Nanostructured Nickel Alloy Electrodes for Alkaline Electrolysers

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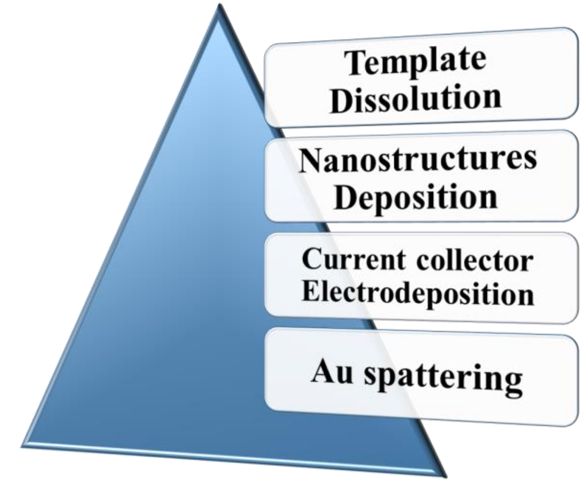
Introduction

Over the last decade, the interest towards green hydrogen has drastically increased due to the global decarbonization process. Green hydrogen is obtained by water electrolysis using only electricity from renewable sources [1]. It is considered one of the best storage systems in terms of environmental sustainability but not in economic ones [2]. Nowadays, the research is focused on improving the Alkaline Water Electrolysis (AE) to reduce the cost of production. An approach to improve AE performance is based on nanostructured electrodes characterized by high electrocatalytic activity due to the very high surface area. In this work, the attention was focused on the fabrication and characterization of nickel-alloy electrodes for both hydrogen and oxygen evolution reaction. Different alloys (Ni-Co, Ni-Zn and Ni-Fe) at different composition were studied in order to determine the most suitable alloy and its optimum composition.

Electrode fabrication

Nanowires of Ni alloys (NiFe, NiCo, NiZn) were fabricated by **template** electrosynthesis by means of polycarbonate nanoporous membranes.

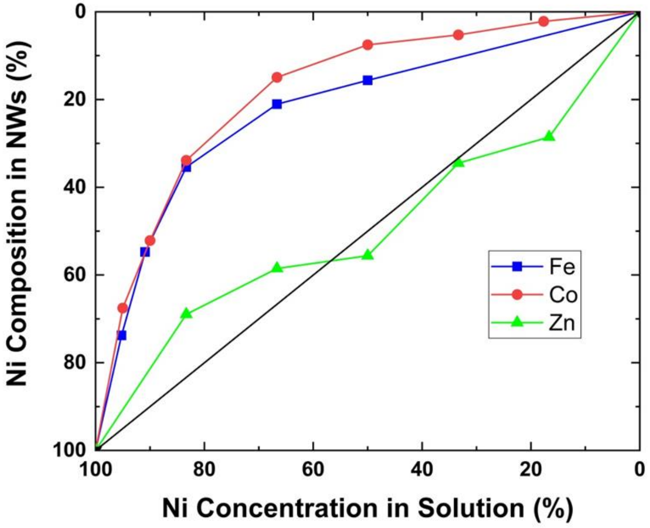


The deposition solution of the NWs consists of the Watt's bath containing different concentrations of the metal precursor:

- **$FeSO_4 \cdot 7H_2O$** for **NiFe** Alloy
- **$ZnSO_4 \cdot 7H_2O$** for **NiZn** Alloy
- **$CoSO_4 \cdot 6H_2O$** for **NiCo** Alloy

Scheme of Template Electrosynthesis

EDS analysis



Ni alloy NWs composition

The alloy composition was evaluated by EDS analysis. The content of the metals in NWs is different from the content in the electrodeposition bath

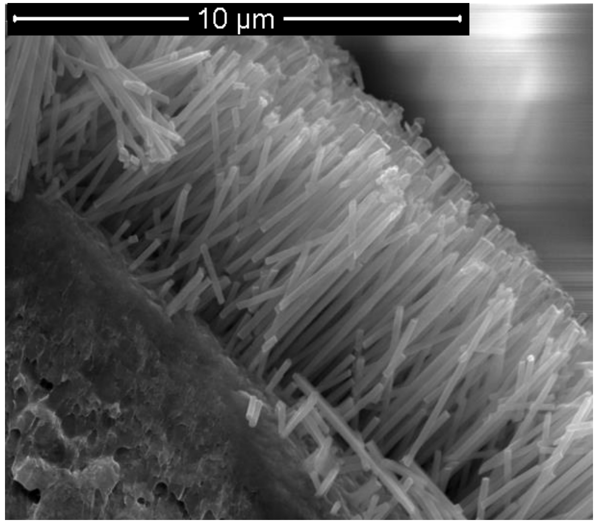
It can be observed that the Co content is higher in the alloy than in the electrolyte. The same behaviour can be observed in Ni-Fe alloy. In the case of the Ni-Zn alloy, its composition is almost linear with the composition of the bath.

