EUROPEAN COMMISSION – FCH JU

HORIZON 2020 PROGRAMME - TOPIC H2020-FCH-02-4-2019
New Anion Exchange Membrane Electrolysers

GRANT AGREEMENT No. 875024

Anion Exchange Membrane Electrolysis for Renewable Hydrogen Production on a Wide-Scale

ANIONE – Deliverable Report

D 4.1 Data set on catalytic activity, electrochemical performance and stability of enhanced catalysts

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (JU) under grant agreement No 875024. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

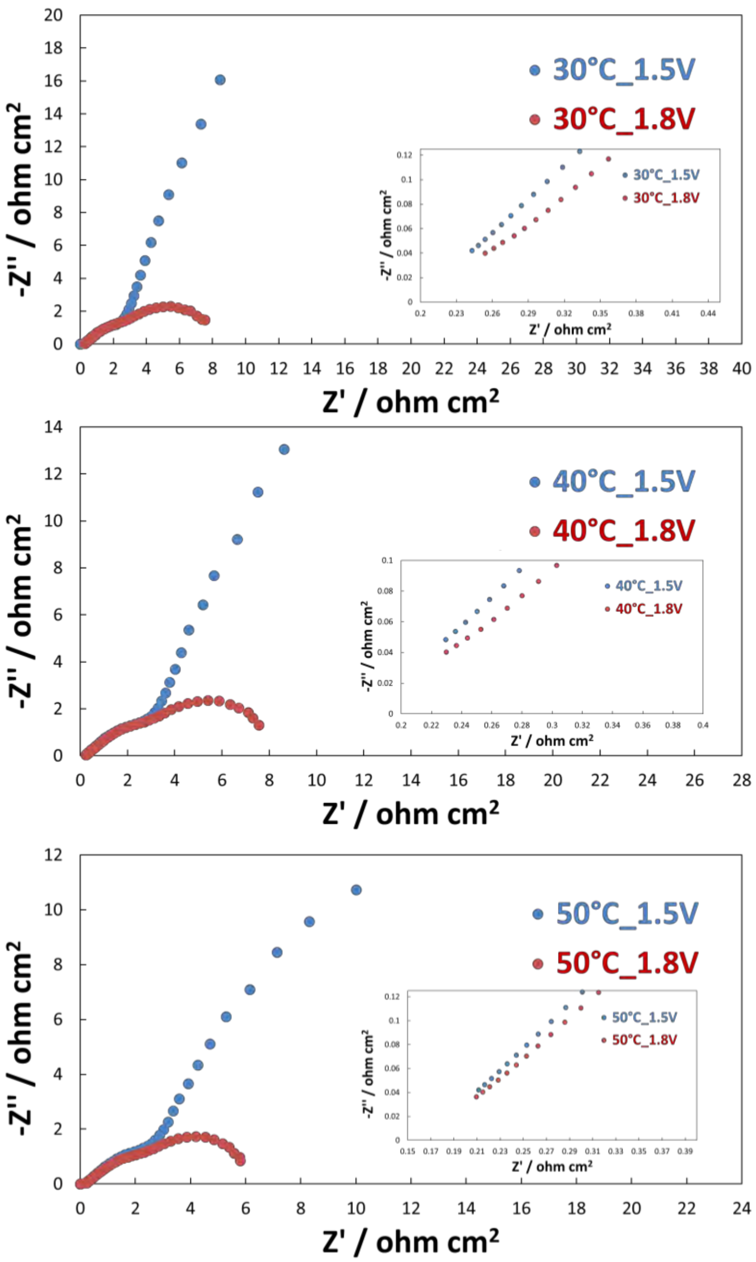

Figure 33. *The EIS of cell based on NiMo as cathode and NiFe* oxide *as anode measured at 1.5 V and 1.8 V at 30 °C (a), 40 °C (b) and 50 °C (c).*

A short galvanostatic test carried out at 50 °C was sufficient to show as the cell improved its performance but the voltage was still high.

