INNOVATIVE SELF HEALING SEALS FOR SOLID OXIDE FUEL CELLS (SOFCs)

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ABSTRACT

A variety of seals such as metal-metal, metal-ceramic, and ceramic-ceramic are required for a functioning SOFC. These seals must function at high temperatures between 600-900°C and in oxidizing and reducing environments of fuels and air for up to 40,000 hours. Among the different type of seals, the metal-ceramic and ceramic-ceramic seals require significant attention, research, and development because the brittle nature of ceramics and glasses can lead to fracture and loss of seal integrity and functionality. A new concept of self-repairing glass seals has been developed and used for making metal-glass-ceramic seals for application in solid oxide fuel cells (SOFC) in order to enhance reliability and life of cell. The performance of these seals under long-term exposure at higher temperatures coupled with thermal cycling is demonstrated by leak tests. Self-reparability of these glass seals has also been demonstrated by leak tests along with the long-term performance. In order to further enhance workability of the self-reparable seals, glass properties require modifications to avoid excessive flow. Towards this goal, the role of ceramic particulate reinforcement/fillers on the thermophysical properties of the self-healing glasses is investigated through measurements of expansion behavior, glass transition temperature, and stability in fuel and air environments typical of a SOFC. The results on glass-composites are presented and discussed in terms of the suitability of these seals in offering long-term and cost effective solutions to SOFC systems.

INTRODUCTION

- **Type of Seals**
  - Ceramic-Ceramic (Electrolyte-Ceramic Insulator)
  - Ceramic-Metal (YSZ-Ferritic Steel)
  - Metal-Metal
  - Rigid and/or Compliant
  - Chemical/Mechanical/Liquid
- **Requirements of Seals for SOFC**
  - Electrochemical-insulating to avoid shorting
  - Lowest possible thermomechanical stresses upon processing, during heat up, cool down, and in steady state/transient operations
  - Long life (40,000h) under electrochemical and oxidizing/ reducing environments at high temperatures ~600-850°C
  - Low cost

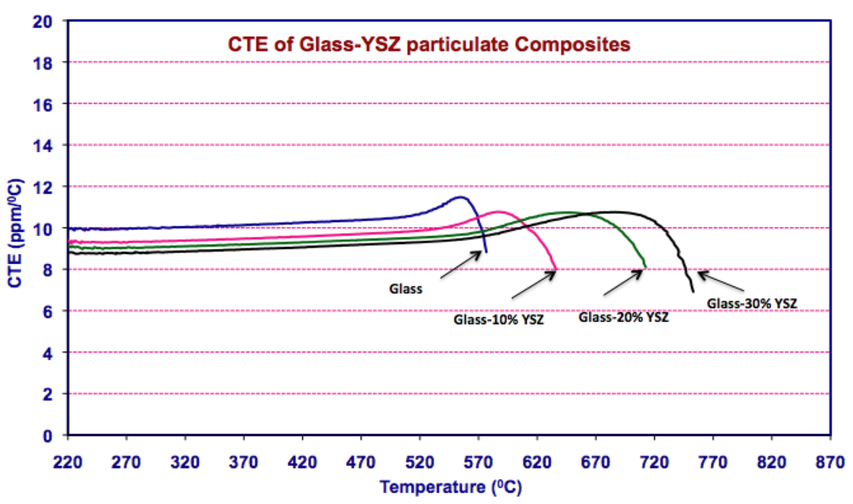
A SELF-HEALING/REPARABLE SEALING CONCEPT FOR SOFC

- **Rationale:** A glass of appropriate characteristics can self-heal the cracks created upon thermal cycling and/or stresses created during SOFC operation
- **Advantages:** The leaks developed upon SOFC operation and thermal cycling can be repaired in situ by the self-healing concept
- **Challenges:** Develop appropriate glasses which satisfy thermomechanical and thermochemical compatibilities, remain stable for long-time against crystallization, and maintain self-healing/reparability capability
- **Approach:** Thermophysical and thermochemical property measurements and glass optimization, self-healing ability, and leak testing to demonstrate self-healing/reparable seals

