Alkaline electrolyzer with nanostructured NiFeP electrodes for hydrogen production

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Significance and Relevance

This paper presents an innovative Alkaline Water Electrolyser (AWE) based on using NiFeP nanostructured electrodes, from its initial design to its subsequent implementation, as suggested by the results of tests simulating the real-field operation of the electrolyzer. The nanostructured electrodes were fabricated by template electrosynthesis, a straightforward and cost-effective process. This fabrication method was analyzed by Life Cycle Assessment from an eco-design perspective. Electrochemical tests were conducted on the individual electrodes and the complete cell to evaluate their electrocatalytic properties in alkaline solution. The electrodes exhibited robust stability over an extended period (125 hours) with no discernible indications of performance degradation.

Preferred and 2nd choice for the topic: green H2 production, Sustainable and clean energy production
Preferred presentation: Oral preferred or Short Oral

Introduction and Motivations

In the future, the electrochemical hydrogen production will play an important role. Nevertheless, the cost of electrochemical hydrogen production remains considerably higher than that of conventional production methods. Consequently, research is concentrated on enhancing the functionality of electrolyzers through the utilization of more efficient and cost-effective materials, such as transition metal alloys [1]. For water-alkaline electrolyzers, the development of nanoporous nickel electrodes with low cost and high electrocatalytic efficiency represents a promising strategy for enhancing their performance. A straightforward approach to producing nanostructured electrodes is template electrosynthesis. The methodology employed resulted in the production of electrodes consisting of Ni alloy nanowires with an exceptionally high surface area. The electrodes were produced via a two-step process, resulting in an ordered array of Ni nanowires that completely covered the surface of the current collector, which was also of the same material.

Materials and Methods

NW electrodes were obtained by template electrosynthesis using polycarbonate nanoporous membranes (Whatman). The template has a mean pore diameter of 200 nm and a thickness of about 20 mm. The template electrosynthesis of NW electrodes was performed according to the procedure detailed in [2][3]. Electrodes were characterized by scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS) and X-ray diffraction (XRD). Each electrode was electrochemically tested, including cyclic voltammetry (CV), quasi-steady state polarization (QSSP), galvanostatic step (GS) and galvanostatic test to evaluate the performance in terms of hydrogen and oxygen production and to verify the medium-term stability under galvanostatic conditions.

Results and Discussion

This study examines the fabrication and characterization of nanostructured nickel alloy electrodes intending to reduce the overpotential losses associated with driving the anodic oxygen evolution reaction (OER) and cathodic hydrogen evolution reaction (HER) in alkaline environments. Ni alloy nanowires (NWs) with an exceptionally high surface area and high electrocatalytic activity were prepared by template electrosynthesis [2]. It was demonstrated that alkaline electrolyzers comprising Ni nanowire electrodes coated with distinct electrocatalysts exhibit robust performance and stability at room temperature [2]. For comparison, functionalized Ni sheets (NS) with the same electrocatalysts were tested. The study of a specific device for alkaline electrolysis was based on the geometry of devices previously analyzed in the literature and already adapted for use with nanostructured electrodes. A laser cutter was used to define and construct the different components of a cell suitable for containing Ni alloy NWs, Ni alloy NS electrodes, and the diaphragm. An AW laboratory-scale electrolysis system was devised to monitor the operating current and voltage. The comprehensive quantification of these parameters is significant for both fundamental and applied research, as it allows for the determination of the efficiency of an electrochemical device. The electrodes were characterized using SEM and EDS. To assess their performance, QSSP, GS, and galvanostatic tests were conducted over a period exceeding 100 hours at a constant current density. The results presented in this work demonstrate the significant potential of nanostructures to enhance cell performance. The electrodes show excellent long-term stability. With negligible drops in potential, the curve remains almost constant. This alkaline electrolyzer can operate continuously for 125 hours at a current density of 50 with a potential of 1.92 showing an increase of about 3-4 mV after 125 hours. The results presented in this paper show how nanostructures can significantly improve AWE performance. However, further improvements and testing are needed to achieve efficiency levels suitable for industrial use: electrocatalysis can be further improved and the cell design needs to be optimized.

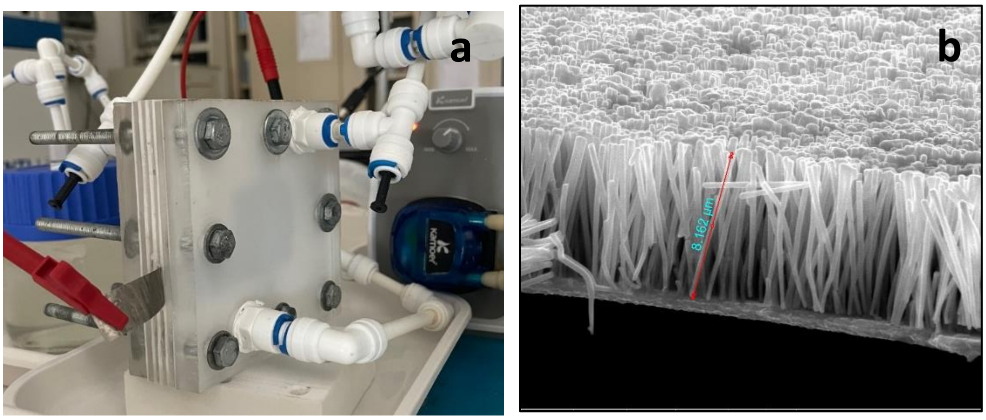

Figure 1. a) The alkaline cell with the NiFeP alloy and b) the SEM of NiFeP alloy NWs used for AWE.

References

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