Effect of ZrO_2 and Y_2O_3 on glass-ceramics as sealing materials

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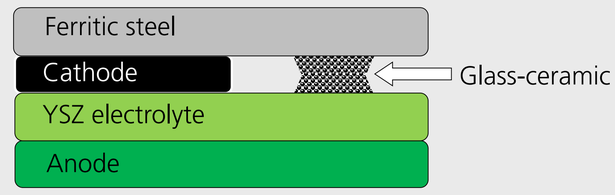
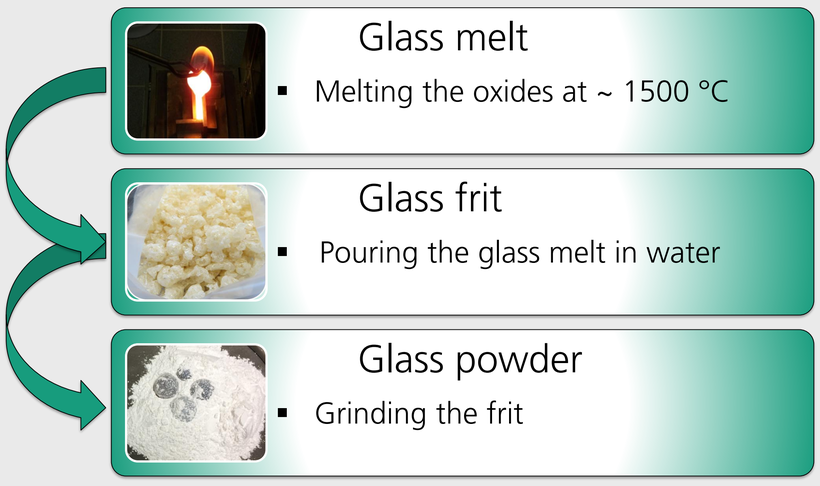
Introduction

Crystallizing glasses are currently the most promising materials as sealants between ferritic steel interconnect and YSZ electrolyte in solid oxide fuel cells (SOFC). The advantages of glass-ceramics compared to amorphous glasses or metal alloys in this application are their high temperature resistance, adjustable CTE, high viscosity under operating conditions and resistance against oxidizing and reducing environments [1]. During the sealing process the electrolyte can be attacked by the viscous glass building melt. The addition of ZrO_2 and Y_2O_3 to the starting composition of the glasses is intended to prevent leaching and dissolution of the YSZ electrolyte, which would result in failure of the fuel cell [2]. By comparing two glass compositions with and without ZrO_2 and Y_2O_3 the interfacial reactions between glass-ceramics and YSZ electrolyte material will be investigated in detail.

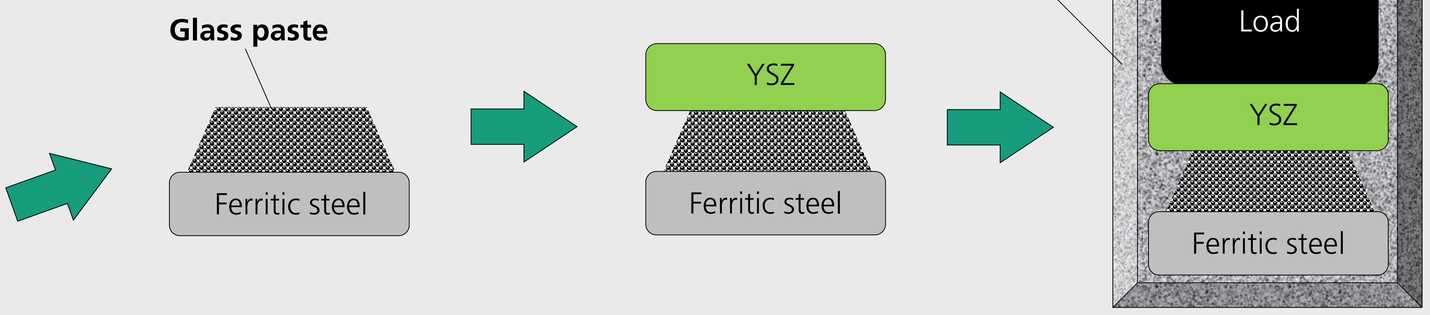


Schematical structure of an SOFC and location of the glass-ceramic sealant.