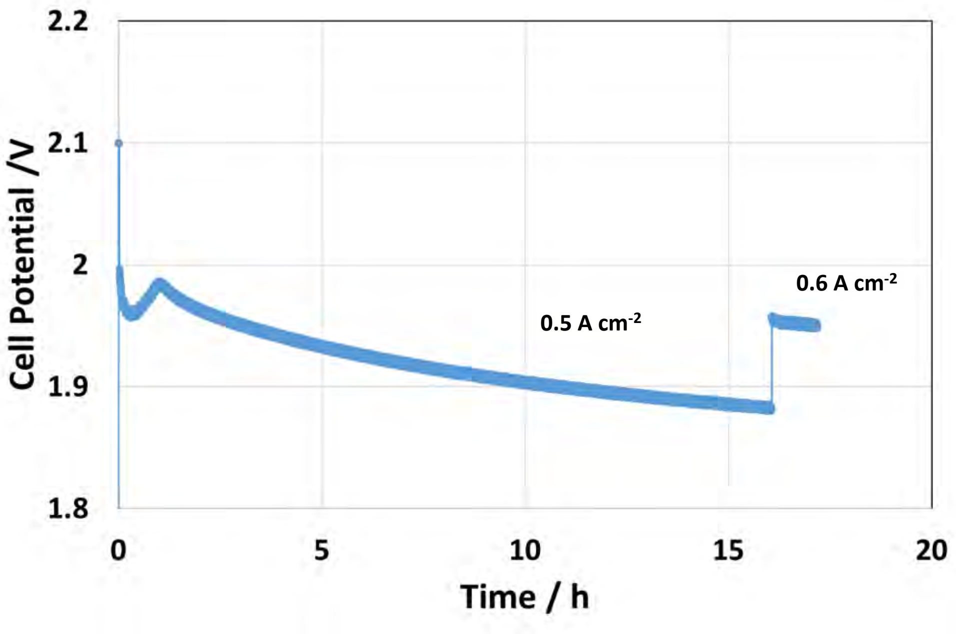

Figure 34. *Durability test carried out under galvanostatic conditions at 50 °C for cell based on NiMo as the cathode and NiFe* oxide *as anode.*

The next experiments are related to the investigation of $Ni_{0.4}Cu_{0.4}Mo_{0.2}$. In Figure 35, the polarisation curves of cell using this electrocatalyst as cathode are reported.

As shown, the best performance was observed at 50 °C that was an optimal compromise between the lower activation overpotential and better conductivity of membrane.

A further increase of current density was achieved vs. NiMo but the performance was still lower than NiCu.

As can be seen, at 60°C a I-V curve with lower performance was achieved. Such behaviour is a consequence of partial loss of electrocatalytic activity from the $Ni_{0.4}Cu_{0.4}Mo_{0.2}$ at temperatures higher than 50 °C.

