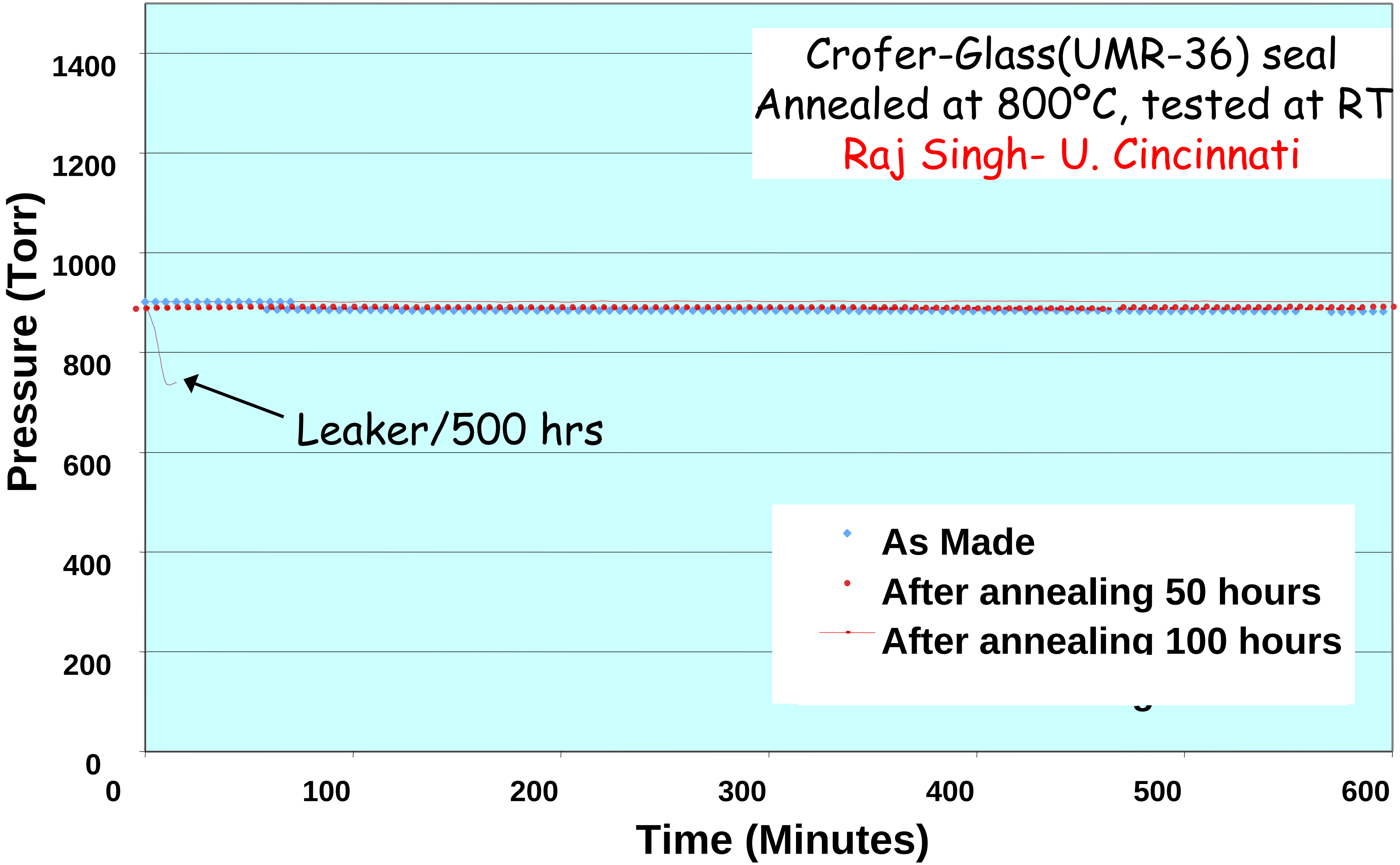
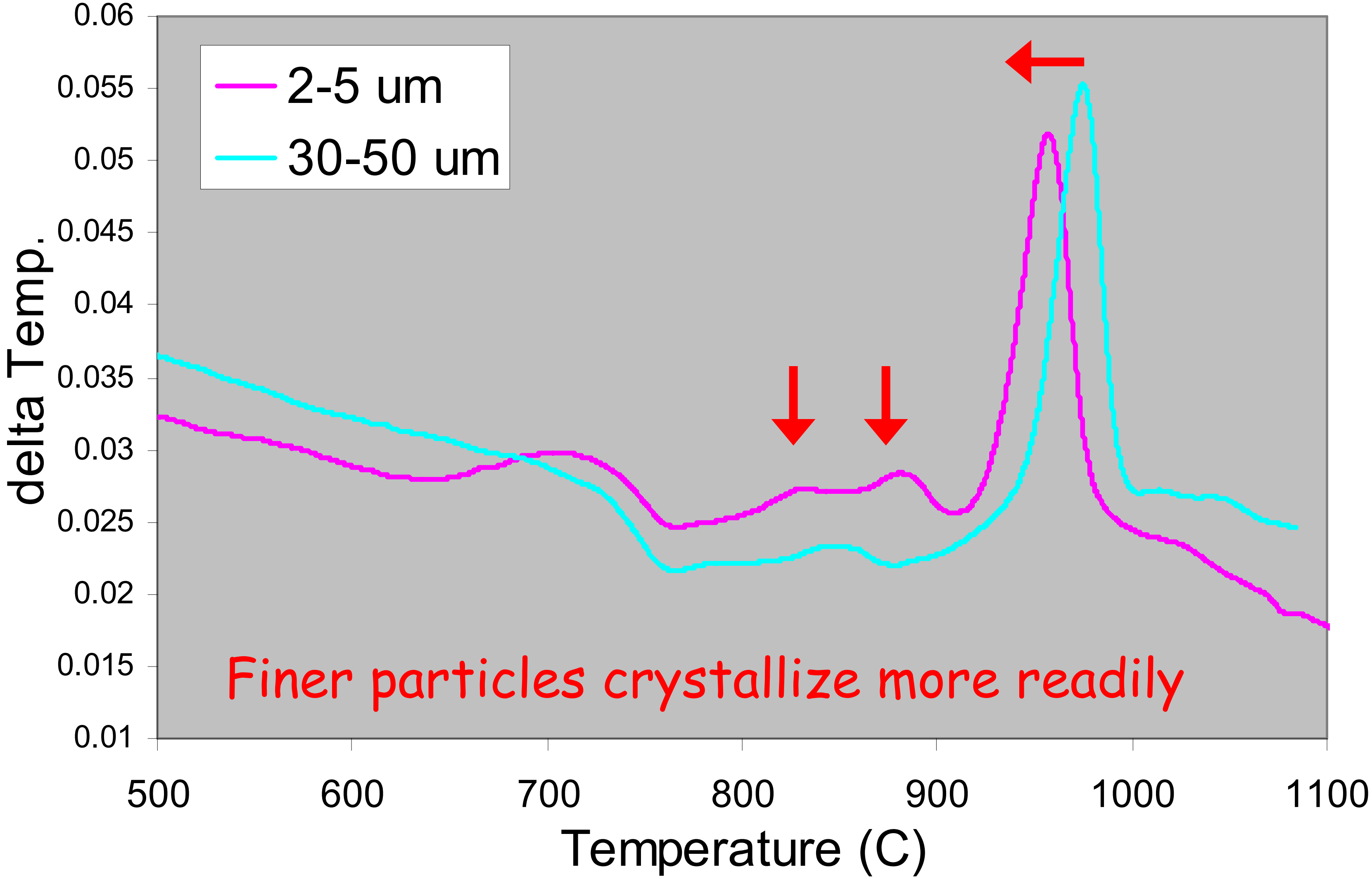
Initial Hermeticity Tests- Mixed Results



