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Publication date:
2013

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Citation (APA):

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Bonding characteristics of glass seal/metallic interconnect for SOFC applications: Comparative study on chemical and mechanical properties of the interface

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Introduction:
Glass and glass-ceramics have been extensively used as seal material in planar solid oxide fuel cell (SOFC) stack. The main objective of the present work was to investigate the bonding properties of a silica-based glass-ceramic as seal material with two different ferritic stainless alloys as interconnect, i.e. SS430 and Crofer 22APU.

A straight-forward approach to evaluate sealing material, sandwiched samples will allow interfacial strength measurements and macroscopic overview on the interfacial situation of a glass-ceramic material. A convenient method for determining the interfacial fracture energies is double cantilever beam (DCB) test. The method allows to measure the crack-growth resistance of these materials to be used for fracture mechanics design methods. Stable crack growth is necessary to get reliable and unambiguous fracture toughness data. If the fracture toughness values are determined from test configurations that do not allow stable crack growth, then the measurement may be related more to crack initiation than crack growth. In such cases, the calculated value of the fracture toughness may depend on the geometry of the machined notch.

Tasks:
- A glass was synthesized with the nominal composition of 30-50 mole%SiO2, 0-10 mole%Li2O, 5-15 mole%Al2O3, 25-50 mole%SrO, 0-25 mole%MgO, and 3 mole%CaO.
- Joint samples of metal/glass/metal were prepared at 850°C for 0.5 h under air and then cooled down to 800°C and aged for 100h.
- Chemical characterization was conducted on glass-metal interfaces by SEM+EDS.
- Mechanical characterization was conducted by double cantilever beam (DCB) and nano-indentation testing (NIT) methods.

Aim:
- Correlating between chemical and mechanical properties of seal/interconnect interfaces is the main topic of this research.

Fabrication of large sandwich samples of metal/glass/metal for macro-mechanical testing

Sandwich samples are joined and aged at 800°C in the furnace and glued between two steel beams.

DCB testing

Fracture toughness for crack initiation was measured with a very good reproducibility.

Fabrication of small sandwich samples of metal/glass/metal for nano-mechanical testing

The XRD peaks revealed the main crystalline compounds formed from the bulk glass are Ca4Y6O(SiO4)6, Y2Si2O7, SrAl2Si2O8, CaSiO3, (Ca-Sr)-orthosilicate, and a-SiO2.

Additional compound characterized at the interface of fractured samples, as interphasites, include: Mo6Y3O14, Ca2Mo9O27, Sr4Mo9O27, BaMo9O27, BaMo9O35.

Typical microstructures of Metal/Glass-ceramic joints after aging for 100h in air at 600°C: low (left), high magnification (right).

Thermal properties of the sealing glass

Typical measured load-opening displacement (P–Ø) curve and fracture energy-displacement (G–Ø) for a precracked glass-ceramic/Crofer22APU sandwiched sample.

Fracture toughness of joint samples:

From the critical energy release rate, GIC under elastic conditions, the critical plane-stress Mode I stress intensity factor can be evaluated by [4]:

$$
G_{IC} = \frac{K^2}{E(1-\nu^2)}
$$

Data of ref. [3] are for bimetallic bonded specimens to determine the interfacial fracture energies and toughness of glass-ceramic sealants in planar SOFCs, corresponded to a given mode mixity, and the a-determined fracture energies and toughness values are related to the materials used and the mode mixity realized. Changing the loading configuration or spectrum type will affect the mode mixity value, and, as a consequence, the fracture energy and toughness will change.

Summary:
- A technique for evaluating the critical energy-release rate/fracture toughness of this glass-ceramic layer and stainless-steel metal strips is described.
- The approach involves a new specimen geometry, in which a sandwich sample is glued onto thicker steel beams.
- The advantages of the technique, stable crack growth, allows fracture energy and toughness of a desired joint materials to be evaluated.
- The fracture toughness for crack initiation was measured with a very good reproducibility.

Acknowledgements:
The authors are thankful to Iranian Ministry of Science and (DTU)-Department of Energy Conversion and Storage for providing the financial support of this study. Also to Prof. Henrik Feddersen (Aarhus University) for nano-indentation measurements.

References: