HIGH TEMPERATURE SEALS FOR SOLID OXIDE FUEL CELLS (SOFC)

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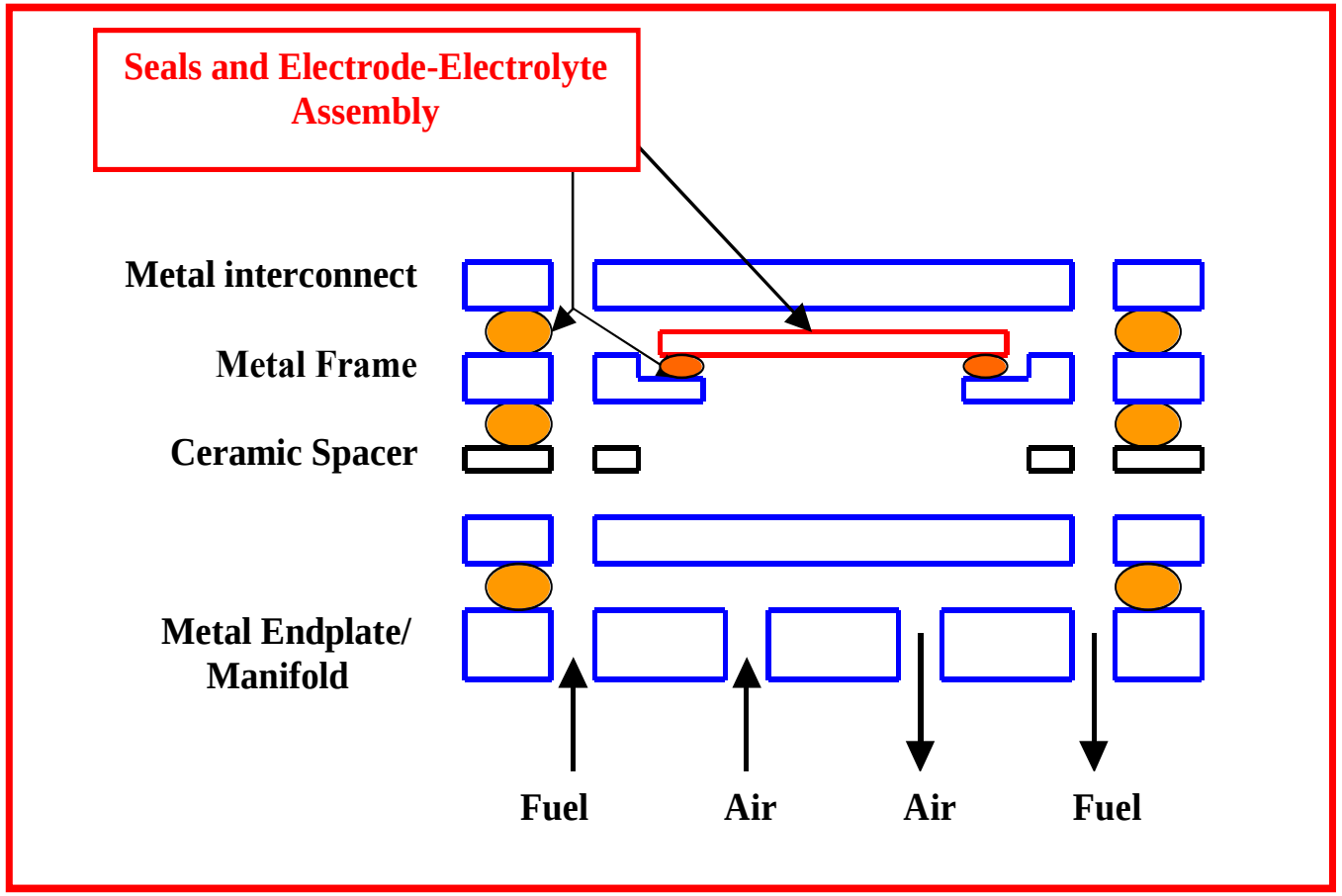
INTRODUCTION

- **SECA Requirements: Seals for SOFC**
  - ★ Electrochemical-insulating to avoid shorting
  - ★ Lowest possible thermomechanical stresses upon processing, during heatup, cooldown, and in steady state/transient operations
  - ★ Long life (5,000-40,000 h) under electrochemical and oxidizing/reducing environments at high temperatures ~600-850°C
  - ★ Low cost