We use DTA to characterize processing effects on properties



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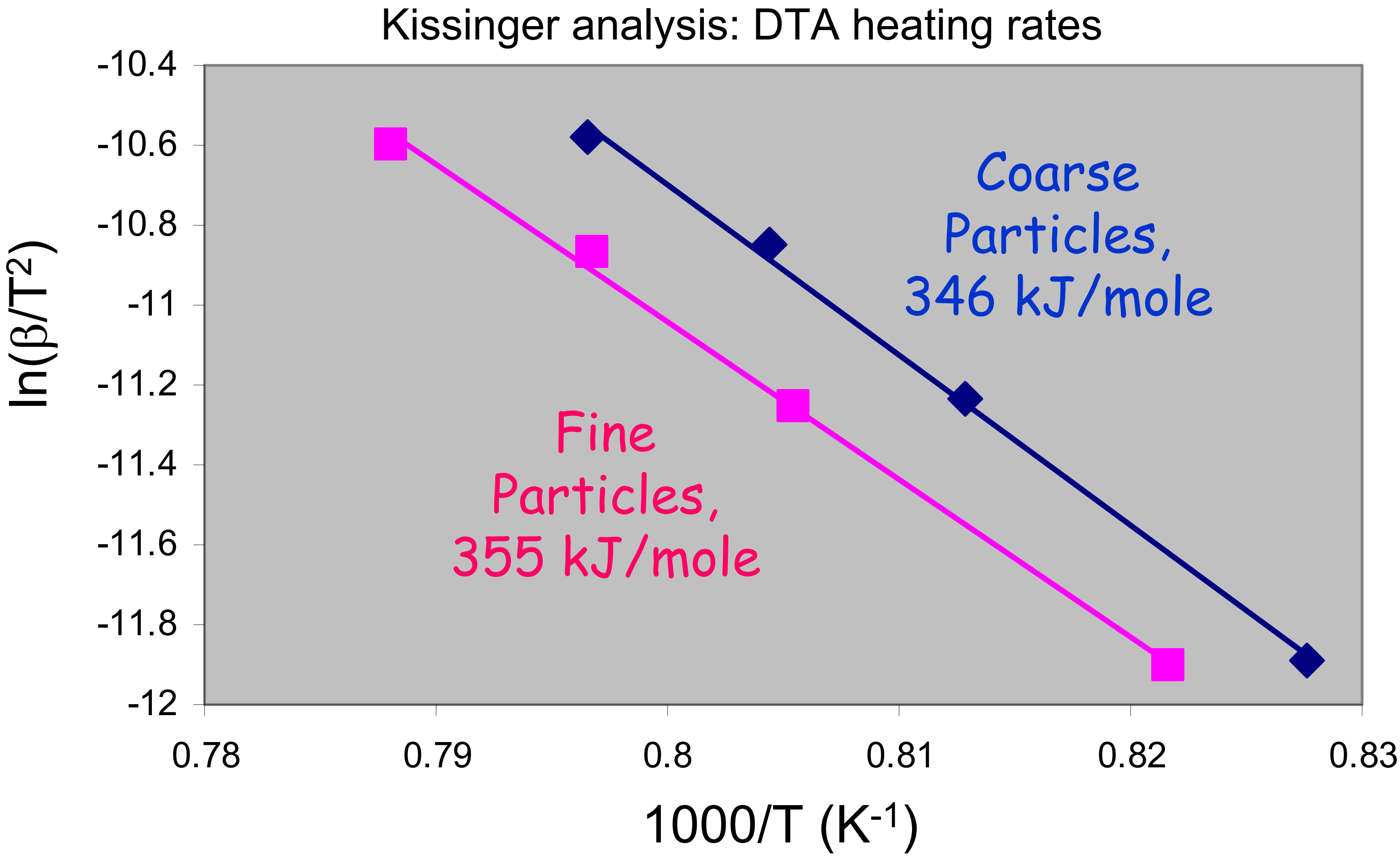
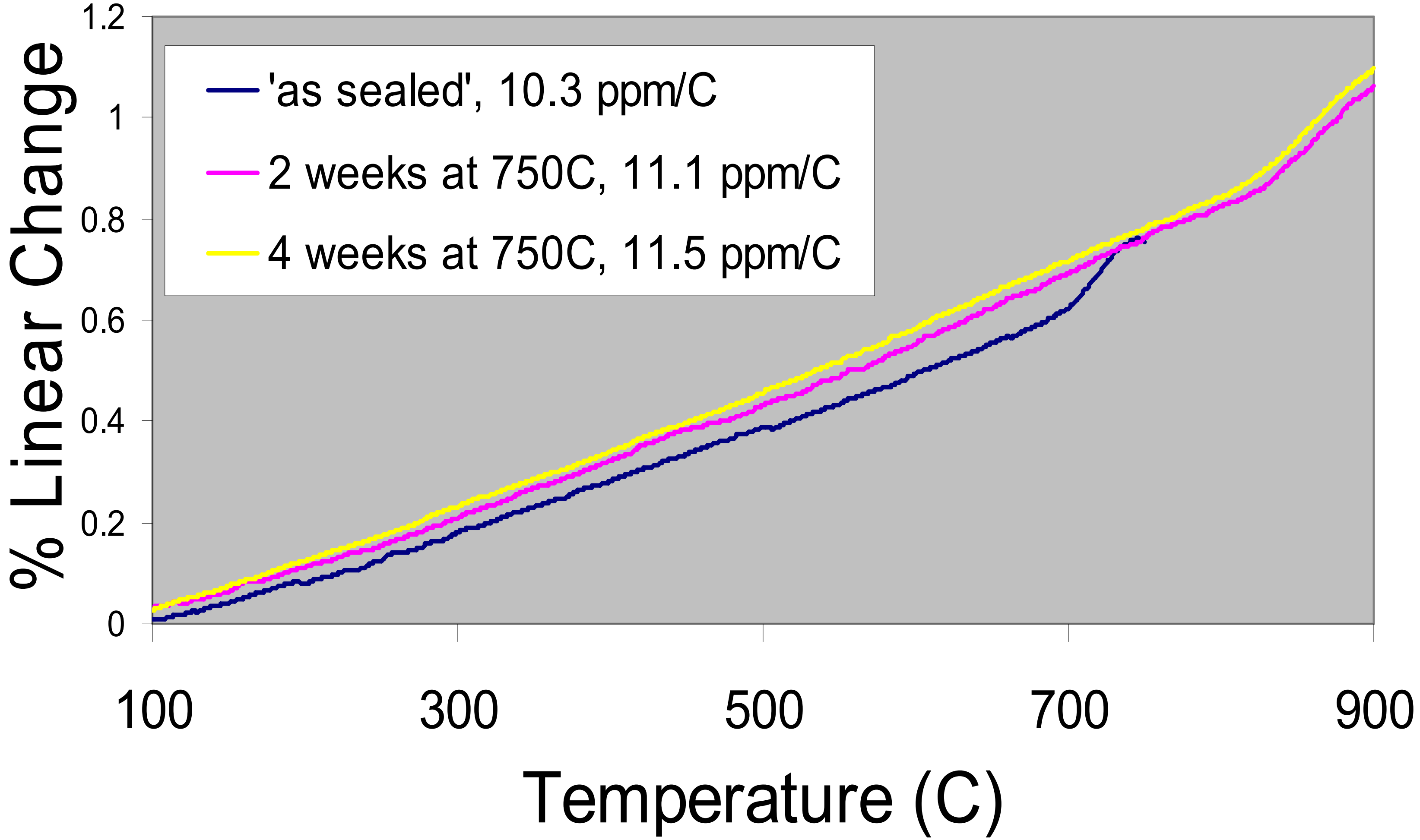
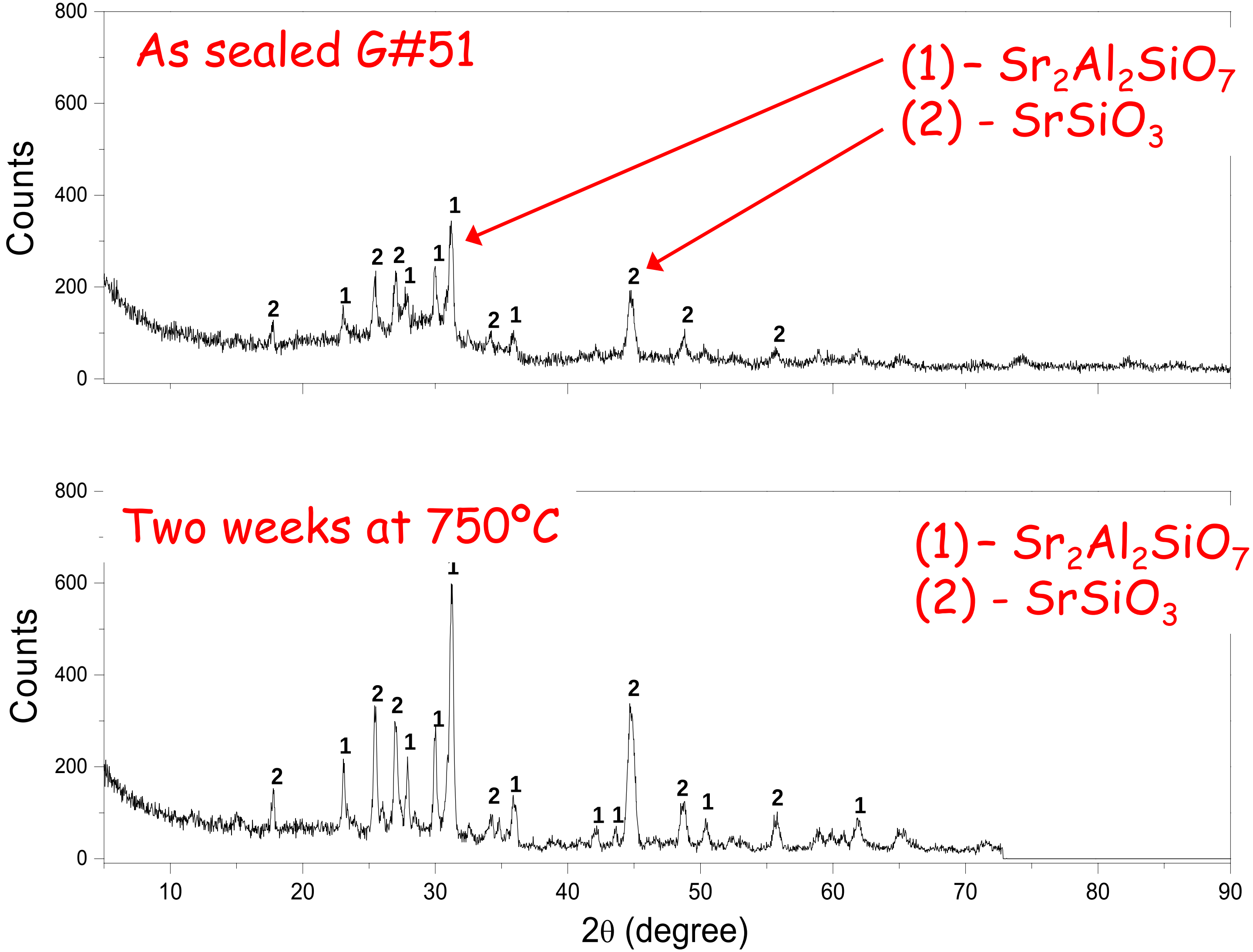


