Exsolution-based nanoparticles for lowest cost green hydrogen via electrolysis

The optimal choice of PTL/electrode for usage in a combination of CCD

(Deliverable D3.3)

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NOTICES

For information, please contact the project coordinator, Elo Meier, e-mail: elo.meier@stargatehydrogen.com. This document is intended to fulfil the contractual obligations of the EXSOTHyC project, which has received funding from the Clean Hydrogen Partnership and its members, concerning deliverable D3.3 described in contract 101137604.

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Reviewer(s)

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Table of revisions

Version	Date	Description and reason	Author	Affected sections
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List of Abbreviations

AEM – anion exchange membrane

HER – hydrogen evolution reaction

HOR – hydrogen oxidation reaction

HTO – hydrogen to oxygen crossover

ISM – ion solvating membrane

OER – oxygen evolution reaction

ORR – oxygen reduction reaction

OTH – oxygen to hydrogen crossover

PGM – Platinum Group Metals

Ra-Ni – Raney-Nickel

RC – recombination catalyst

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1 Objectives

For catalyst coated diaphragms (CCDs) to function, a current must be appropriately delivered to the catalyst coating layer. For such a transfer of current usually Ni foams or felts are often used. As a Zero-Gap is used the thickness of the porous transport layer (PTL) must be optimal between the current supplier/collector and the CCD. The PTL needs to be porous to allow for gasses to leave the interface quickly, while simultaneously allowing access of the electrolyte. Furthermore, the ohmic resistance by using a PTL should not be increased too significantly, which would otherwise lead to high cell potentials, especially, at high current densities. As such the goal of this deliverable is to find a PTL which will result in optimal electrical contact between the current supplier and collector, without increasing the ohmic resistance significantly.

2 Methodology and Work done

2.1 PTLs for Zirfon UTP 500

For the application with Zirfon UTP 500 we have chosen two different thicknesses of Ni felts to compare against each other: 200 and 100 µm (sintered Bekaert CURRENTO® 2NI06-0.20 and Bekaert CURRENTO® 2NI06-0.10), which have a porosity of 83% and 66%, respectively. The performance of the PTLs against a benchmark (perforated Ni electrode) are presented in *Figure 1*. We observed that the potential was increasing with the usage of thicker Ni felts, however, the difference between 200 and 100 µm is minor as most of the electrolyte passes the electrode at the back of the cell. This also allows for high flow rates of up to 7 mL/s in the cell. We compared high and low flow rates and noticed that at really low flow rates of less than 0.5 mL/s and increase in ohmic resistance can be seen. When accounted for the internal resistance, the internal resistance corrected potential is not too dissimilar between the perforated Ni benchmark electrode and the Ni PTLs (see *Figure 2*). Especially, at high temperatures of 85 °C the differences become really minor.

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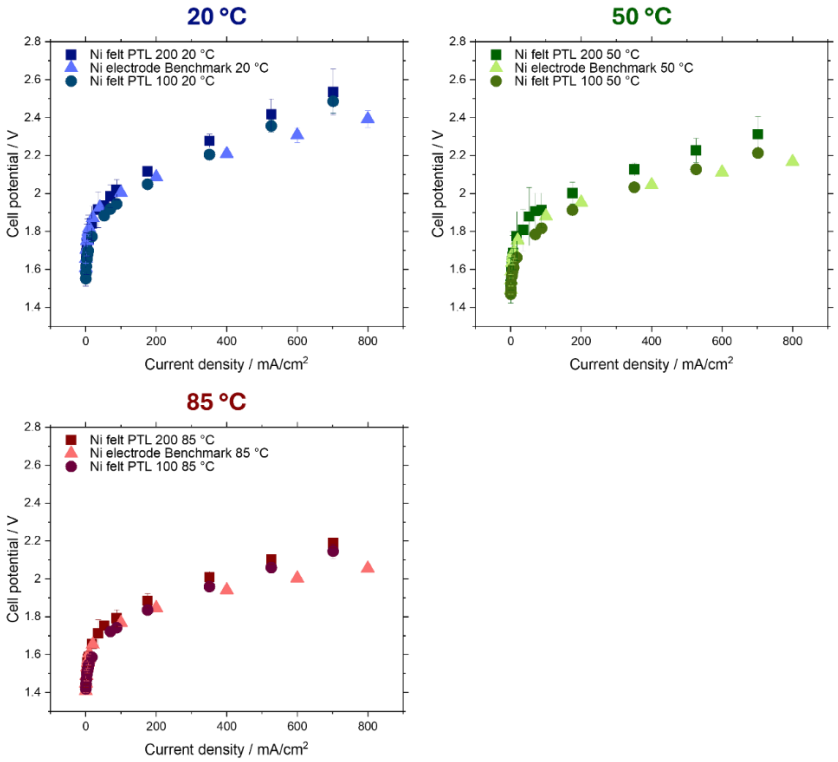

