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Development and testing of an anion exchange membrane electrolyser

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ABSTRACT

In the context of energy policy and the use of renewable energies, our research institute collaborates with other partners on the development of a compact, environmental-friendly and effective electrolyser for efficient power storage. This electrolyser combines the positive properties of the alkaline water electrolysis and the proton exchange membrane (PEM) electrolysis. On the cathode side on porous current collectors were electrodeposited in one step multi-component non-precious alloys. New cross-linked anion-exchange membranes have been developed to achieve high ionic conductivity. The anode side was coated with the sol–gel method. The catalytic activity of the electrodes was investigated by electrochemical studies. Current collectors have been tested under real conditions of electrolysis. For the construction of a corresponding single cell, media supply was taken into consideration and appropriate materials for current collectors, the bipolar plates and gaskets were selected.

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Introduction

In the recent years the renewable energy sources got an increasing significance. A disadvantage of these sources is the fact that the produced electricity is not constant. Alkaline water electrolyzers (AWE) may store the excess electricity, produced from solar or wind power sources, converting it into chemical energy via H₂ production. The present effective AWE are based on large-scale concepts of limited current densities,

using KOH as electrolyte. These caustic solutions are not quite eco-friendly and require a complex system design.

Therefore it would be an advantage to abandon the caustic solution like in a PEM electrolyser but without using platinum group metals (PGM). In order to do this, there have to be developed new anion conducting membranes and a new type of current collectors – substrates with a distinct and well developed porous surface [1,2] covered with multiple component non-precious metal catalysts [3,4]. In one previous work we presented the three alloys NiWTiO_x, CoMn and CoNiMoW

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and their positive effect on the Hydrogen Evolution Reaction (HER) [5]. The usage of such reasonably priced substrate and catalyst materials for both current collectors will reduce the costs of the electrolyser.

Water electrolyzers based upon alkaline anion exchange membranes (AAEM) give the opportunity to replace the KOH in AWE with solid polymer electrolyte [6–9]. This will make them environmentally friendly and compact, which means user-friendly and suitable also for small and medium-sized enterprises.

The goal of this project was to develop an anion exchange membrane electrolyser with separate fabrication of the different components of the electrolyser with a subsequent membrane electrode assembly (MEA). This technique offers certain advantages: a high variability is possible by using several different substrates, combined with various methods of layer deposition and different layer types; a treatment of the layers (for example thermal activation) is possible; the used anodic and cathodic current collectors could be composed of different materials.

In this work we want to sum up the different aspects of the development of such electrolyzers and the difficulties in the early stages by assembling the alkaline cell. The main targets were as follows: producing economically priced electrodes with low hydrogen and oxygen overpotential, which are stable at the electrolysis conditions; development of a cross-linked AAEM with high ionic conductivity; testing the different components assembling a real alkaline cell.

The fundamental design of an alkaline anion exchange membrane water electrolyser cell (AAEMWE) is shown in Fig. 1. The cell contains an AAEM which separates two electrode compartments. Both electrodes consist of a bipolar plate with a flow field and a substrate covered with a catalyst layer. The purpose of the channels in the flow fields is the conduction of water and produced gases. The two bipolar plates are separated by a gasket, which defines the electrode compartment with the facing sides of anode and cathode assemblies (Fig. 1) and seals the cell against the environment in order to run the cell safely.

In this study, we demonstrate the electrochemical deposition of three alloys with different structures on various substrate materials, the production of AAEM and first operations of MEAs containing the new developed current collectors.

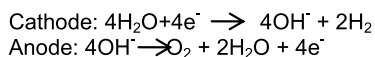
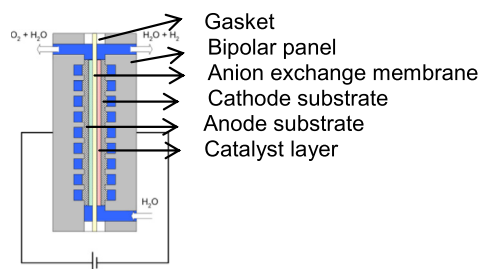


Fig. 1 – Construction of an alkaline anion exchange membrane water electrolyser.

Experimental and procedures

Experimental setup

The surface morphologies of the anode and cathode current collectors were investigated by EDX-analysis, X-Ray fluorescence spectrometer (XDAL, Helmut Fischer GmbH & co. KG) and scanning electron microscopy (SEM) with a Leo Supra 55VP microscope from Carl Zeiss AG.

The electrodes with a geometrical surface of about 2 cm² were tested for HER and for OER in 1 M KOH (p.A., Sigma Aldrich) in a classical 3-electrode electrochemical cell using electrochemical workstation IM 6 (Zahner). Ti–Pt mesh was used as counter electrode (CE), saturated calomel electrode (SCE) as reference electrode (RE). All potentials are given versus SCE.

The ZBT test cell has an active area of about 25 cm². The bipolar plates are made of stainless steel and are galvanically gold-plated. The flow field is arranged in a parallel plane. A PTFE material is used as a gasket

V–I-measurements are performed with a power supply from Elektro-Automatik.

Impedance measurements are carried out with the Electrochemical Workstation Im6 (Zahner).

The membranes and electrodes (catalyst coated current collectors) are hot-pressed together to get a MEA. The membranes have to be transformed into OH[−] conducting state before the measurements. This is done inside the test cell by flushing both electrode compartments with 0.5–1 M KOH solution for several minutes. After removing the KOH by rinsing the test cell with pure water for at least 1 h the cell is ready for testing.

Materials

As cathode and anode substrates were tested the stainless steel non-woven fabrics PACOPOR ST AL3 (VS) from PACO PAUL GmbH & co. KG

NiWTiO_x layer was prepared under galvanostatic condition using galvanostat LPS 301 from AMREL Inc. The applied current density was $i = 0.24 \text{ A cm}^{-2}$. It was not possible to estimate the real surface for VS, therefore we used the constant current $I = 1.28 \text{ A}$. The electrolyte composition and deposition conditions are published elsewhere [5]. A Ni electrode was used as an anode.

Co–Mn–B catalyst was fabricated under potentiostatic deposition at $E = -1.8 \text{ V vs. SCE}$. The electrolyte composition and deposition conditions are the same as the one described previously [5,10]. A Co electrode (99.9% Co, ChemPur) was used as an anode.

CoNiMoW was deposited under galvanostatic condition. The applied current density/constant current were the same, as for the NiWTiO_x. The Ti–Pt mesh PLATINODE (Umicore Galvanotechnik GmbH) was used as anode. The electrolyte composition and deposition conditions are published elsewhere [5].

The solutions and the sol–gel preparation procedure are the same as described previously [11]

Novel AEMs have been prepared and characterized as already published [12–15]. The most promising of these new

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