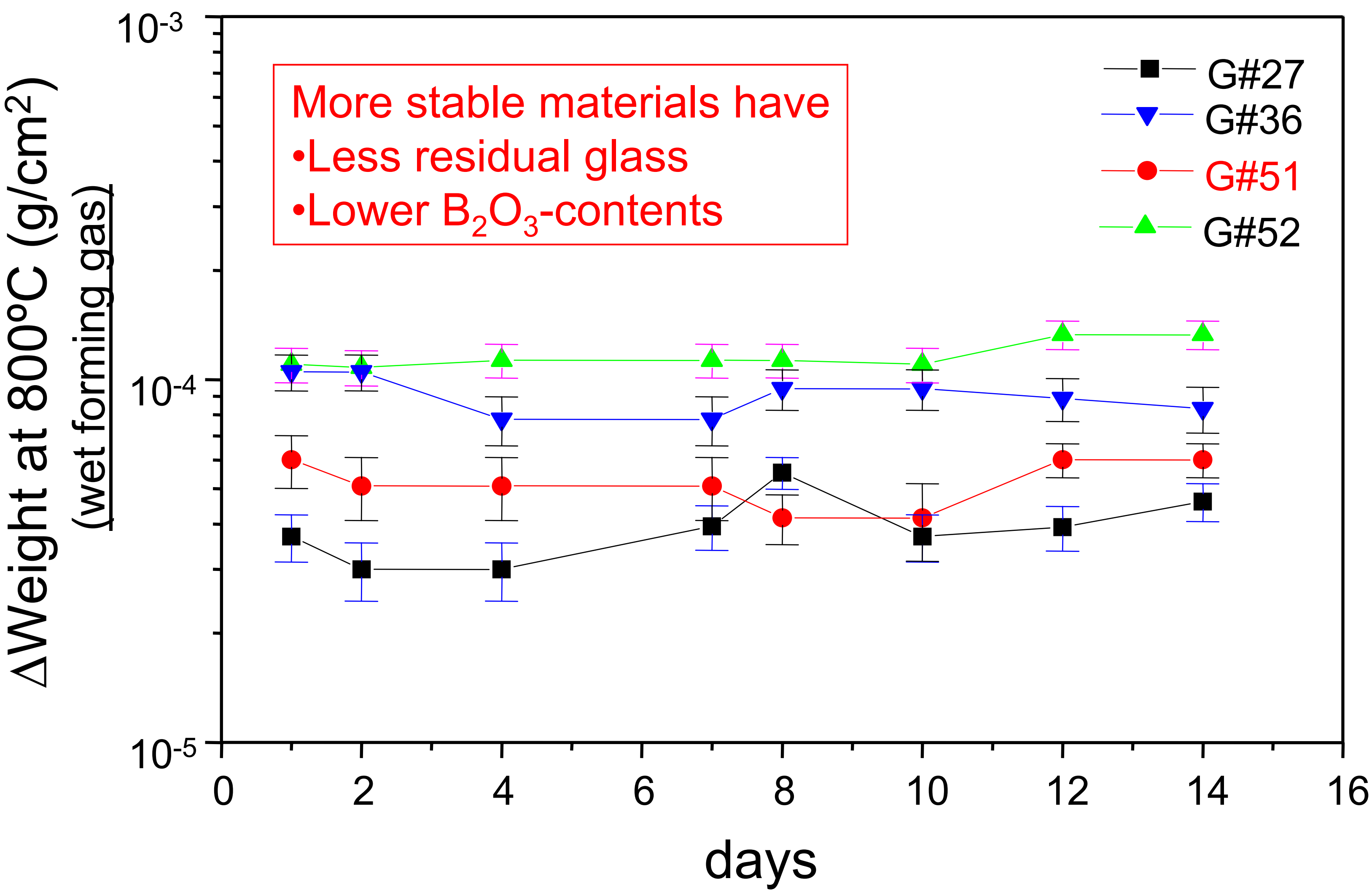
Glass#51 has promising dilatometric characteristics