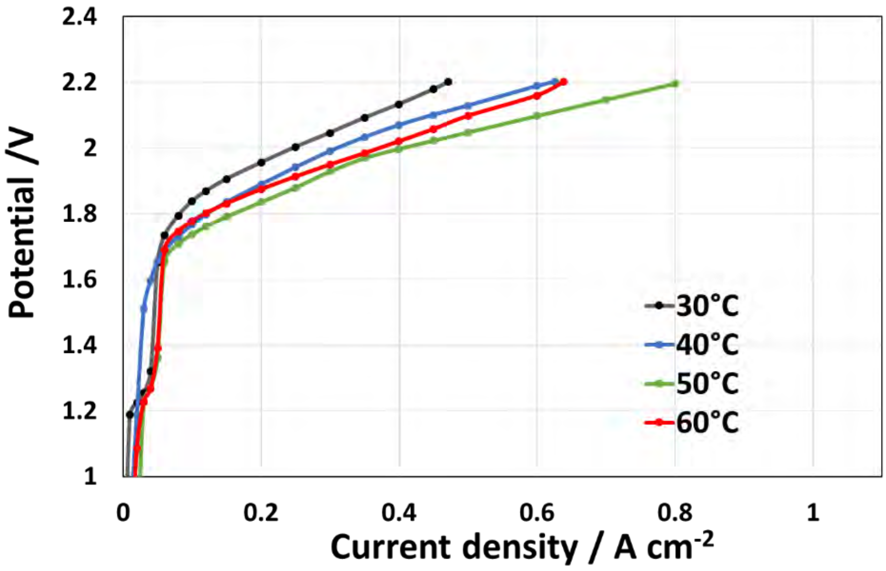

Figure 35. *Comparison of polarization* curves carried out on the cell mounting $Ni_{0.4}Cu_{0.4}Mo_{0.2}$ as cathode and NiFe oxide as anode in the temperature range 30 °C - 60 °C.

EIS analyses are reported in figure 36. As for the other experiments, this cell exhibited two well defined semicircles with the one appearing at low frequencies being highly sensible to the cell potential.

Nevertheless, in the case of this cell, the increase in temperature the series resistance as a whereas the total resistance (low frequency intercept with x-axis) showed an increase between 50 and 60 °C.

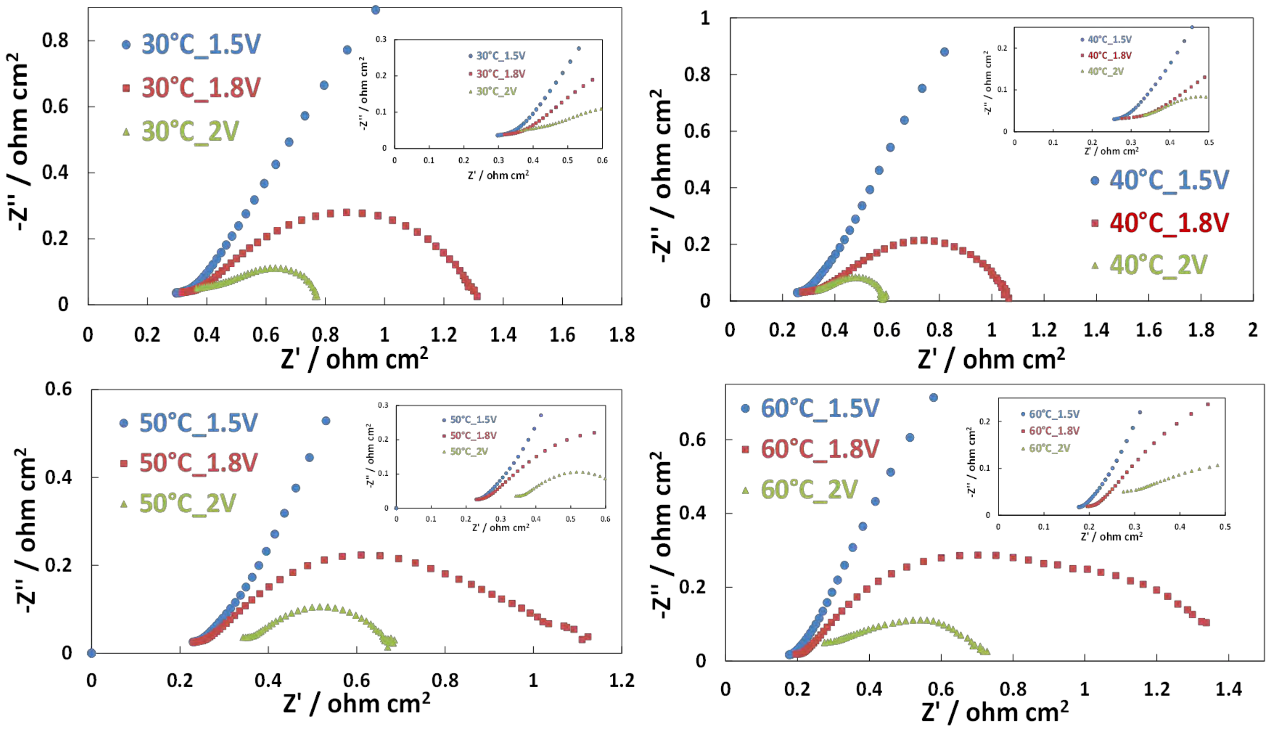

Figure 36. *The EIS of cell based on* $Ni_{0.4}Cu_{0.4}Mo_{0.2}$ *as cathode and NiFe* oxide *as anode measured at 1.5 V and 1.8 V at 30 °C (a), 40 °C (b), 50 °C (c) and 60 °C (d).*