***Figure 1**. Comparison of polarization curves between a benchmark (perforated Ni electrode) and a 200 µm and 100 µm thick PTL Ni felt using 30 wt.% KOH with 50 µM electrolyte Fe.*

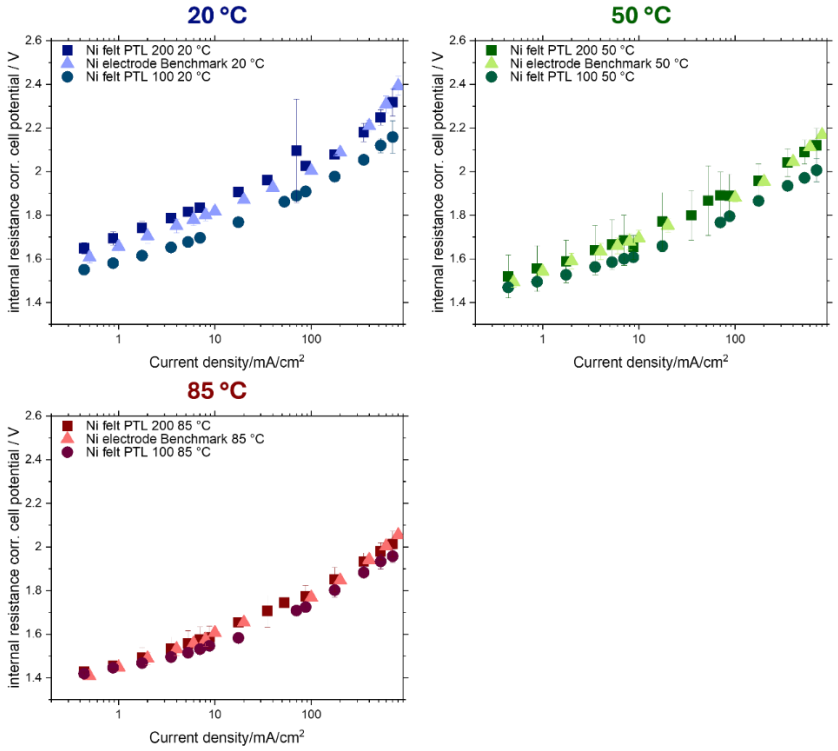

***Figure 2.** Comparison of internal resistance corrected polarization curves between a benchmark (perforated Ni electrode) and a 200 µm and 100 µm thick PTL Ni felt using 30 wt.% KOH with 50 µM electrolyte Fe.*

To ensure the best electrical contact possible, we decided to use the thicker 200 µm PTL for ensuring good contact with the CCDs (see *Figure 3*). We decided to test the electrical contact by making CCDs

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with Raney Ni and using the 200 µm PTL while applying a compression force of 2.5 Nm per screw of our cell. This would result in a force of 3125 N per screw and consecutively a contact pressure of 340.1 on the cell and 8.8 bar on the felt.

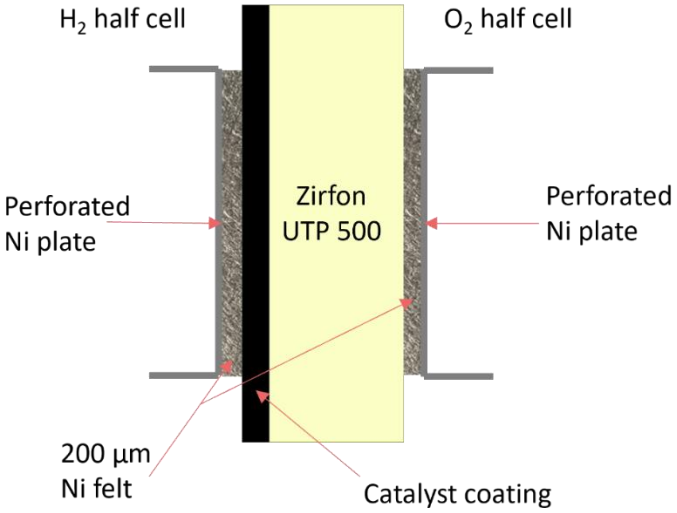

Figure 3. *Schematic representation of the CCD, PTL, electrode assembly within the flow cell.*

If there is good electrical contact between the current supplier/collector, the PTL, and the Raney Ni CCDs, we would observe a decrease in cell potential due to the increase in available catalytic surface area from the Raney Ni. We did see that consistently throughout all temperatures as can be observed in *Figure 4*. With increasing Raney Ni loading the internal resistance corrected polarization curves are shifted to lower values, while being parallel to each other. As Raney Ni and Ni PTL are made from the same electrochemical catalyst, the kinetics of the hydrogen evolution reaction (HER) will not change (the oxygen evolution reactions (OER) stays constant between those experiments).