- **Type of Seals**
  - ★ Ceramic-Ceramic (Electrolyte-Ceramic Insulator)
  - ★ Ceramic-Metal
  - ★ Metal-Metal
  - ★ Rigid and/or Compliant
  - ★ Chemical/Mechanical/Liquid

SEALS FOR PLANAR SOFC



- **Metal-Ceramic and Metal-Metal Seals Must Work at 650-850°C in Corrosive Environments of Fuel and Air**

MATERIALS FOR CELL COMPONENTS

- Electrolyte: YSZ, 10-30 µm, dense
- Anode: Ni-YSZ Cermet, 25-600 µm, porous
- Cathode: Doped La-Perovskite, 25-2000 µm, porous
- IC (Interconnect): Doped Chromites/Alloys, 30 µm -5 mils, dense
- Seals: Insulating Ceramics/Glasses, dense
- Manifolds: Heat Resistant Alloys

- Operating Temperature: 650-850°C
- Fuels: Reformed PNG, Propane, Diesel etc.

- **Highly incompatible materials require seals**

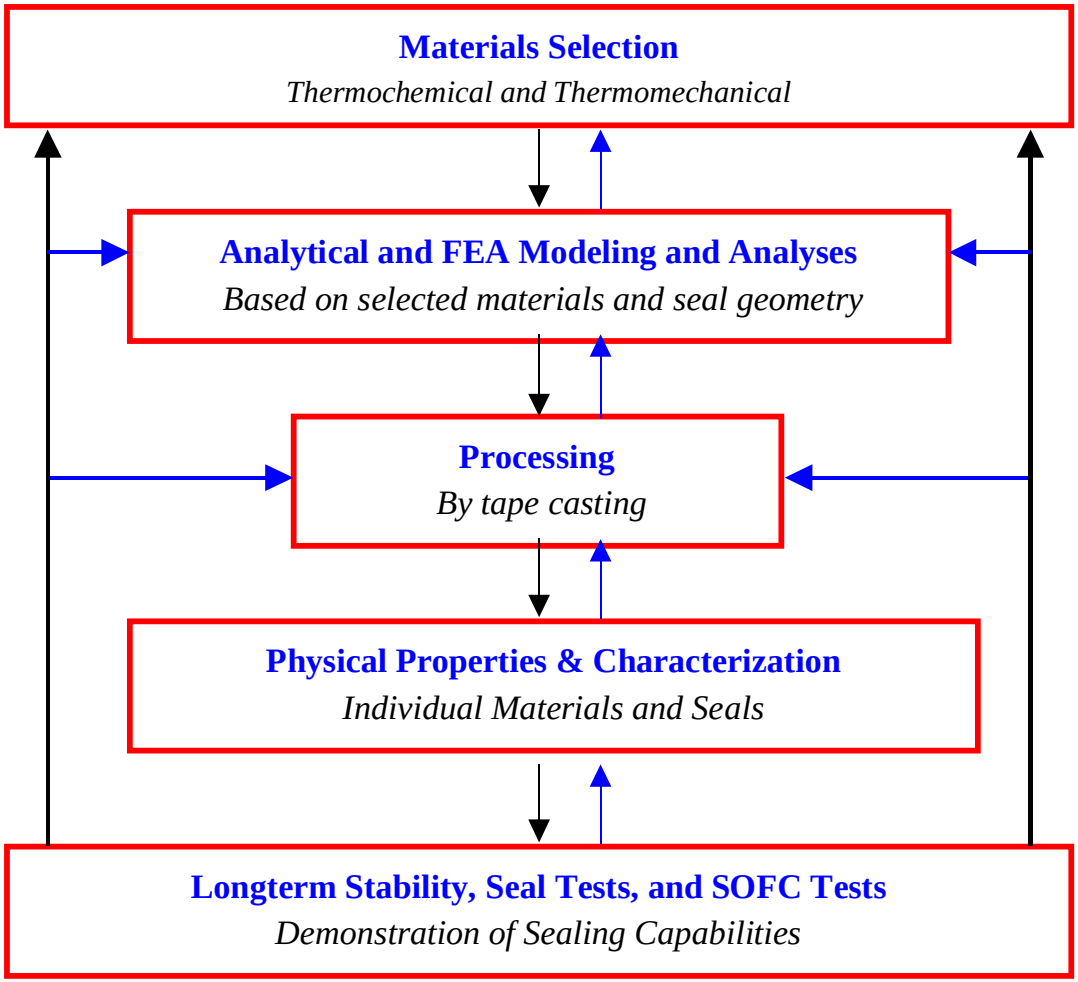
POSSIBLE APPROACHES TO SEALS FOR SOFC

- **Rigid Seals**
  - Glass-Metal, Ceramic Polymer-Ceramic/Metal, Brazes: require stable glasses, brazes, preceramic polymers
  - Low leak rates but susceptible to failures due to stresses
  - Feedback to materials and seal concept modifications to reduce stress buildup and avoid failure
- **Compliant Seals**
  - Bellows, Viscous Glass, Wet-Seals (MCFC): require flexible seal designs, stable glasses with appropriate viscosity over a range of temperature, wet-sealing materials and their containment
  - Moderate leak rate, some concepts may require pressure
- **Our Approaches for Seals**
  - Self-Healing Glass Seals
  - Reinforced-Glass Seals
  - Layered Composite Seals

PROJECT OBJECTIVES AND APPROACH

- **Develop Scientific Understanding and Viability of Sealing Concepts**
  - Self-healing glass seals
  - Reinforced-glass seals
- **Self-Healing Glass Seals**
  - Self-healing glasses can heal cracks generated during cell operation thereby enhance life and reliability of seals
  - Identify promising glasses, demonstrate self-healing behaviors in situ and by seals and leak check
- **Reinforced-Glass Seals**
  - A suitable reinforcement phase can enhance strength and toughness of self-healing glasses thereby enhancing reliability and life of seals
  - Identify suitable reinforcement phase and demonstrate strengthening and toughening by seals and leak tests