Production of the glass-ceramic seal

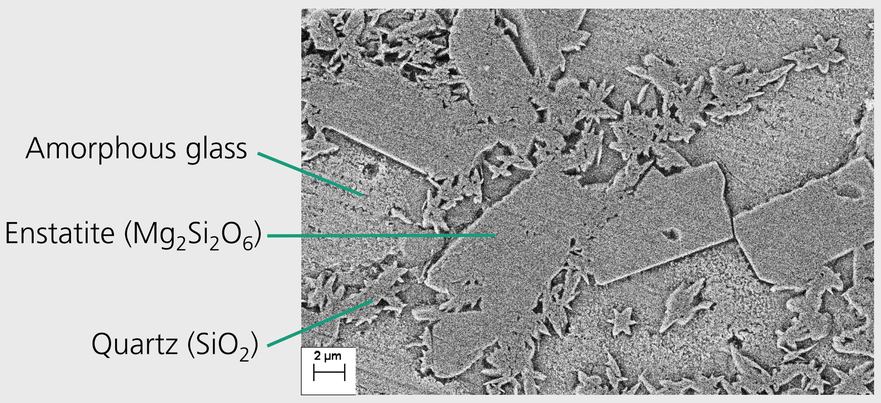


- Dispersing glass powder to form a paste
- Applying glass paste to ferritic steel by scraper or screen printing
- Placing YSZ electrolyte plate on top to form a sandwiched sample
- Placing sandwich in a furnace with applied load
- Crystallizing and ageing the glasses at 800 - 900 °C



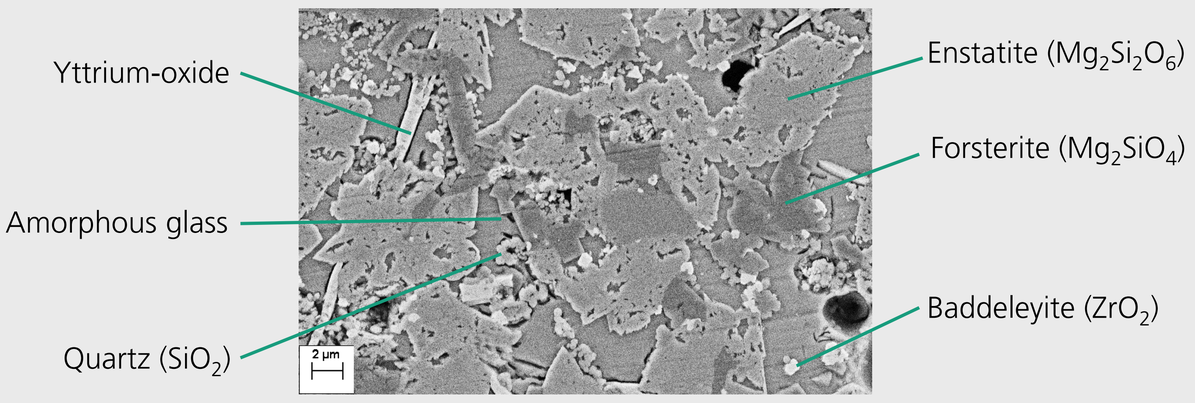
Microstructure of the glass-ceramics after ageing for 100 h at ~ 850 °C

Glass-ceramic 1 without ZrO_2 and Y_2O_3



SEM-image of glass-ceramic 1 (without ZrO_2 and Y_2O_3).

