Part I
Identification of fuel cells and electromagnetic reverberations chambers

1. Fuel cell

1.1. Fuel cell technology use

Fuel cells belong to the group of galvanic elements, which, as electrochemical energy converters, can convert the chemical energy of a fuel into electrical energy. Since fuel cells can generate electricity directly from chemical energy, they are much more efficient than internal combustion engines [1]. The principle of the fuel cell was discovered in 1838 by Christian Friedrich Schönbein and soon after, Sir William Grove, along with Schönbein, recognized the reversal of electrolysis and power generation. With the invention of the electrical generator by Werner von Siemens, the invention known as the "gas battery" fell into oblivion. It wasn't until the 1950s that the idea was revived due to the need for compact and portable power sources in space travel and the military. Global warming and air pollution gave research into this technology decisive impetus that continues to this day.

1.2. Principle of operation

A fuel cell consists of a cathode, anode coated with catalysts such as platinum or nickel and a membrane Fig 1.

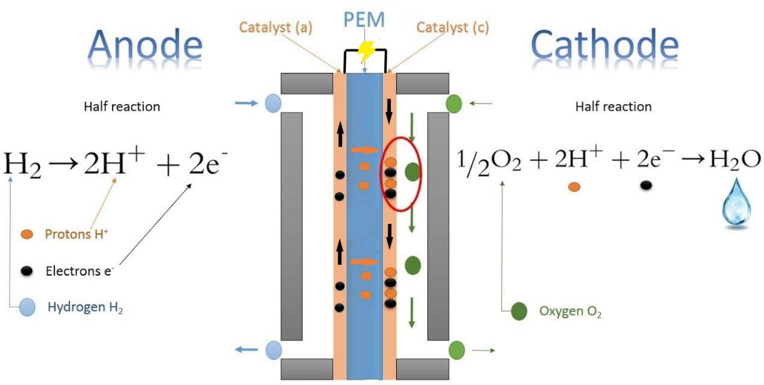

Figure 1: Basic structure and functioning of a fuel cell [2]

The anode is supplied with hydrogen $[H_2]$, which oxidizes to protons $\left[2H^+\right]$ on the catalyst layer, giving off electrons $[2e^-]$. The proton exchange membran (PEM) is only permeable for ions, so only the ions flow to the cathode via PEM. The electrons flow from the anode to the cathode via an external circuit and form the electric current. Both hydrogen protons and electrons migrate to the cathode, where they react with the supplied oxygen [O_2] to form water [H_2O]. Depending on the operating point, a single cell delivers a certain voltage between 0.5 and 1.0 volts. For higher voltages, individual cells are connected in series and a so-called stack is obtained as the core element of the fuel cell.

1.3. Types of fuel cells

There are different types of fuel cells, which differ in the electrolyte used, in the operating temperature, in the fuels that can be used and in the power range and thus the areas of application Fig 2.

Fuel Cell	Electrolyte	Operating Temperature	Electrical Efficiency	Fuel 'Mixture'
Alkaline Fuel Cell (AFC)	Potassium hydroxide (KOH) solution	Room temperature to 90°C	60-70%	H_2 - O_2
Proton Exchange Membrane Fuel Cell (PEMFC)	Proton exchange membrane	Room temperature to 80°C	40-60%	H_2 - O_2 or Air
Direct Methanol Fuel Cell (DMFC)	Proton exchange membrane	Room temperature to 130°C	20-30%	CH_3OH - O_2 or Air
Phosphoric Acid Fuel Cell (PAFC)	Phosphoric acid	160-220°C	55%	Natural Gas, Biogas, H_2 - O_2 or Air
Molten Carbonate Fuel Cell (MCFC)	Molten mixture of alkali metal carbonates	620-660°C	65%	Natural Gas, Biogas, Coalgas, H_2 - O_2 or Air
Solid Oxide Fuel Cell (SOFC)	Oxide ion conducting ceramic	800-1000°C	60-65%	Natural Gas, Biogas, Coalgas, H_2 - O_2 or Air

