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The climate Change and its consequences are the most important problems that the civilization faces today. The sixth report of the Inter-governmental Panel on Climate Change (IPCC) has now provided a clear correlation between greenhouse gas emissions from human activities and rapid climate change. To avoid dramatic ecological and economic consequences due to drought disasters, storms and heavy rain, the global warming must be limited to 1.5 ?C [1]. To achieve this, the global energy infrastructure needs to change to a CO2-neutral energy infrastructure. This is a major challenge that needs to be addressed urgently through world-wide collaboration and concerted research efforts.

During the last decades, especially the PEM technology with polymer electrolyte membranes has been developed to be used in various technical applications and it has provided reliable operation stability. In the automotive industry, PEM fuel cells are currently being developed with current densities between 2 and 3 A cm-2 [7]. The results of different PEM fuel cells are presented in [8] with current densities around 1.5 A cm-2 at usable voltages of around 0.6 V. The efficiencies of these cells are in the range of 40-50%.

It can be concluded that AEMs are not enough stable at higher temperatures because partly drying and embrittlement can damage the membranes. This is the reason for the lack of availability of commercial fuel cells equipped with AEMs. In electrolyzers the risk is much lower since there is always liquid water at the membrane. The ENAPTER company is starting production of small modular electrolyzer devices using AEMs, but temperature level and efficiency are still relatively low. This is unfavorable since much high efficiencies can be reached with alkaline systems especially at high temperatures.

Since alkaline membranes are sensitive to high temperatures, a promising attempt is given in [24], avoiding the use of any membrane. In a small test cell, a capillary flow of electrolyte is feeding a porous structure made of a hydrophilic polyether-sulfone (PES) separator in-between two electrodes. Hydrogen and oxygen evolution can be obtained without the formation of bubbles. The results are impressing: at current densities of 500 mA cm-2 the electrolyzer cell works with a voltage of only 1.51 V, corresponding to an efficiency of about 98%.

In fuel cells the chemical energy of the hydrogen is directly converted into electric energy using an electrochemical process. The maximum effectively useful energy (exergy) is given by the GIBBs free reaction enthalpy DG. Hereby, the bond enthalpy DH represents the chemical energy of the hydrogen and cannot be fully converted into electrical energy. It is diminished by a term of the absolute temperature T and the change of entropy DS.

Alkaline fuel cells and electrolyzers in the classic design are generally based on an aqueous solution of potassium hydroxide (KOH). Here, the hydroxide ions (OH-) are responsible for the electrochemical current in-between the electrodes. In fuel cell mode (gas consumption) hydroxide ions are produced at the oxygen electrode and consumed at the hydrogen electrode. In electrolysis mode (gas production) the flow direction is reverse. The electrochemical equations are given below; they are reversible in general:

Accordingly, when catalysts are researched not only the chemical element or compound, but also the micro-structure of the metal catalyst must be considered. In a standard textbook of chemistry, the overvoltage of hydrogen and oxygen at different electrode materials are given with the clear result that platinized platinum shows significant lower overvoltage than blank platinum [26]. In [27] an electrode treatment for water electrolysis is presented using high-performance pulsed laser processing. Herewith, Ni-Fe catalysts could be produced based on nanosheets coated on thin nickel fibers for the creation of very high active surface area, with the result of significantly reduced overvoltage in alkaline media.

Structural design and working principle of alkaline gas diffusion electrodes, exemplary at the hydrogen side [25]

One objective of the on-hand work is the design of a highly-efficient fuel cell system for the storage of electric energy from renewable sources. To achieve this, an experimental investigation program was developed using two different designs: a reversible alkaline fuel cell with an electrolyte gap and an alkaline membrane electrolyzer with zero-gap design. All the experimental investigations herewith were conducted in the laboratory of fuel cell technology at the FRANKFURT UNIVERSITY OF APPLIED SCIENCES (UAS). The experimental data are being compared with a reversible PEM fuel cell working in fuel cell and electrolyzer mode which was investigated in a former study of the corresponding author at the FRAUNHOFER INSTITUTE OF SOLAR ENERGY SYSTEMS (ISE) in Freiburg, Germany [29].

For the alkaline technology used in the on-hand work, a test section was developed where hydrogen and oxygen are supplied from an external electrolyzer cell, allowing an over pressure of 4 bar. With a data acquisition system, cell current and voltage, the important temperatures and the gas pressures were recorded.

The two different cell concepts were executed as given below. These designs have been carefully developed to meet the objectives of the research:

Design A: classic AFC with electrolyte gap configuration--see Fig. 3