Glass-ceramic 2 containing ZrO_2 and Y_2O_3

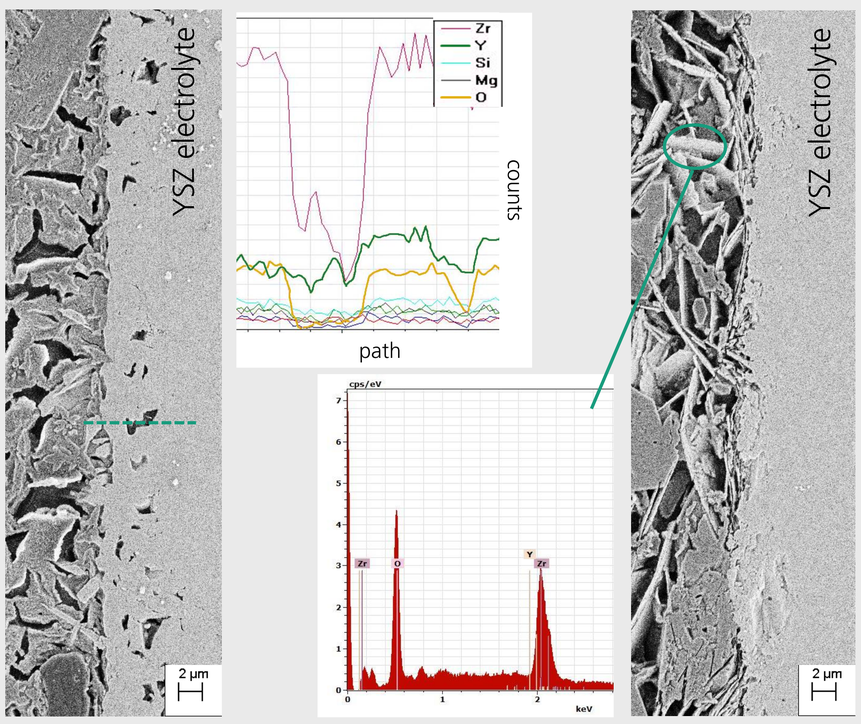


SEM-image of glass-ceramic 2 (with 2 mole% ZrO_2 and 2 mole% Y_2O_3).

Interface between glass-ceramic and YSZ electrolyte after 100 h of ageing at ~ 850 °C

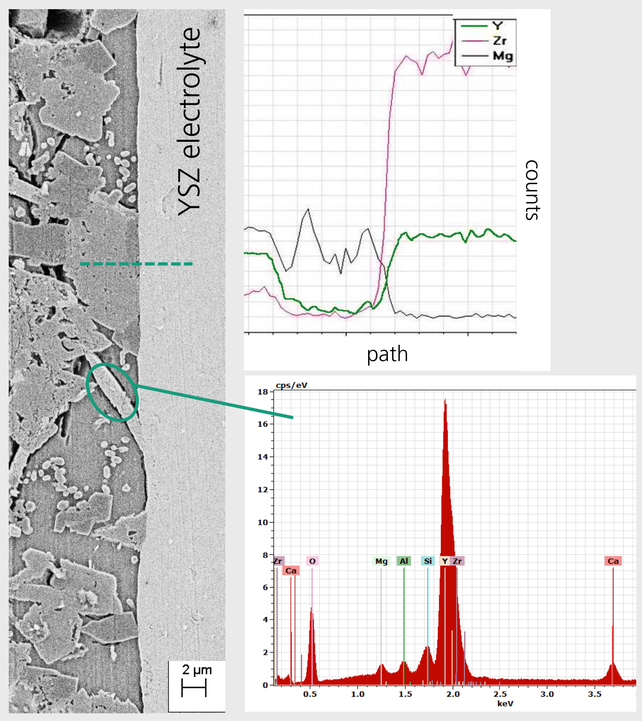
Glass-ceramic 1 without ZrO_2 and Y_2O_3

SEM-image of the interface between glass-ceramic 1 (without ZrO_2 and Y_2O_3) and YSZ electrolyte. Formation of holes within the electrolyte due to leaching. Also delamination can occur. EDS-linescan between glass-ceramic 1 and YSZ electrolyte, EDS-analysis of delaminated electrolyte.



Glass-ceramic 2 containing ZrO_2 and Y_2O_3

SEM-image of the interface between glass-ceramic 2 (with 2 mole% ZrO_2 and Y_2O_3) and YSZ electrolyte. No delamination or leaching effects detectable. Electrolyte forms a smooth interface with the glass-ceramic. EDS-linescan between glass-ceramic 2 and YSZ electrolyte, EDS-analysis of yttrium-oxide crystal.



Summary

Glass-ceramics are a suitable material for joining the ferritic steel interconnect to the YSZ electrolyte in SOFCs. The investigated glass-ceramics consist of several crystalline phases and an amorphous phase. Even though ZrO_2 and Y_2O_3 are incorporated into crystals, especially after 100 hours of ageing of the sealant, the addition of those oxides to the initial composition of the sealing glass helps to prevent leaching and delamination of the electrolyte.

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References:
[1] B. Cela Greven, Glass-ceramic sealant reinforcement for high-temperature applications, Forschungszentrum Jülich, Jülich, 2015.
[2] Y.-S. Chou, J.W. Stevenson, J.-P. Choi, Long-term evaluation of solid oxide fuel cell candidate materials in a 3-cell generic short stack fixture, Part II: Sealing glass stability, microstructure and interfacial reactions, Journal of Power Sources 250 (2014) 166–173.

Acknowledgements:
The Federal Ministry of Economic Affairs and Energy is thanked for funding the SealS II project.
The project partners ElringKlinger AG, IAM-KWT and Fraunhofer IZFP are thanked for the close collaboration.

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

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