AN INTEGRATED APPROACH OF SEALS DEVELOPMENT FOR SOFC

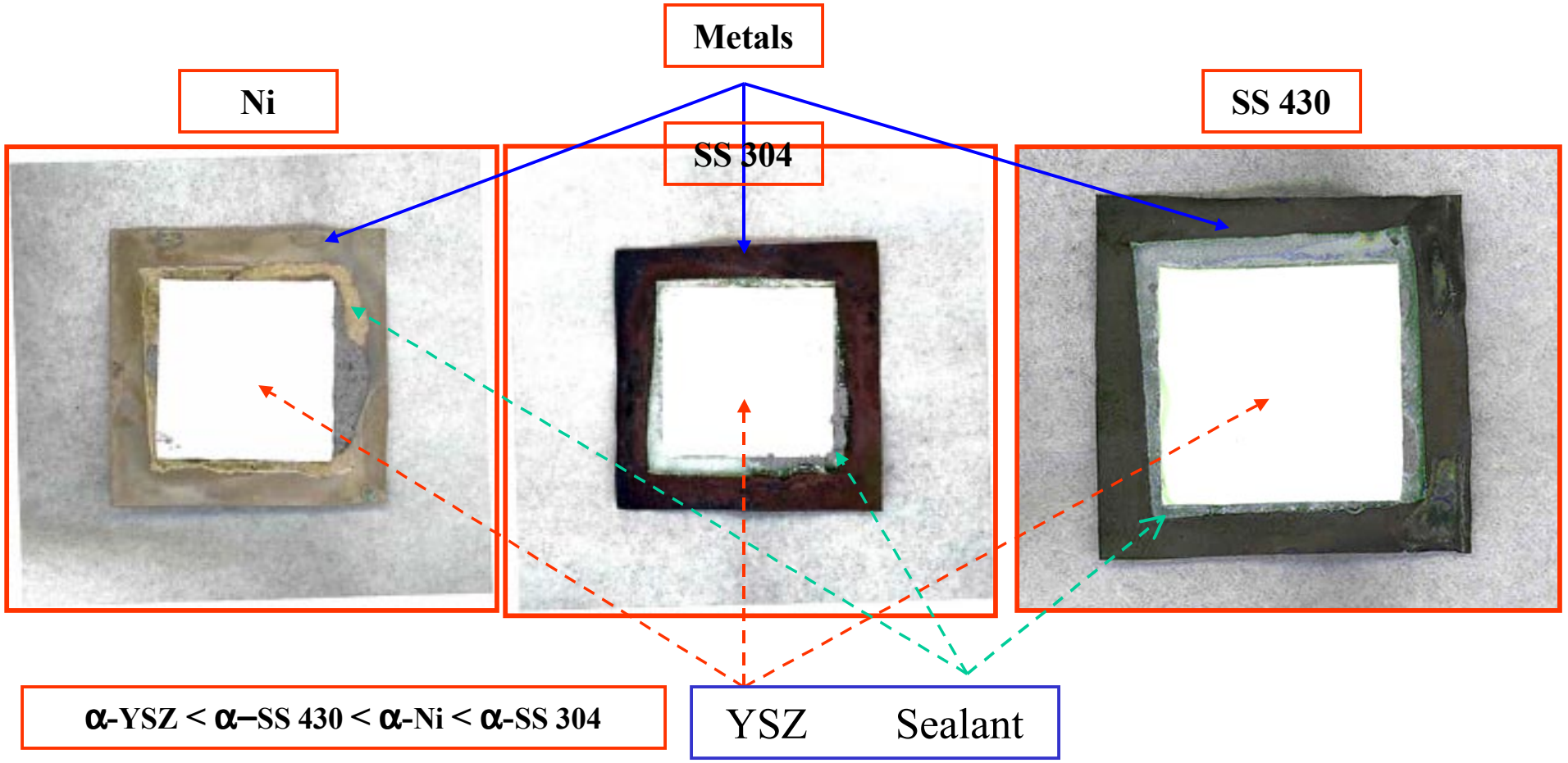


- **A successful seals development is very challenging**

SELF-HEALING GLASS DEVELOPMENT FOR SOFC

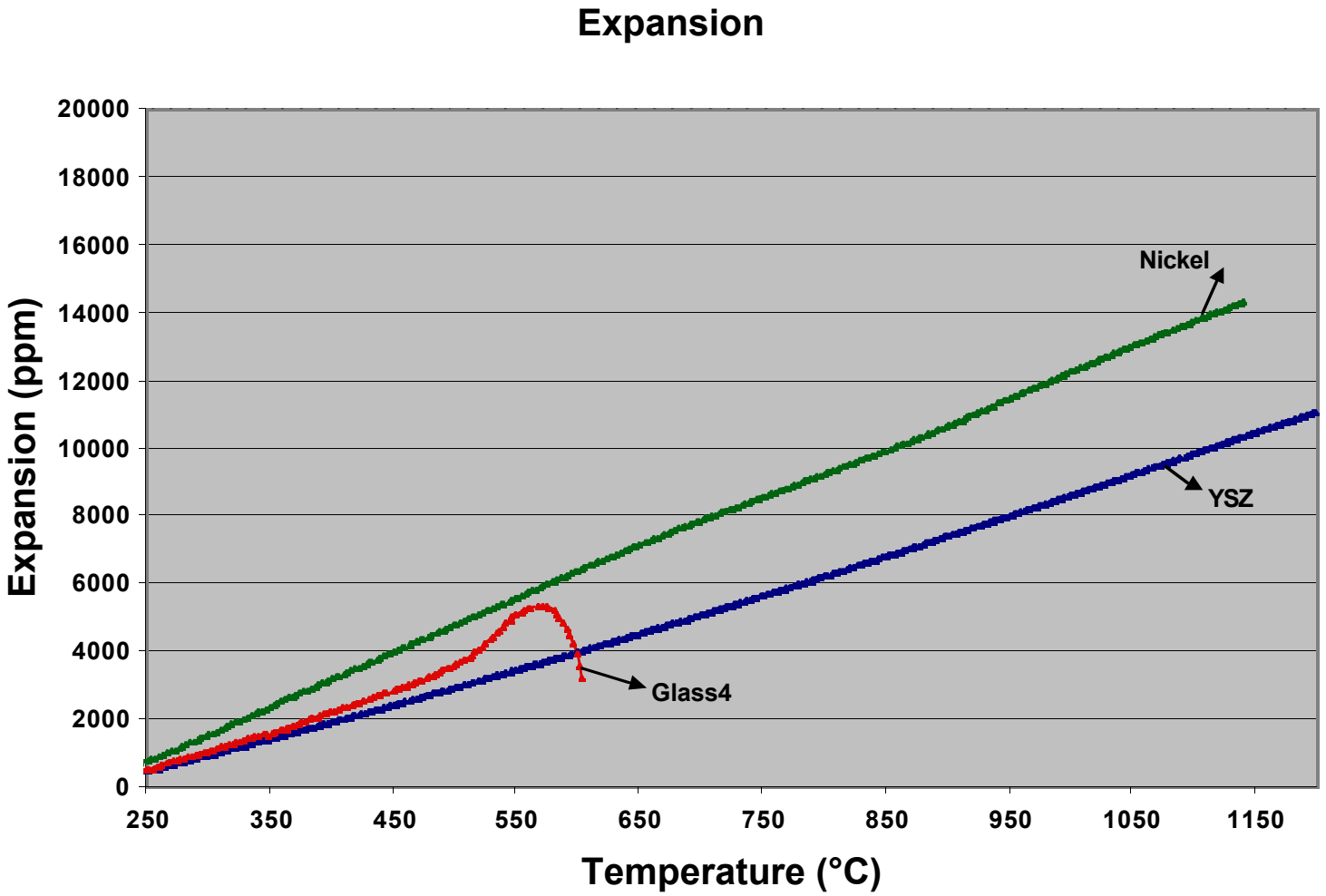
- **Rationale:** At the SOFC operating temperature a sealing glass of appropriate properties can heal cracks created during thermal transients.
- **Advantages:** Materials with dramatically different expansion can potentially be used for seals because at the cell operating temperatures induced thermomechanical stresses can be relaxed/reduced.
- **Challenges:** Select glasses that show potential for self-healing, remain stable for long-time, and maintain sealing capability.
- **Approach:** Thermophysical property measurements, in situ video imaging, and leak testing to identify/demonstrate self-healing glasses and seals.