Sr-silicate phases form on crystallization



Glass stability in wet forming gas (800°C)



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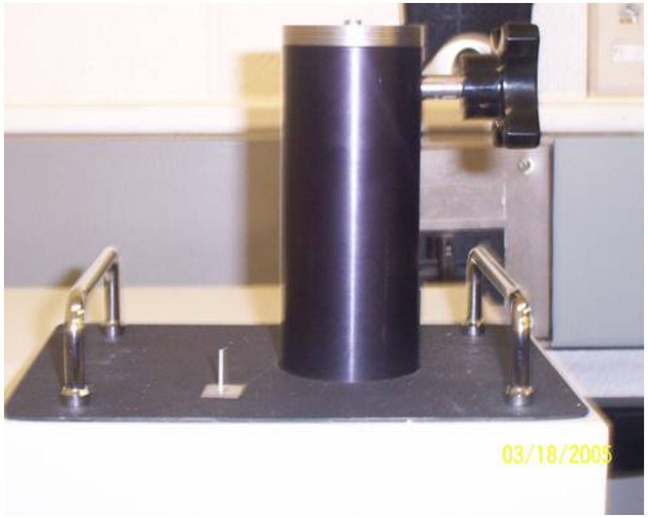
Glass-metal adhesion strength measured by pin-pull test



Romulus adhesion testing machine- Quad Group Inc.

~300μm glass coatings on interconnect substrates; 'as sealed' and after heat treatments

G51/430SS- 'as sealed'	20.9±6.9 MPa
G51/430SS- 750ºC/700hrs	20.7±10.2 MPa
G52/430SS- 'as sealed'	19.8±3.8 MPa
G52/430SS- 750ºC/700hrs	18.9±2.6 MPa

Sealing materials can be modified by adding fillers

- Tailor CTE
- Control crystallization
- Affect interfacial reactions
- Relieve thermal stresses
  - Controlled cracking in glass matrix; healing by viscous flow of residual glass
    - Design CTE and elastic mismatches