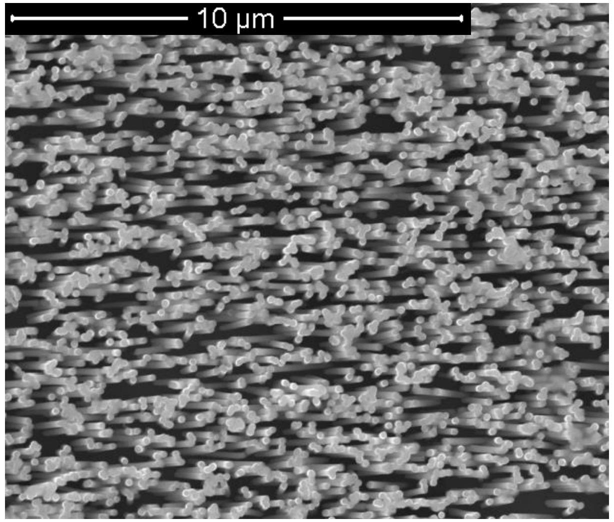
References

[1] B. Ceran, Multi-Criteria Comparative Analysis of Clean Hydrogen Production Scenarios, ENERGIES. 13 (2020).
[2] J.L.L.C.C. Janssen, M. Weeda, R.J. Detz, B. van der Zwaan, Country-specific cost projections for renewable hydrogen production through off-grid electricity systems, Appl. Energy. 309 (2022).

SEM

SEM images show how the current collector surface is uniformly covered by NWs. It is not worth specifying which alloy it is, because The morphology is independent on Ni alloys because is related only to the type and shape of nanoporous template

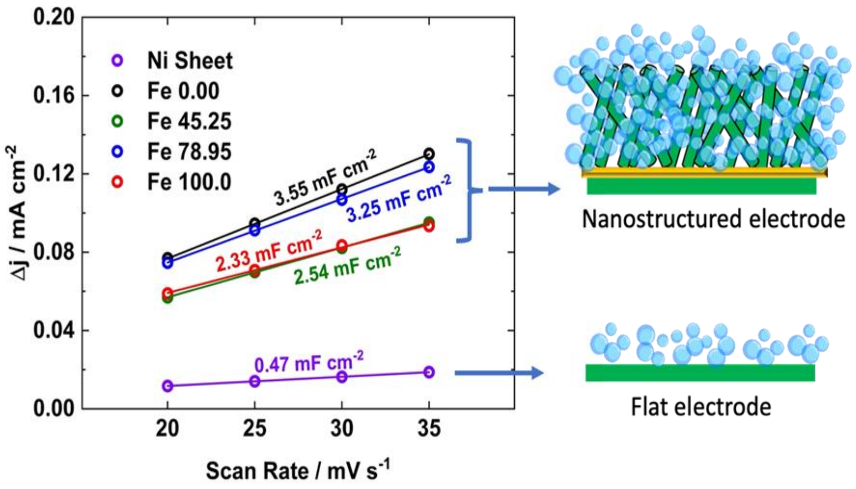




Electrochemical characterization

All the electrochemical tests (**CV, QSSP, Galvanostatic test**) were carried out at room temperature, in 30% KOH weight solution, using a three-electrode cell. A Ni sheet was employed as counter electrode and Hg/HgO as reference. In the following, all potentials will be referred to the value of reversible hydrogen electrode at pH 14. All alloys have been tested for both OER and HER. **We have identified best composition for each alloy and then we have identified best alloy for OER and HER.** Electrode names are referred to metal content (Zn, Co, Fe).

CV



By CVs at different scan rates, we can evaluate the specific capacitance by the double layer capacitance method. **The specific capacitance is directly proportional to the real electrode surface**. The figure shows the specific capacitance of NiFe alloy, but the same behavior was observed in all alloys.

