Water electrolysis at elevated temperatures

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Outline

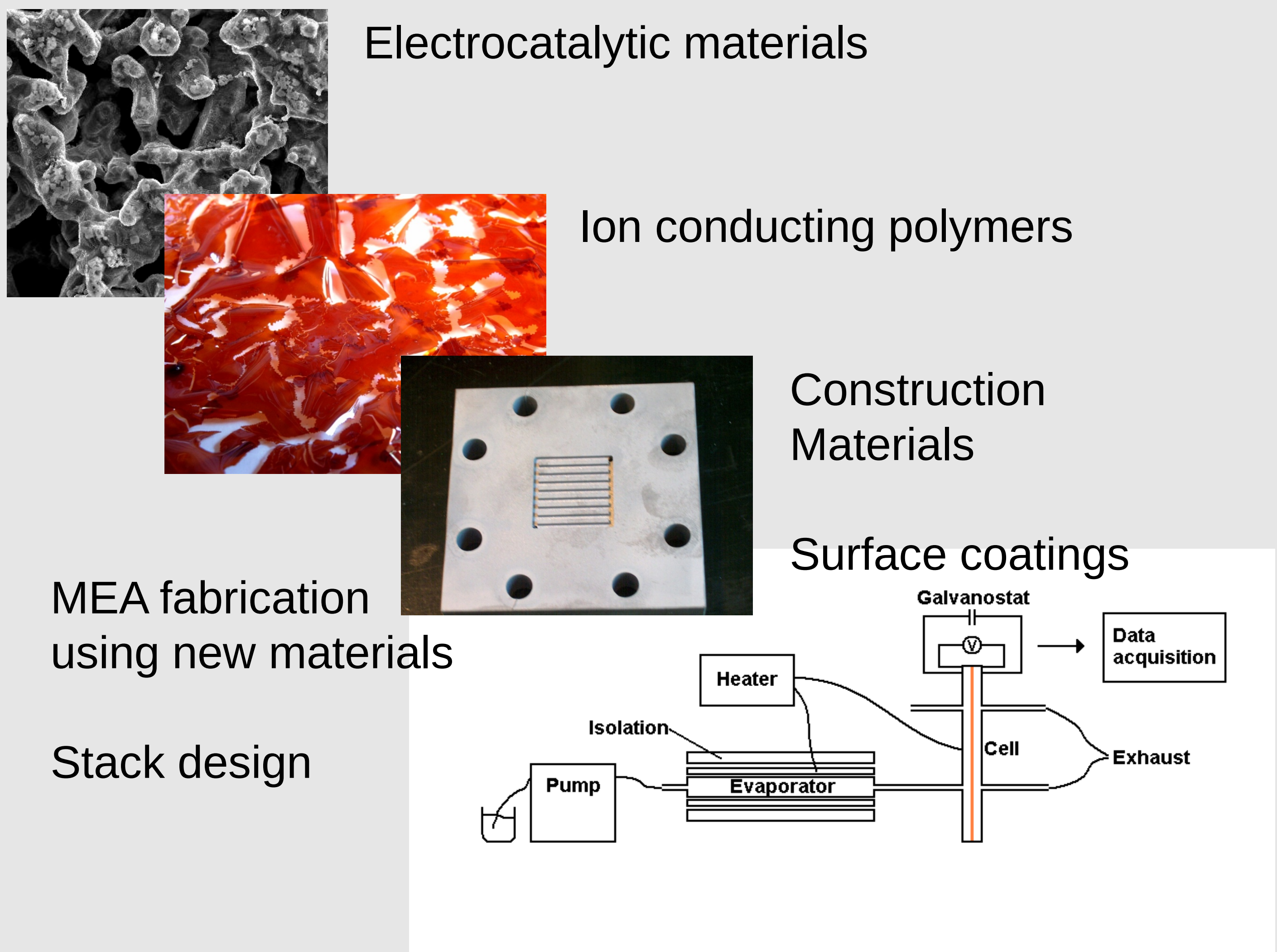
Today the world is on the edge of the hydrogen society. So it is important to find a way to produced clean and sustainable hydrogen. One way is to use electrolysis, and get very pure hydrogen from water. A major part of the hydrogen production cost by electrolysis is energy consumption. Therefore, there is a large potential in improving the efficiency of the electrolysis in order to make hydrogen produced this way cheaper.

The strategic way to reach this goal is to increase the operating temperature of the Proton Exchange Membrane (PEM) electrolyser.

The energy efficiency will be significantly improved because of the decreased thermodynamic energy requirement, enhanced electrode kinetics, and the possible integration of the heat recovery.