However, the available surface area for electrochemical reactions to occur is increasing with a higher loading of Raney Ni, which in turn increases the exchange current density. As the exchange current density is directly related to the available surface area/active surface sites, the entire polarization curve is shifted.

This way we were able to confirm that using the 200 µm Ni PTLs we achieved good electrical contact. In further studies, we did also confirm that the electrical contact between Pt CCDs and FeNi layered double hydroxides was good as well.

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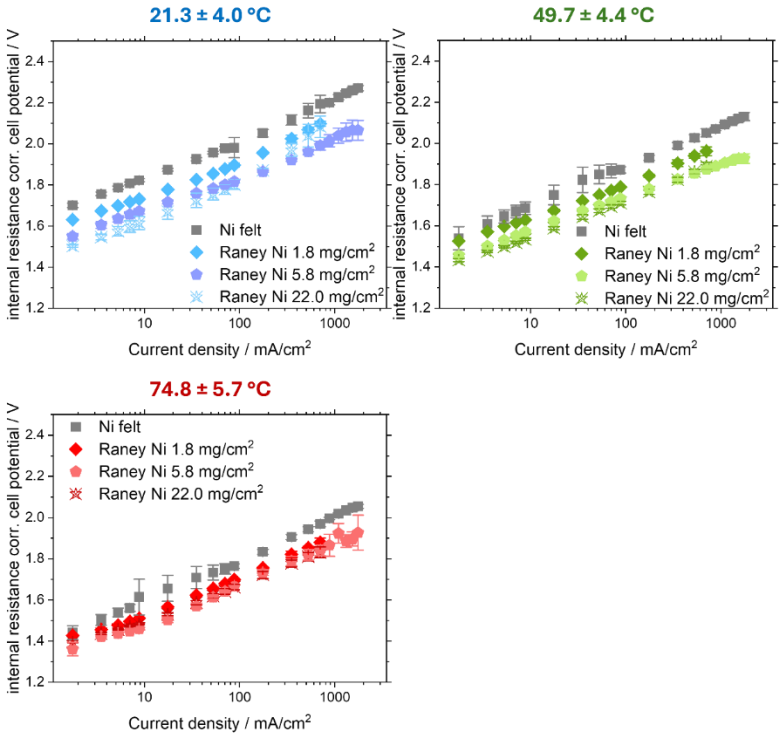

Figure 4. *Polarization curves showcasing the total internal resistance corrected cell potential of benchmark Ni felt and Zirfon UTP 500 and CCDs coated with varying loadings of Raney Ni applied for the HER in 27 wt.% KOH with 50 µM Fe.*

2.2 PTLs for Zirfon UTP 220

We conducted experiments for CCDs on Zirfon UTP 220. As the dimensions of the flow cell stay constant, we needed to use Ni PTLs of different thickness for these kinds of measurements. The diaphragm becomes 280 µm thinner, which needs to be compensated for with thicker PTLs. The total thickness of 2x 200 µm PTLs and a Zirfon UTP 500 is 900 µm. There are no PTLs available with a thickness of 340 µm, which would be the exact thickness needed to compensate for the thinner Zirfon UTP 220. Thus, we decided to use 500 µm thick PTLs (Currento® PTL Ni-80/500), which resulted in a total thickness of the 2x 500 µm PTLs and the Zirfon 220 of 1220 µm. This is reasonably thicker, however, thich high porosity of 80% between the individual fibers should allow for compression compensation.

When we compared the internal resistance corrected polarization curves between stencil coated Zirfon UTP 500 and Zirfon UTP 220, we can see especially at elevated temperatures that they fit each other quite well (see *Figure 5*). Thus, we can see that the using a 500 µm thick Ni felt for Zirfon UTP 220 ensured good electrical contact to the CCDs.