Figure 2: Different fuel cell types [3]

AFC are among the earliest researched fuel cell types and were mainly used in space travel deployed. Operating efficiency: about 60% to 70%. Proton Exchange membrane fuel cells (PEMFC) use membrane foil called Nafion and Electrodes with platinum layers as catalysts. They are powered by hydrogen or finely purified reformate from simple hydrocarbons such as natural gas, LPG or alcohols. These cells are used in home power supplies, power plants, submarines and space travel and have an efficiency of 40-60%. Direct methanol fuel cells (DMFC) are operated with liquid methanol and a membrane foil is used as the electrolyte. Due to the low power density, these cells are mainly used as battery chargers. Molten carbonate fuel cells (MCFC) have a molten carbonate electrolyte. Because of the operating temperature of approx. 650°C and the resulting high reaction speeds, therefore no expensive noble metal catalysts are required. They are operated with desulfurized natural and coal gas or suitably cleaned biogas. MCFC systems are developed for the power plant range from 200 kW to several MW and have an efficiency of 50% to 65%. Solid oxide fuel cells (SOFC) are operated with a solid ceramic metal oxide as the electrolyte. The operating temperature of 800°C enable that no expensive noble metal catalysts are required. These cells can be operated with fossil gases or biogas. SOFC systems are developed in the power range from 1 kW to 200 kW and have an efficiency of 60-65% [4].

1.4. Challenges and solutions

The fuel technology is mature in many areas and in regular operation. In particular, passenger cars, forklifts and micro combined heat and power plants (CHP) for residential buildings are among the mature applications and are already commercially available, followed by buses, emergency generators, industrial CHP plants and various network services. However, there are many possible ones Hydrogen and fuel applications Cells where no comparable experiences have been made so far and which are still in the research and development phase. These include, for example Trains, waste disposal vehicles and delivery vehicles, but also heavy duty trucks as well airplanes and ships. The challenge for the use of the technology also remains in terms of infrastructure as well as expanding the filling stations for hydrogen. In addition to the infrastructure The further development of the production facilities is a challenge, especially in the transition to serial production. For this reason Know-how transfer is essential for the market ramp-up, to reduce existing reservations and gaps in knowledge [5].

2. Electromagnetic reverberations chambers

References

[1] Kurzweil, Peter: *Brennstoffzellentechnik - Grundlagen, Materialien, Anwendungen, Gaserzeugung.* Berlin Heidelberg New York : Springer-Verlag, 2016. – ISBN 978–3–658–14935–2

[2] Prezi.com: *Https://i.ytimg.com/vi/oqF8MD6AReM/maxresdefault.jpg.* https://prezi.com/7-gy0isu-giy/httpsiytimgcomvioqf8md6aremmaxresdefaultjpg/. Version: 2017

[3] Panayiotou, Gregoris ; Kalogirou, Soteris ; Tassou, Savvas: PEM Fuel Cells for Energy Production in Solar Hydrogen Systems. In: *Recent Patents on Mechanical Engineering* 3 (2010), 11, S. 226–235. http://dx.doi.org/10.2174/2212797611003030226. – DOI 10.2174/2212797611003030226

[4] Schaloske, MC ; Schott, B: Energieträger der Zukunft. In: *Potentiale der Wasserstofftechnologie in Baden-Württemberg, Stuttgart* (2012)

[5] Weichenhain, U ; Lange, S ; Koolen, J ; Benz, A ; Hartmann, S ; Heilert, D ; Henninger, S ; Kallenbach, T: Potenziale der Wasserstoff-und Brennstoffzellen-Industrie in Baden-Württemberg. In: *Roland Berger, Studie für das Ministerium für Umwelt, Klima und Energiewirtschaft des Landes Baden-Württemberg* (2020)