A much recent investigation for this electrocatalyst was conducted with a KOH feed at both electrodes. Figure 37 compares the results of this new approach with the performance of the cell investigated in a conventional configuration (i.e. by feeding KOH to the anode). As observed, the presence of KOH on both sides of cell worsened the performances in terms of both activation and ohmic overpotentials.

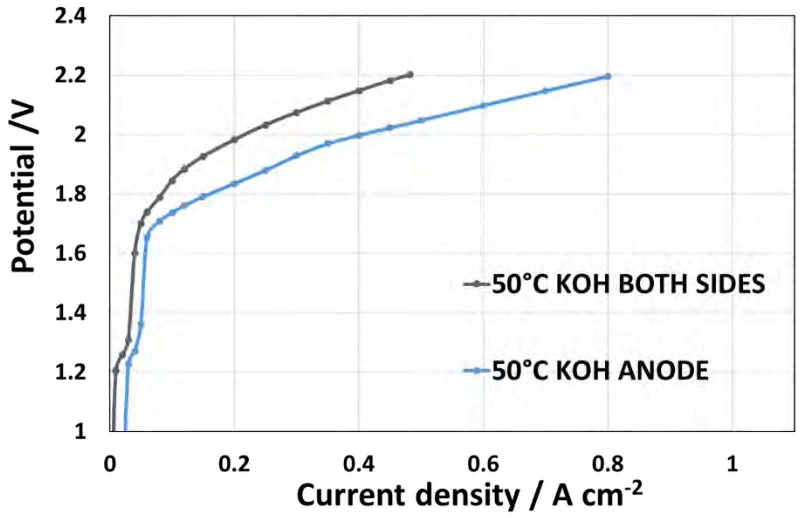

Figure 37. A comparison of polarization curves carried out on the cell based $Ni_{0.4}Cu_{0.4}Mo_{0.2}$ as cathode and NiFe oxide as anode at 50 ° by feeding KOH on one or both sides of cell.

The EIS reported in the figure 35 shows as the presence of KOH on both sides of cell caused an increase of semicircle appearing at low frequencies. Thus, hydrogen evolution is negatively affected by the presence of KOH at the cathode.

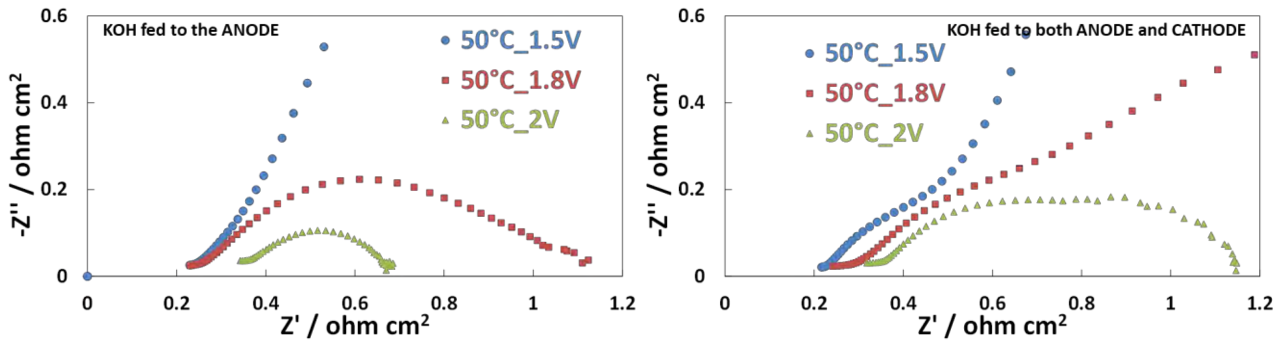

Figure 38. *The EIS of cell based* $Ni_{0.4}Cu_{0.4}Mo_{0.2}$ *as cathode and NiFe* oxide *as anode measured* at 50 °C by feeding KOH at one or both sides of cell.