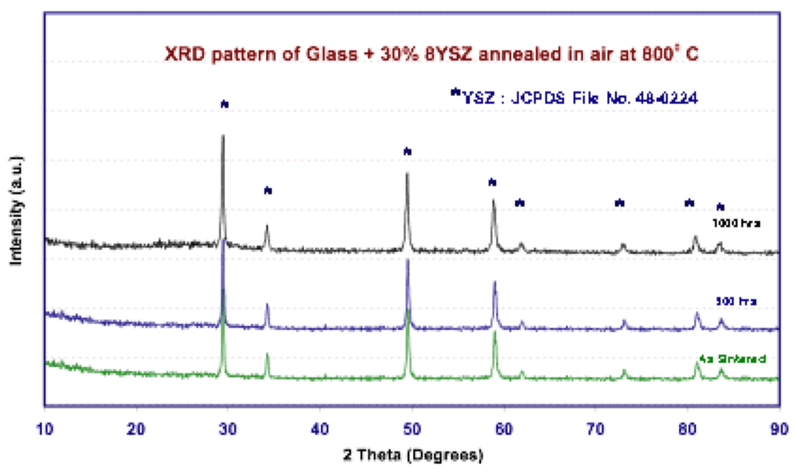
CURRENT PROGRAM OBJECTIVES AND ACCOMPLISHMENTS

- **Phase-I: Objectives (October 2009-March 2011)**
  - Demonstrate control of self-healing glass flow via addition of fillers for use as seals for SOFCs
  - Develop self-healing glass-composites containing fillers for functionality as seals for SOFCs
  - Select appropriate filler materials suitable for making glass-composites
  - Characterize thermomechanical properties of glass-composites
  - Measure stability of the self-healing glass-composites in SOFC environments
  - Assess stability of the glass-composites in contact with YSZ
- **Accomplishments**
  - Selected Alumina, Magnesia, and YSZ as fillers for making glass-composites
  - Measured thermomechanical properties of glass-composites
  - Demonstrated response of self-healing glass-composites over a range of temperatures between 25-800°C and identified promising filler materials
  - Down-selected YSZ filler for making promising glass-composites and assessed stability of glass-YSZ composites in SOFC environments for 1000h
  - These results provide great promise towards meeting SECA goals of seals for SOFC

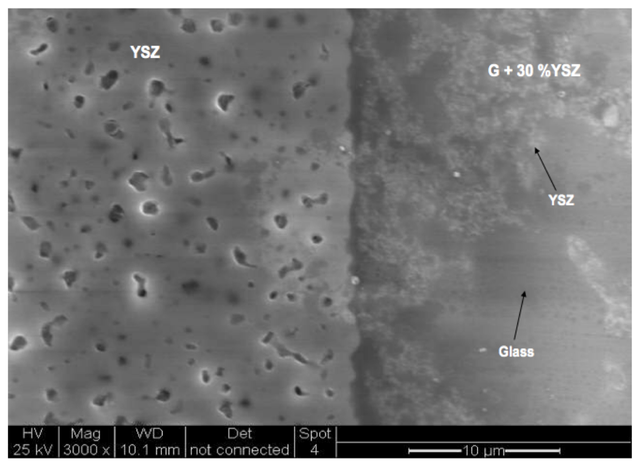
CTE OF GLASS-YSZ COMPOSITE



STABILITY OF GLASS-YSZ COMPOSITE



INTERFACE STABILITY OF GLASS-YSZ COMPOSITE



No reaction of glass with YSZ upon annealing at 800°C

SUMMARY

- A self-healing sealing concept is further advanced for SOFC to find suitable filler materials to avoid excessive flow of the sealant
- Thermomechanical behavior and stability of glass-composites with Al_2O_3, MgO, and YSZ fillers was assessed up to 800°C
- YSZ is a promising filler material. Stability demonstrated for 1000 hours
- Future Work: Long-term stability studies

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