Exercise 6 solutions

1. Solid oxide and molten carbonate fuel cells. O'Hayre (2016), Sections 8.5 and 8.6, Review questions 8.1 and 8.4

Problem

a) Why is nickel used in many high-temperature fuel cells?
b) In SOFC anodes, why is YSZ mixed with the nickel?
c) In MCFC anodes, why is chromium added to the nickel?
d) What do you think is the single most significant advantage of high-temperature fuel cells compared to low-temperature fuel cells? Defend your answer.

Solution

a) Nickel is used to offer **electrical conductivity, catalytic activity** and **corrosion resistance** in high-temperature fuel cells.
b) YSZ is mixed with the nickel to offer **ion conductivity, thermal expansion compatibility, mechanical stability** and to maintain **high porosity and surface area** of the anode structure.
c) Chromium is added to the nickel to maintain **high porosity and surface area** of the electrode structure.
d) The most significant advantages of high temperature fuel cells are **fuel flexibility, possibility to co-generation** and **high efficiency**. The high temperature allows a wide use of different fuels, for example simple hydrocarbons and simple alcohols, in addition to hydrogen. The excess heat can be used to provide heating, which also increases the efficiency. All in all, the efficiencies of high temperature fuel cells are better compared to low temperature cells.

2. Mixed ionic-electronic conductors. O'Hayre (2016) Section 4.5.4.

Problem

a) Why are mixed ionic-electronic conductors interesting from fuel cell electrode application?
b) Could they be used also as electrolyte material with similar benefits?
c) Why have they not replaced the conventional electrode materials in commercial SOFC yet?

Solution

a) The MIEC structures significantly increase electrochemical activity in the electrodes. The material allows both ions and electrons to travel in it, thus increasing the triple-phase-boundary of the electrode, when reactions can happen on the whole MIEC surface.

b) The MIEC material cannot be used in the electrolyte, because of its electric conductivity. The fuel cell would be short circuited if electrons were allowed to move through the bulk of the electrolyte and they would not do useful work in the external circuit. No electricity could be generated.

c) MIECs have not yet replaced the conventional electrode materials due to some stability issues and other problems with the relatively new materials. Some MIEC materials, for example LSCF, are incompatible with the electrolyte material. This causes delamination and makes the adhesion of the material bad. This can, however, be avoided by manufacturing a protective layer of for example GDC

between the LSCF electrode and electrolyte. There can also be some structural changes in the LSCF material due to mobile strontium during sintering processes, which can cause problems.

3. Fuel cell characterization. O'Hayre (2016) Section 7.

Problem

a) What are the typical main reason to characterize a fuel cell?
b) Using Section 7 of the course book, discuss how you would characterize experimentally the properties of a fuel cell device, its components, and its materials listed in the table below. List the measurable quantities or parameters of a fuel cell model related to each property, including their typical units and the experimental techniques used for their measurement.

Fill your answers in this common Google Sheet jointly with others.

Property	Quantity parameter (incl. units)	Measurement technique
Overall performance		
Kinetic properties		
Ohmic properties		
Mass transport properties		
Parasitic losses		
Electrode structure		
Catalyst structure		
Flow structure		
Heat generation/heat balance		
Lifetime issues		

Solution

See the filled Google Sheet.