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Novel nickel-based electrodes for hydrogen production

Ragne Pärnamäe
ragne.parnamae@wetsus.nl

Motivation

Hydrogen is considered the most promising fuel for its high energy density, abundance, and no emissions during combustion. Today, however, it is almost entirely produced via steam methane reforming, a process which uses natural gas to produce syngas – H_2 mixed with CO_2. To avoid the use of natural gas, a non-renewable hydrocarbon, and the production of a greenhouse gas CO_2, hydrogen can instead be sustainably produced by water electrolysis using renewable electricity. Water electrolysis is a process where electric current between two electrodes is used to decompose water into hydrogen and oxygen on their surface. The performance of electrolysis depends heavily on the electrodes, which need to be highly catalytic to facilitate the gas' formation. Platinum group metals have outstanding catalytic performance but are expensive. Therefore, new cost effective alternatives are necessary.

Technological challenge

Since the development of electrolysers, nickel-based materials have remained state of the art non-noble hydrogen evolution reaction (HER) catalysts for alkaline water electrolysis. While nickel is the most active non-noble metal[1], it does not outperform platinum group metals. Thus, much effort has been put into optimizing nickel based catalysts' chemical structure and morphology. Modifying the chemical structure of pure nickel materials by doping them with other highly catalytic materials can significantly improve their catalytic activity[2]. Optimizing the morphology of such electrodes enhances the detachment of the formed hydrogen and oxygen bubbles from the electrode surface[3-4].

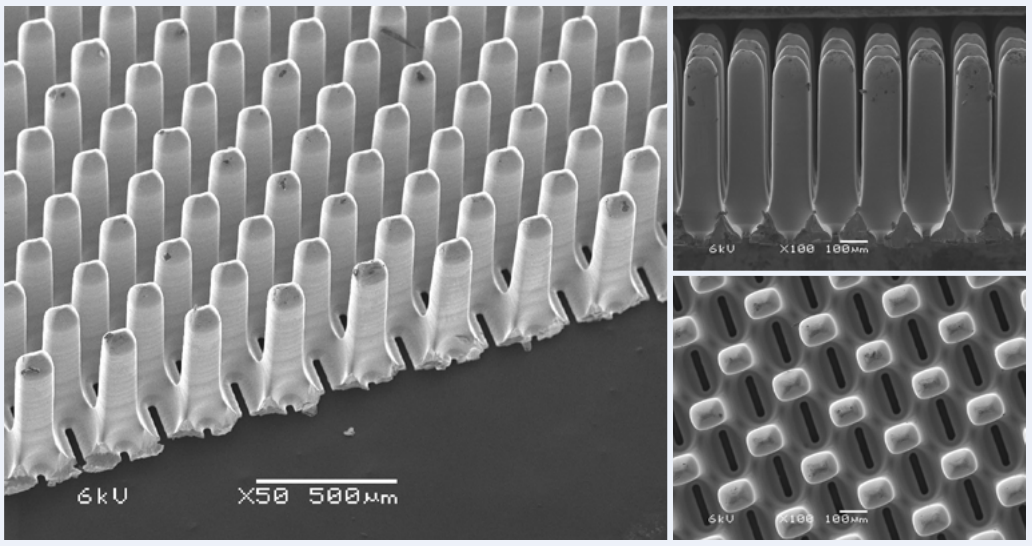

Fig 1. SEM images of the electrodes as provided by the manufacturer (Veco Precision BV).

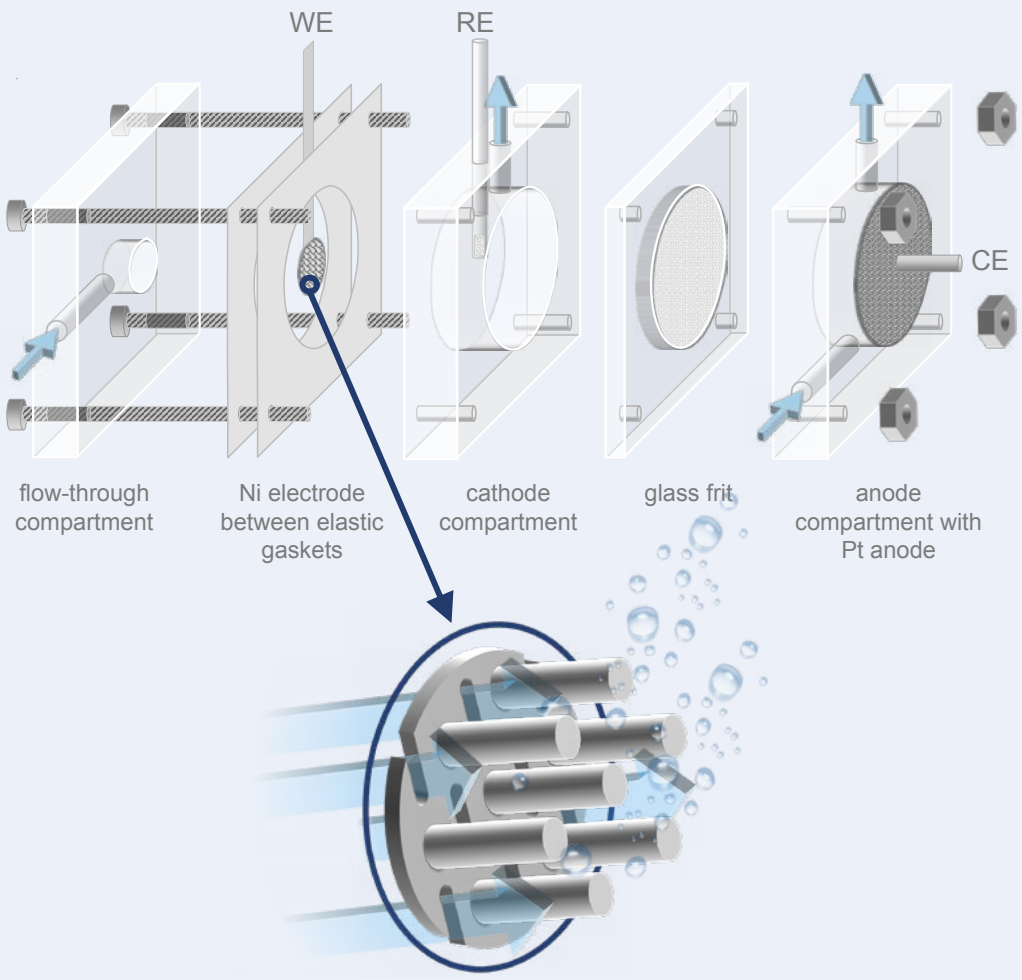

Fig 2. Experimental cell with a flow through configuration for improved bubble detachment.

Research goals

This project investigates pillared nickel electrodes and optimizes their design for hydrogen production via alkaline water electrolysis.

Focus is put on three research objectives:

1. Testing the electrodes against state of the art alkaline HER catalyst (Raney nickel) and optimizing the electrode design (pillar spacing and length, electrode porosity) for improved performance.
2. Improving the electrodes' catalytic activity with noble and non-noble dopants.
3. Identifying and demonstrating novel applications for such electrodes.

[1] S . Trasatti, J. Electroanal. Chem., 39, 163 (1972)
[2] Y . Li et al., Nat Commun 11, 2720 (2020)
[3] B.S . Taşçı et al., Int. J. Hydrogen Energy, 43, 23 (2018)
[4] A . Gabler et al., Int. J. Hydrogen Energy, 42, 16 (2017)