DEMONSTRATION OF SEALS FOR SOFC BASED ON THE PROPOSED APPROACH



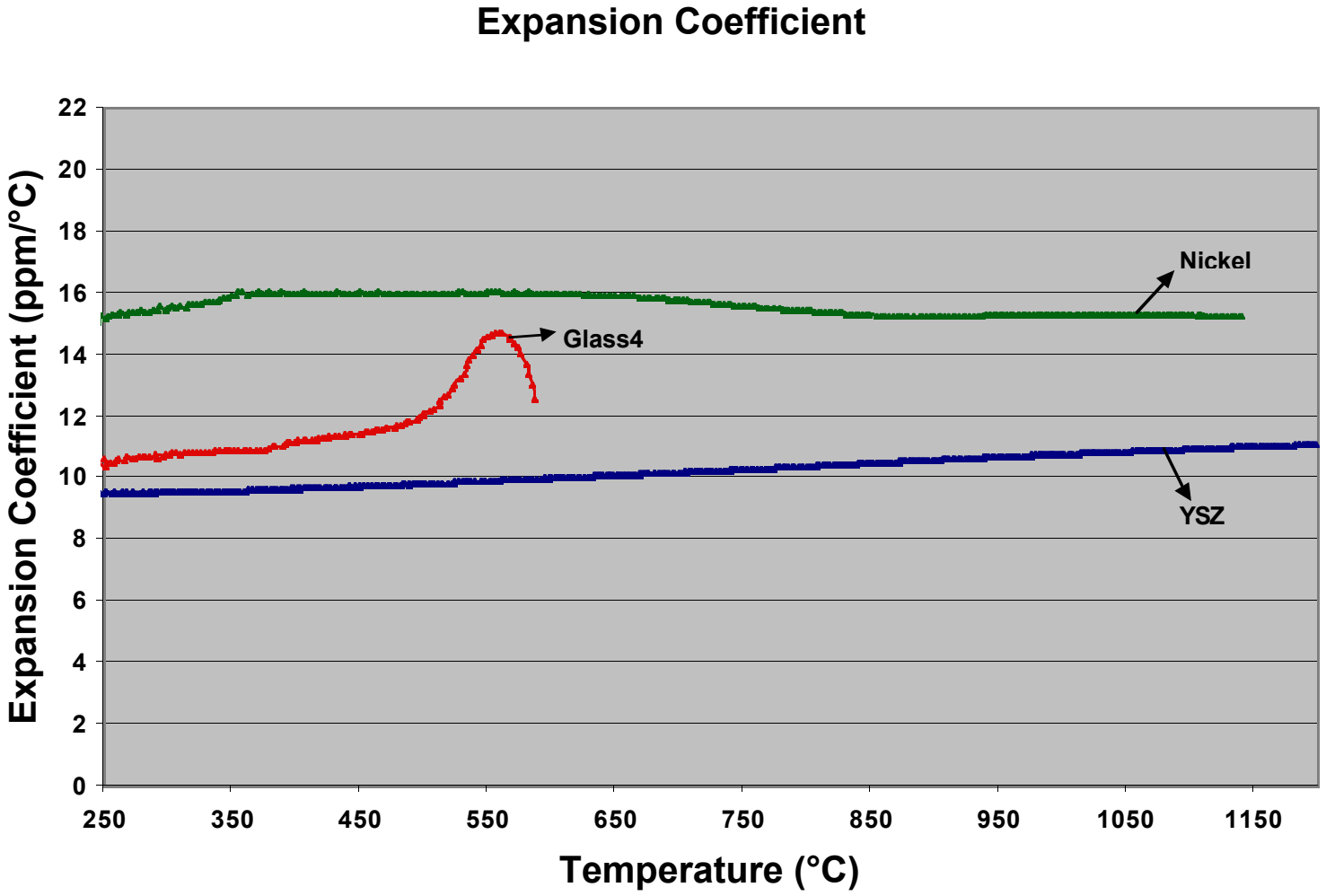
- **Materials with dramatically different expansion coefficients were sealed to YSZ**