Electrochemical characterization

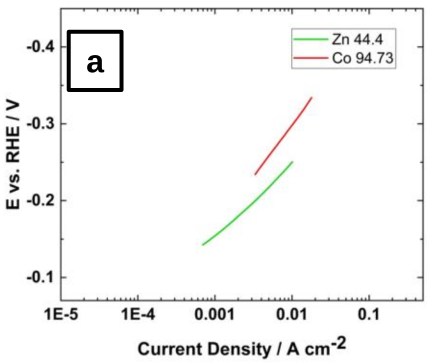
QSSP

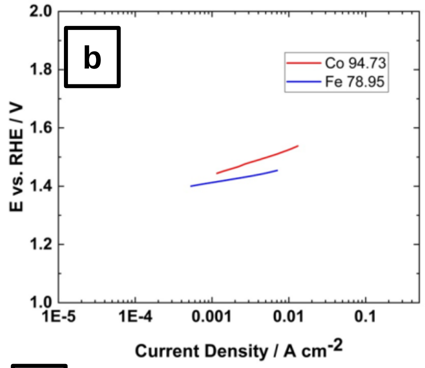
QSSP curves were fitted **with Tafel's equation** where a and b parameters are related to the exchange current density and to the Tafel's slope

Scan Rate: 0.167 mV s^{-1}

Solution: KOH 30% w/w

Temperature: Room





a

Electrode	a (V)	b (V/dec)	R^2
Co 94.73	-0,441	-0,103	99,98
Zn 44.4	-0,449	-0,104	99,66

b

Electrode	a (V)	b (V/dec)	R^2
Co 94.73	1,677	0,088	99,95
Fe 78.95	1,515	0,040	99,90

Fig. a) *Linear range of cathodic QSSP for HER*

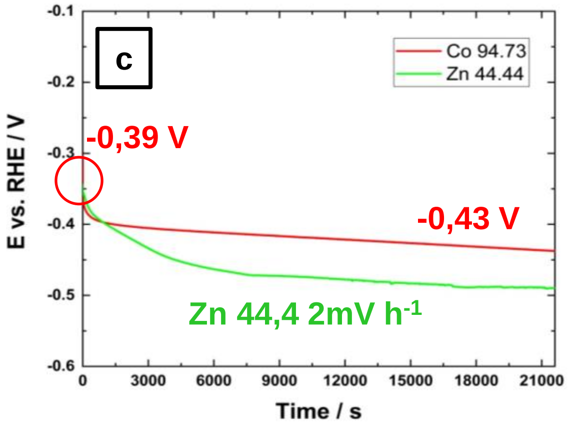
Table a) *Fitted Tafel's parameters for HER*

Fig. b) *Linear range of anodic QSSP for OER*

Table b) *Fitted Tafel's parameters for OER*

Galvanostatic Test- Mid term behaviour

To study stability over time, constant current density mid-term tests were carried out for 6 h at **-**50 mA cm^{-2} and +50 mA cm^{-2} for HER and OER, respectively.



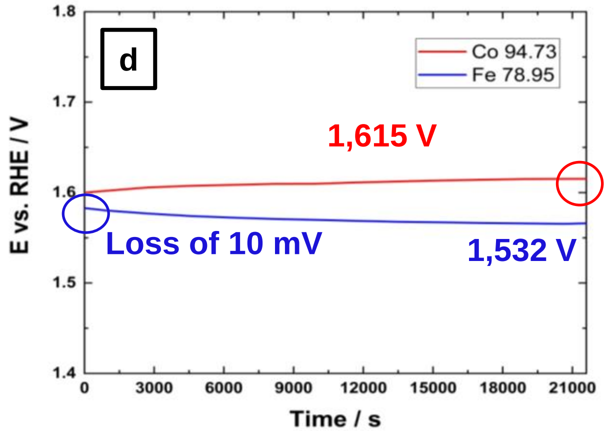


Fig. c) *Constant current density mid.-term stability for HER*

Fig. d) *Constant current density mid.-term stability for OER*

Conclusions

In this work, nanostructured electrodes were manufactured with a simple and cheap method, Template Electrosynthesis. Ni-Fe, Ni-Zn, Ni-Co alloy electrodes were manufactured using several mixture bath solutions. Nanostructured morphology was observed by SEM. Ni alloy NWs, in particular NiFe NWs have shown good performance due to the high surface area in respect to planar electrode. Electrochemical and electrocatalytic properties of Ni Alloy NWs electrodes showed good perfomances. In particular, electrode with around 95% content of Co is the best for HER and electrode with around 78% content of Fe is the best for OER. These results will be the basis for the development of an asymmetric electrolyzer. More research activities are in progress for using a homemade cell with these electrodes, in which it is possible to set temperature, water flow, etc.. Furthermore, other activities continue to deal with performance in sea water.