Then, the cell was placed under galvanostatic mode to evaluate the durability using circulation of KOH at both sides. Figure 36 shows a slight increase in performance with time at low current density.

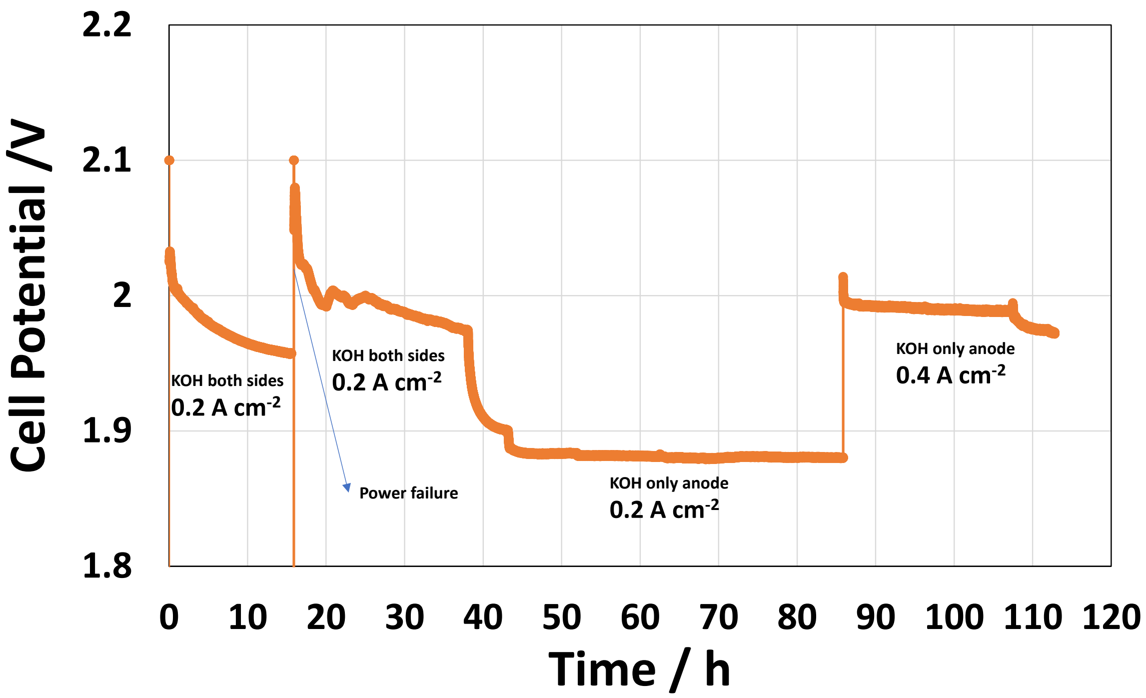

Figure 39. *Durability test conducted under galvanostatic conditions (i.e. 0.2 A cm^{-2}- 0.4 A cm^{-2}) for the cell based on $Ni_{0.4}Cu_{0.4}Mo_{0.2}$ as cathode and NiFe* oxide *as anode at 50 °C and by feeding KOH on both sides of cell.*

The EIS reported in the figure 40 shows as the presence of KOH on both sides of cell caused an increase of semicircle appearing at low frequencies. Thus, hydrogen evolution is negatively affected by the presence of KOH at the cathode.