DEMONSTRATION OF SEALS FOR SOFC BASED ON THE PROPOSED APPROACH



- Materials with dramatically different expansion

DEMONSTRATION OF SEALS FOR SOFC BASED ON THE PROPOSED APPROACH



- Materials with dramatically different expansion coefficients

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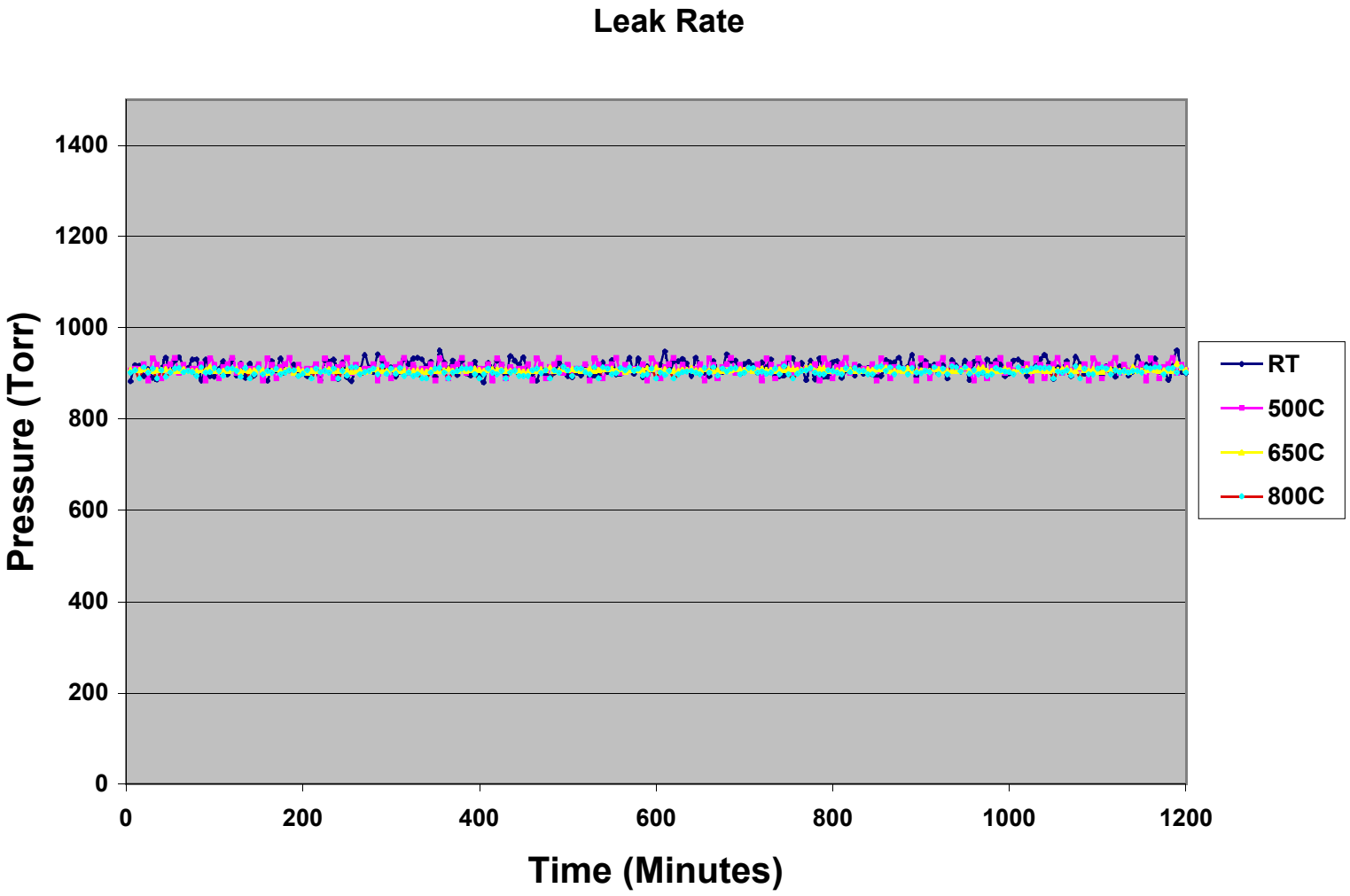
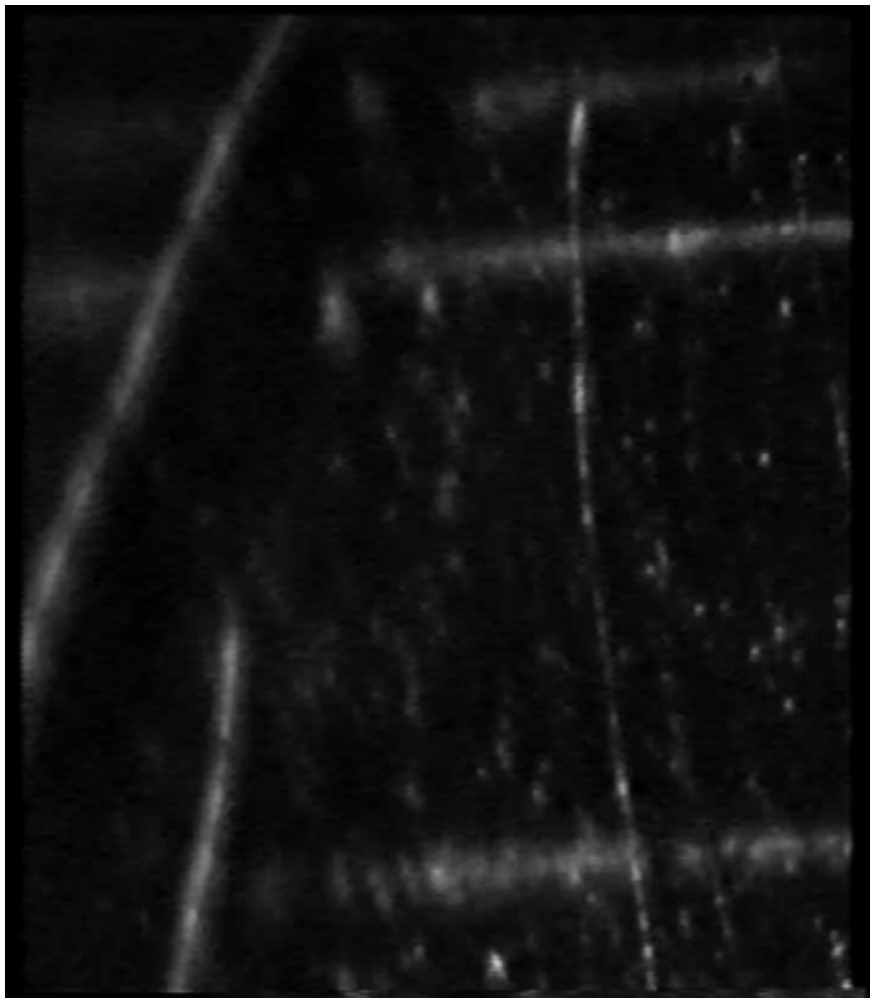


