Manufacturing process for a quick starting Solid Oxid Fuel Cell (SOFC)

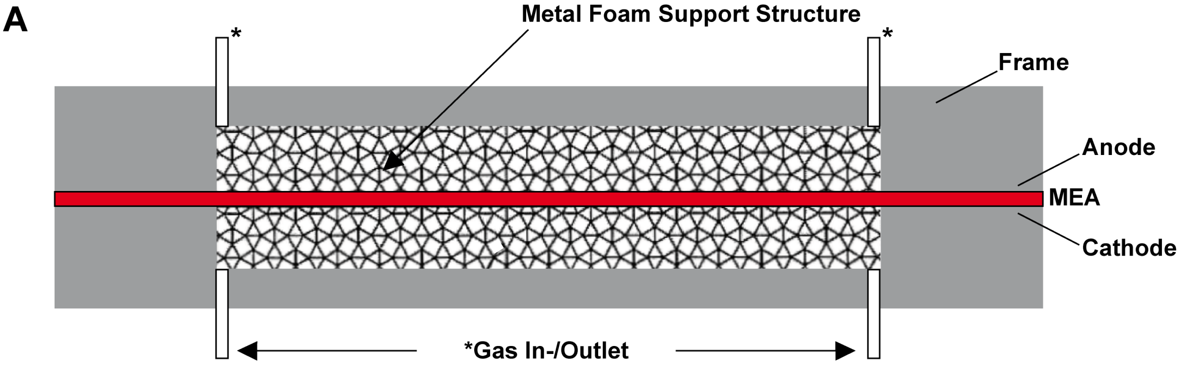
For the energy revolution, fuel cells play a key role for future energy systems. Especially high temperature solid oxide fuel cells (SOFC) are well-suited for decentralized energy production, as they allow flexible and highly efficient power and heat generation from renewable and conventional energy sources.
Presented here is a manufacturing process for a new, mechanically robust and efficient Metal Foam Supported SOFC (MFS-SOFC), that allow a quick startup and can be run at lower temperatures.

Challenge

At the heart of a fuel cell is the Membrane Electrode Assembly (MEA), that consists of an anode layer, a cathode layer and an electrolyte membrane, separating the two.
Problematic with so-called Solid Oxid Fuel Cells (SOFC), in which the electrolyte membrane is made from a solid material (such as ceramics), is that different thermal expansion coefficients of the different SOFC materials pose a high demand on an uniform and well-regulated heating process, leading to long startup times in order not to damage the SOFC. In addition, high operating temperatures of 600 to 1000°C put severe stress on peripheral devices such as the gas supplies and the cooling. Especially the manufacturing process of the membrane stacks and their respective sealing resemble process- and cost-related problems, that make SOFC sensitive and expansive.

Our Solution

To solve the aforementioned problems, a manufacturing process of a mechanically robust and energy efficient Metal Foam-stabilized SOFC (MFS-SOFC) that can be run at lower temperatures is presented. The present SOFC is based on a mechanical support structure made of a open-pore metal foam (e.g. Nickel foam), on which the MEA is directly applied via vapor deposition (s. Fig. 1 A). Thereby, optimal layer thickness can be achieved to make the MEA as efficient as possible. To ensure that during coating the anode material of the MEA is not infiltrating into the open-pore support structure, it is first infiltrated with an infiltration material (e.g. a polymer). The three functional layers of the MEA are then deposed via vapour deposition (CVD or PVD) onto the sealed support structure. The coating process can be achieved by one continuous co-depositioning process so that fluid transitions between the layers can be realized (s. Fig. 1 B). The MEA can thus be produced with improved tightness. The infiltration material can easily be removed afterwards by thermal or chemical treatment. Finally, another metal foam support structure is added to the cathode layer.



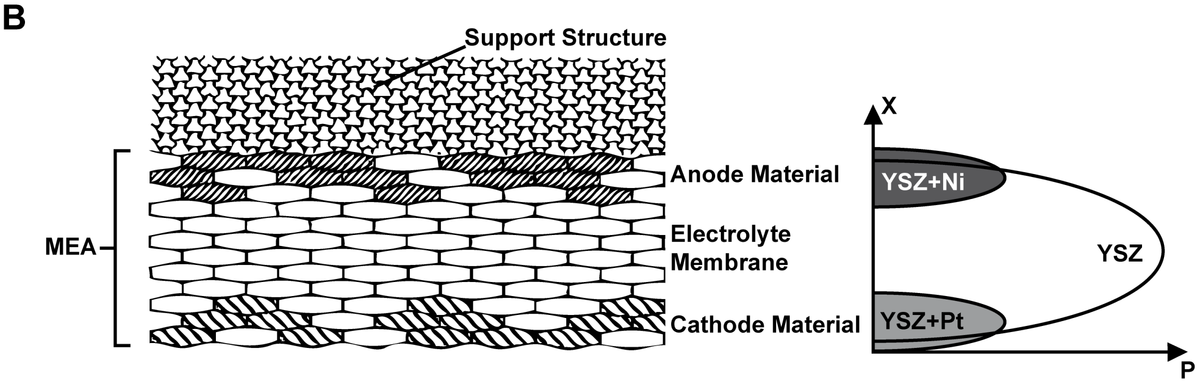


Fig.1: Sectional view of the Solid Oxid Fuel Cell (SOFC). A) The MEA of the SOFC is subdivided into an upper anode layer and a lower cathode layer separated by an electrolyte membrane. The MEA is embedded into a mechanical support structure in form of a open-pore metal foam, that is held inside a support frame. For electrical contacting, the MEA stretches through this frame. Through gas in- and outlets (*) fuel or oxidation gases can be injected into the respective chamber of the fuel cell. B) Detailed schematic of the MEA substructure with a diagram of MEA material distribution. Shown is a detailed view of the MEA's layer structure and the adjacent metal foam support structure (left). Shown is the material distribution within the MEA layers that is also illustrated in the graph (right). In the anode layer region, the MEA is composed of Yttrium and Zirconia (YSZ) with a proportion of Nickel (Ni) that is decreasing in amount towards the core of the MEA, that is made up by the electrolyte membrane consisting only of YSZ. Towards the cathode layer an increasing amount of Platinum (Pt) is codepositioned into the YSZ. (Source: adapted from patent application)

To eliminate the need for additional seals, ideally the single cells of a fuel cell stack can be arranged according to the janus principle. For that, coating of anode layers onto both sides of a support structure block, so that they resemble deliminations between two neighboring cells.
The resulting SOFC structure offers excellent mechanical and thermal stability and can thus be started quickly and resist a larger number of temperature cycles (on and off cycles). It thus has a better long-term durability and prolonged lifetime.
By expanding the three-phase boundary at the MEA region, the electricity yield and power density is increased, which results in higher efficiency of the SOFC that thus can be run at lower operating temperatures (600°C). Hereby, the thermostability requirements for peripheral devices such as gas

supplies or the cooling are markedly reduced, resulting in an overall reduction in system costs.

Advantages

- increased air-tightness, thus higher efficiency
- higher electricity yield and power density
- increased mechanical stability (faster startup, longer life cycle)
- lower operating temperature (reduced stress on peripheral devices)

Applications

- energy generation in power plants
- combined heat and power units (CHP) / decentralized energy supply
- power and hot water or steam production
- large scale systems for e.g. ships are possible

Development Status

The coating process was successfully tested at lab scale.

Patent Status

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