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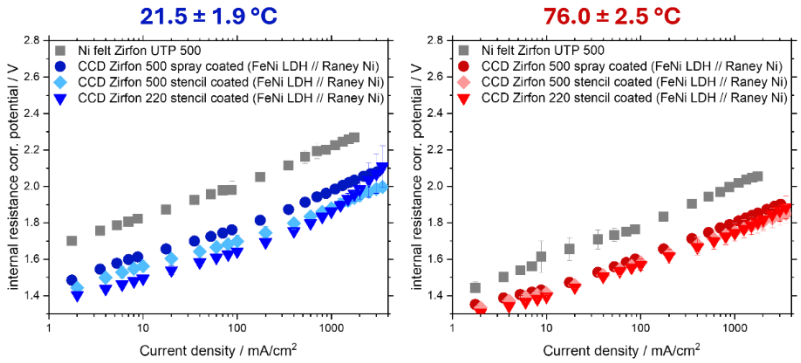

Figure 5. *Internal resistance corrected polarization curves obtained for benchmark Ni felts and Zirfon UTP 500, compared to catalyst coated diaphragms (Zirfon UTP 220 and 500) at varying temperatures in 30 wt.% KOH. 50 µM Fe concentration was used in the stencil coated CCD experiments, while a 500 µM Fe concentration was used for the spray coated CCD.*

Although we used a thicker PTL, it did not increase the ohmic resistance drastically, as we still observe an ohmic resistance drop, that can be well connected to the usage of a thinner diaphragm when going from Zirfon UTP 500 to Zirfon UTP 220 (see *Figure 6*). The ohmic area resistances of exclusively the diaphragms for Zirfon UTP 500 and Zirfon UTP 220 at 80 °C in 30 wt.% KOH are 0.10 and 0.05 Ω cm^2, respectively. Both of our measured values are increased by around 0.03 to 0.05 Ω cm^2, which is reasonable due to extra ohmic resistances of the flow cell system arising from contact, electrolyte, and bubble resistances.

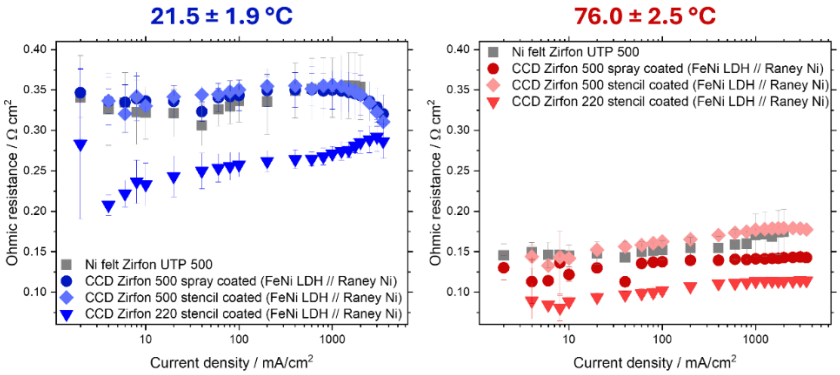

Figure 6. *Ohmic area resistances obtained for benchmark Ni felts and Zirfon UTP 500, compared to catalyst coated diaphragms (Zirfon UTP 220 and 500) at varying temperatures in 30 wt.% KOH. 50 µM Fe concentration was used in the stencil coated CCD experiments, while a 500 µM Fe concentration was used for the spray coated CCD.*

In conclusion, we can state that we found an optimal PTL to ensure good electrical contact between the current supplier/collector and the CCD. This was possible not only for Zirfon UTP 500, but also Zirfon UTP 220.

3 Deviations

There are no significant deviations from the initial workplan, and all the expected result have been achieved.

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4 Conclusions

Within this deliverable we were able to find PTLs that are suitable to use for Zirfon 500 and Zirfon 220. Ni felts have proven to give consistent results, without leading to a significant increase in ohmic resistance. Further, we achieved good electrical contact between the PTL and Raney Ni, nanoparticular Pt, carbon supported Pt, and FeNi layered double hydroxide CCDs. This shows, that the PTL could be administered universally, but attention needs to be paid that the thickness of the PTL corresponds well to the dimensions and the Zero-Gap of the cell. If the concept is transferred to industrial usage, the PTLs to be used need to be slightly bigger than the expected gap between current supplier and collector, so that the PTL is slightly compressed and touches both the CCD and the current supplier/collection perfectly.

For upscaling we seek to apply the same PTLs in the Stargate electrolyser system. The main challenge that needs to be overcome here is the large gap between bipolar plate and the diaphragms, which spans around 10 mm. Here, an elastic element would prove useful, as it can conduct the current efficiently and contact both bipolar plate as well as diaphragm the diaphragm-PTL interface.

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