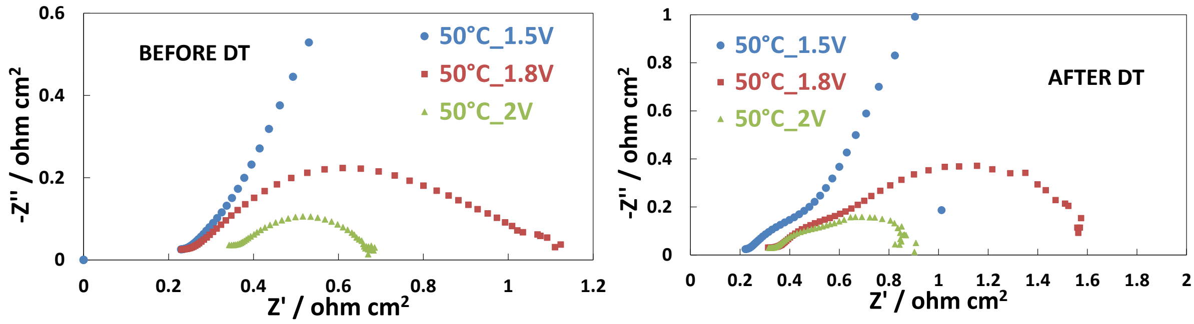

Figure 40. *The EIS of cell based* $Ni_{0.4}Cu_{0.4}Mo_{0.2}$ *as cathode and NiFe* oxide *as anode measured* at 50 °C by feeding KOH after durability test.

Figure 41 shows slight losses in performance at the end of the test and it is essentially ascribed to a lower activation constraint probably associated with the cathode reaction (i.e. hydrogen evolution). No evidence of membrane degradation was observed since the ohmic slop remained the same after the prolonged test (fig 40).

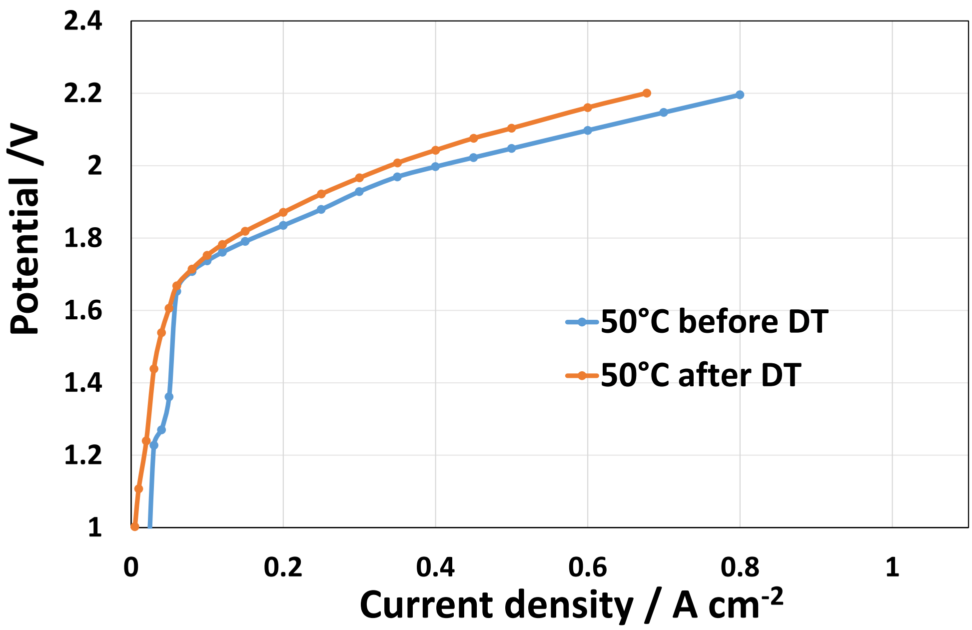

***Figure 41**. Comparison of polarization curves at the beginning and end of the Durability test conducted under galvanostatic conditions) at 50 °C with the cell based on* $Ni_{0.4}Cu_{0.4}Mo_{0.2}$ *as cathode.*

As shown in the figure 42, the best performance was observed at 50 °C for CNR-ITAE catalysts compared with commercial materials, that was an optimal compromise between the lower activation overpotential and better conductivity of membrane.