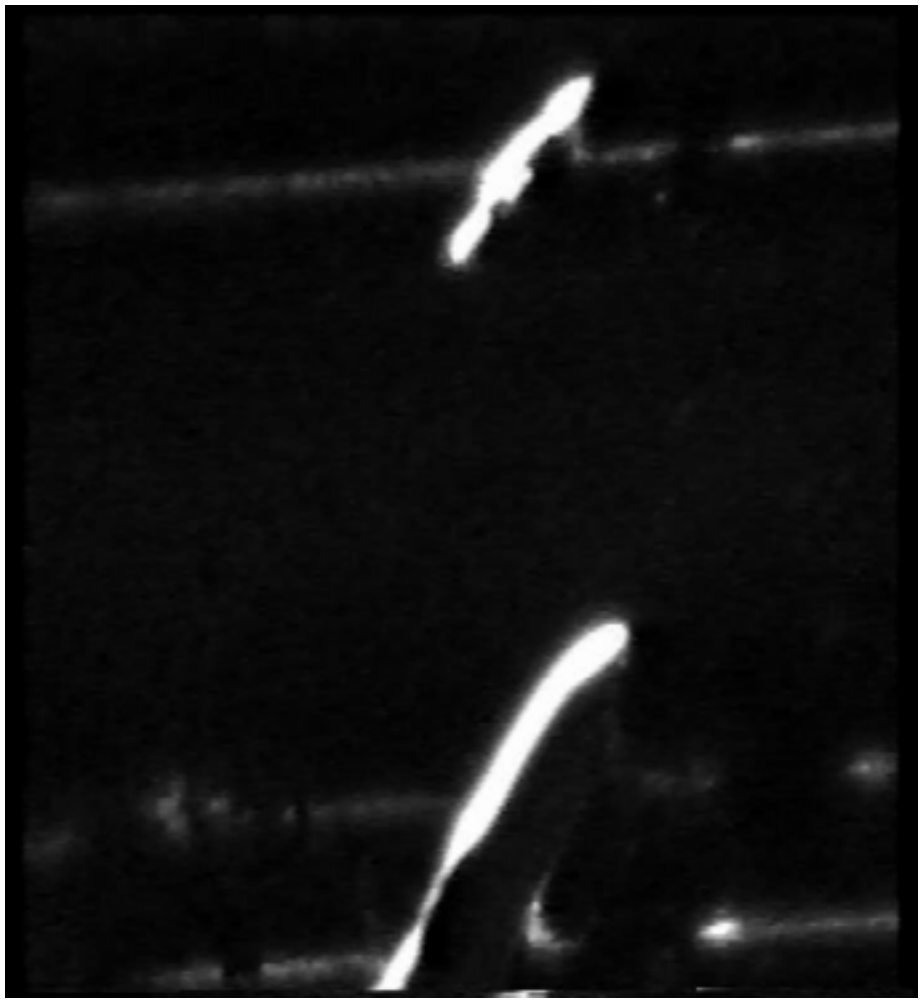
- Hermetic Metal-Glass-YSZ seals: survived thermal cycles

IN SITU CRACK HEALING BY A SEALING GLASS

VIDEO



Before Healing (25°C)



Healing (800^0C)

SUMMARY

- A generic approach utilizing analytical modeling, materials selection, optimum seal/cell geometry, novel sealing concepts, and environmental degradation testing is being used for fabricating durable seals for SOFC.

- A self-healing sealing concept is being developed for SOFC to provide active sealing during cell operation and satisfy significant thermochemical and thermomechanical incompatibilities among materials requiring hermetic seals.
  - ★ selected self-healing glasses
  - ★ measured properties of glasses
  - ★ demonstrated self-healing response
  - ★ fabricated seals using self-healing glasses
  - ★ measured performance by leak tests

- Preliminary leak test results demonstrated promise of the self-healing approach for forming hermetic seals for SOFC.

APPLICABILITY TO SOFC COMMERCIALIZATION AND FUTURE ACTIVITIES

- **Successful Demonstrations of Self-Healing and Reinforced Glass Seals are Expected to Enhance SOFC Reliability/Life, Performance, and Cost, and Help Industrial Teams in Making Cost-Effective SOFC Seals and Systems**

- **Future Activities/Plans**
  - **Demonstrate self-healing glasses- 3/05**
  - **Determine stability of self-healing glasses- 9/05**
  - **Reinforced-glass development- 1/06**
  - **Survey of commercial glasses suitable for seals- 3/06**

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