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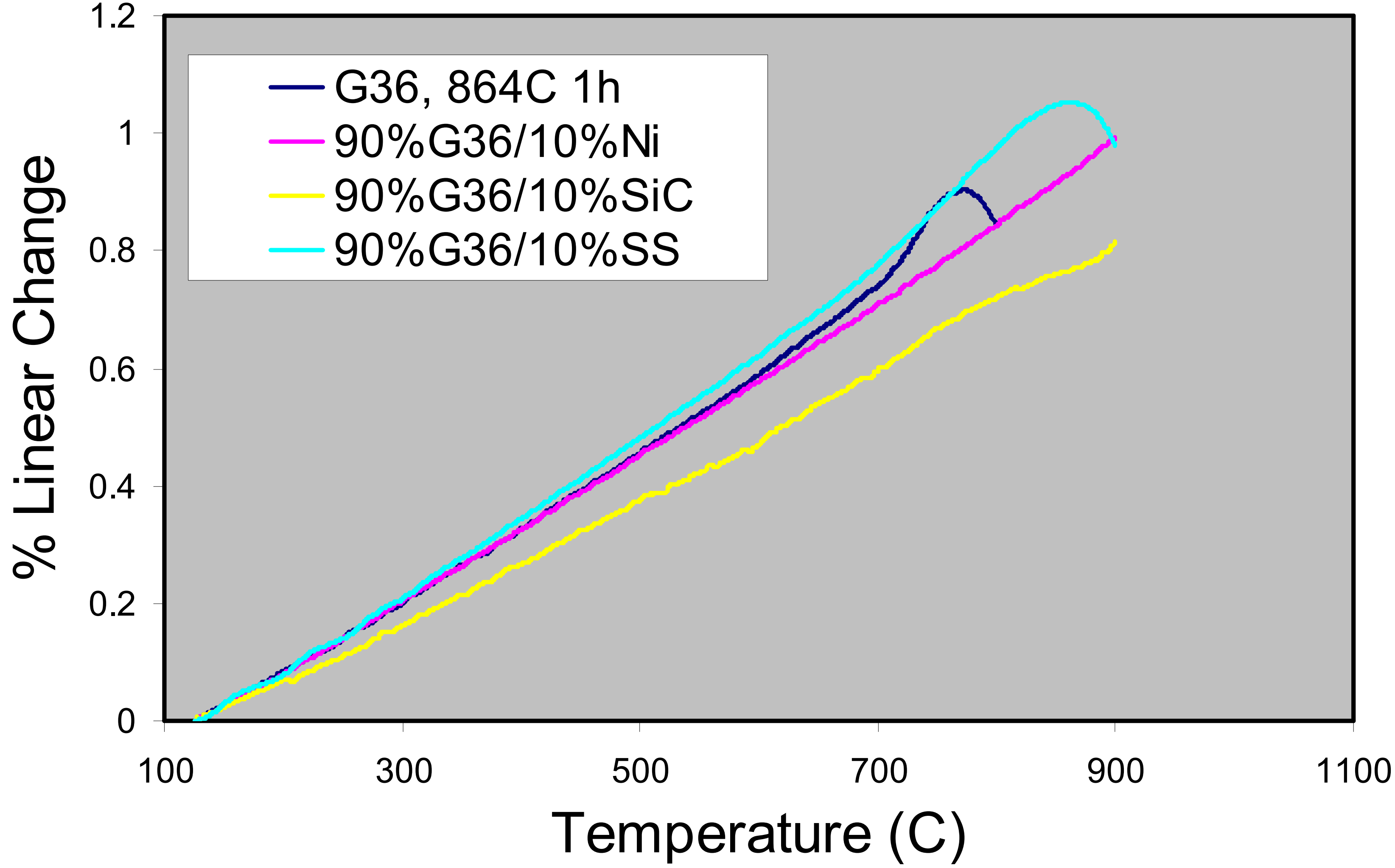
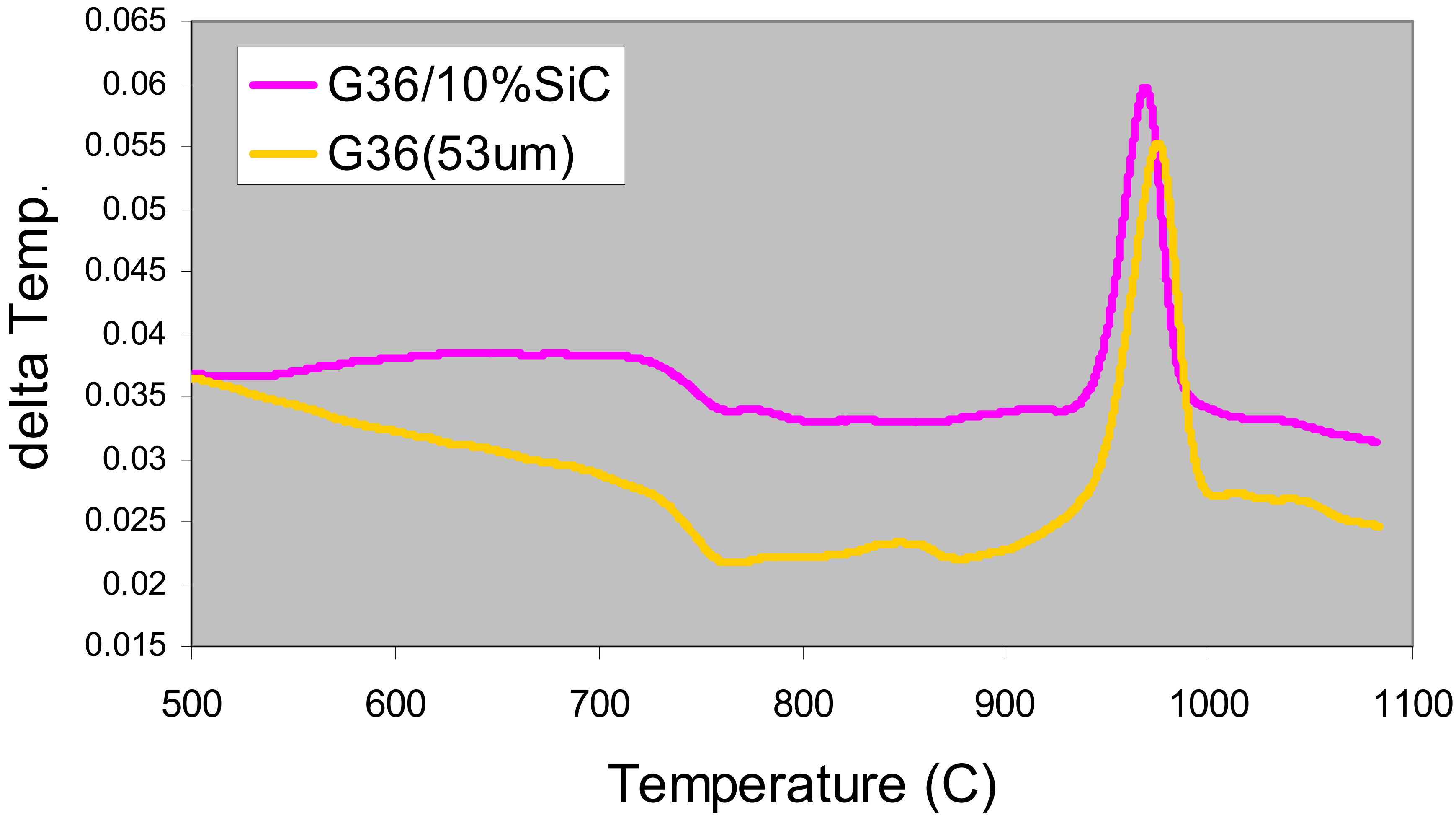
Composite Overview

Material	CTE (ppm/°C)	Elastic Modulus (GPa)	Notes
G36	12.1	80	
Ni	13.3	207	
Mo	5.1	324	
316SS	17	193	
Ti-Ni		34-83	Phase transition
WC	5.2	669	
SiC	4.3	483	
Quartz	7.0→13.3		Phase transition
ZrO_2	7.0→10.5	138-210	Phase transition

Dilatometric characteristics depend on filler



Composite crystallization behavior will be characterized by DTA



Experiments Underway

- Composite processing
  - Dense seals using tape-casting techniques
- Composite properties
  - Tailoring CTE
  - Induced cracking?
- Composite reactivity
  - Filler/matrix compatibility'
  - SOFC interfaces

SOFC Seal Summary

- SOFC seals offer an interesting materials challenge
- RO- polysilicate compositions have promising combinations of properties
  - Polysilicate glass-ceramics can be designed with thermal and chemical properties desired for some SOFC seal designs.
  - Thermo-chemical and thermo-mechanical stabilities are critical for long-term applications.
- Composite seals based on RO-polysilicate glasses
  - Reduce stresses due to thermal cycling?

Thank you for your attention!