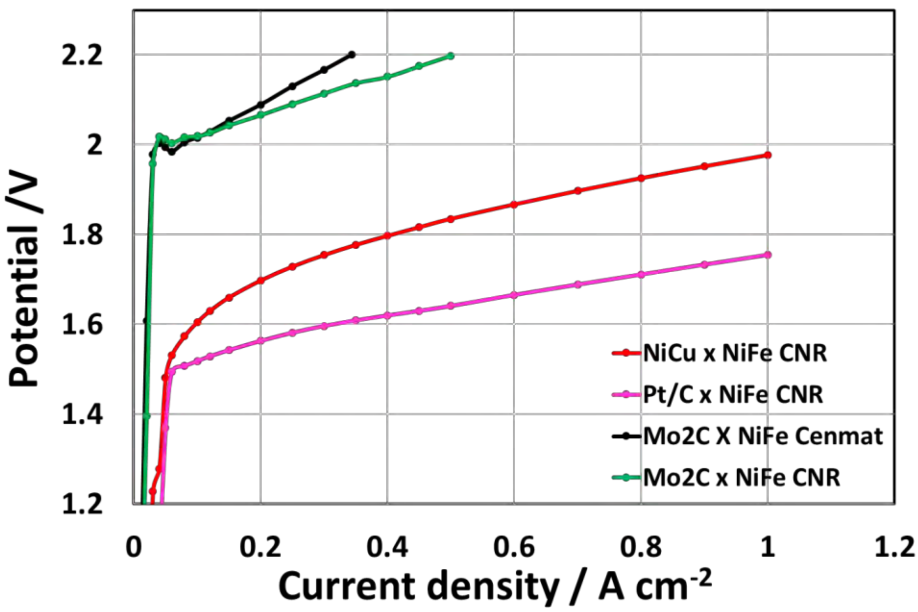

***Figure 42**. Comparison of polarization curves at 50 °C with the cell based CNR-ITAE catalysts and the cell based commercial catalysts.*

Conclusions

The performance targets have been almost achieved using NiFe oxide anode and NiCu cathode catalyst showing 170 mV and 190 mV overpotentials at 1 A cm^{-2} at 50°C with a Tafel slope indicative of a one electron transfer rate determining step.

The durability target was fully achieved with the NiFe oxide anode catalyst showing no degradation in a 1000 hrs durability test at 1 A cm^{-2}. On the contrary, the stability target was not achieved with the investigated Ni-based cathode catalysts both NiCu and NiMo.

NiCu is promising in terms of performance but shows rapid degradation whereas NiMo is not yet properly optimised with regard to composition, surface and morphology. Additional steps are necessary to improve these catalytic systems and their interface with the membrane developed in the project needs to be assessed.

References

[1] G. Abellán, E. Coronado, C. Martí-Gastaldo, J. Waerenborgh, A. Ribera, *Inorg. Chem*., 2013, 52, 17, 10147–10157

[2] L-J. Zhou, X. Huang, H. Chen, P. Jin, G-D. Li, X. Zou, *Dalton Trans.*, 2015, 44, 11592

2 Recommendation

3 Risk Register

Risk No.	What is the risk	Probability of risk occurrence[1]	Effect of risk[1]	Solutions to overcome the risk
WPx.x	Describe the risks here! And please refer to the section of the text in the document dealing with this.	Indicate the level	Indicate the level	Give a description of how to overcome the risk / describe / give possible solution(s)

1) Probability risk will occur: 1 = high, 2 = medium, 3 = Low

4 References

5 Acknowledgement

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

Project partners:

#	Partner	Partner Full Name
1	CNR-ITAE	CONSIGLIO NAZIONALE DELLE RICERCHE
2	CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE
2.1	UM	UNIVERSITE DE MONTPELLIER
3	POCELLTECH	POCELL TECH LTD
4	PV3	PV3 TECHNOLOGIES LTD
5	IRD	IRD FUEL CELLS A/S
6	HYDROGENICS	HYDROGENICS EUROPE NV
7	UNR	UNIRESEARCH BV

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