To achieve this strategic target, it is critical to develop and improve fundamental materials such as anodic catalysts, membranes, current collectors, bipolar plates, and other construction materials. The final target of the project, a 1 kW prototype PEM steam electrolyser will be designed, constructed and tested for demonstration.

Work tasks



Electrocatalytic materials

Ion conducting polymers

Construction
Materials

Surface coatings

MEA fabrication
using new materials

Stack design

Figure 1: Scheme for work tasks during project

Corrosion tests

The most widely used bipolar plate material is titanium, which is ideal in terms of corrosion resistance and conductivity[1-3]. Although, the corrosion resistance decreases significantly in acidic media at temperatures above 80°C. A possible alternative for titanium bipolar plates at elevated temperatures can be the use of iron or nickel based alloys[4]. The Energy and Materials Science Group at Department of Chemistry has been involved in PEM fuel cells activity (operated at elevated temperatures of up to 200°C) for a number of years. The most successful membrane system so far has been polybenzimidazole (PBI) doped with phosphoric acid[5]. Hence, an 85% solution of phosphoric acid was used as an electrolyte in our experiments to simulate the PEM water electrolyser anode compartment.

The experimental set consists of a specially designed corrosion cell (Figure 2), which presents a typical three-electrode electrochemical cell. Tests were performed at 30°C, 80°C and 120°C at ambient pressure and atmosphere.

From Figure 2:
R.E. : Reference electrode
C.E.: Counter electrode
W.E.: Working electrode

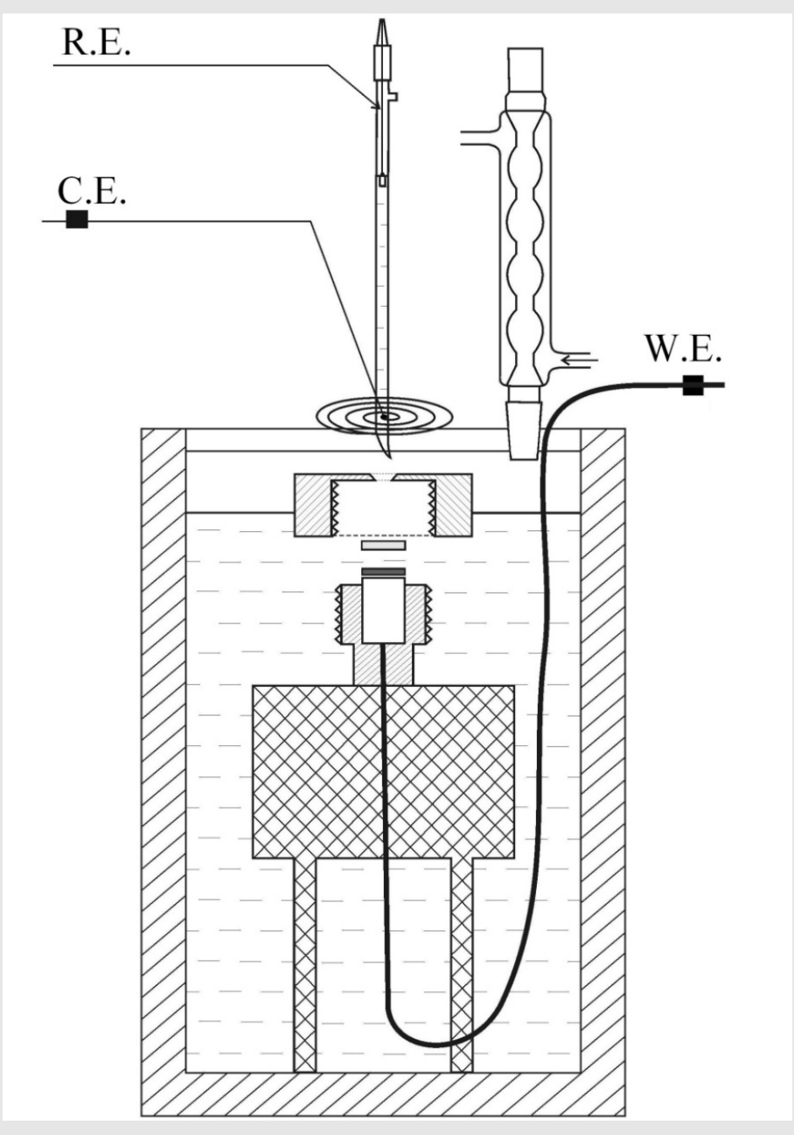


Figure 2: Scheme for corrosion test rig

Corrosion test results

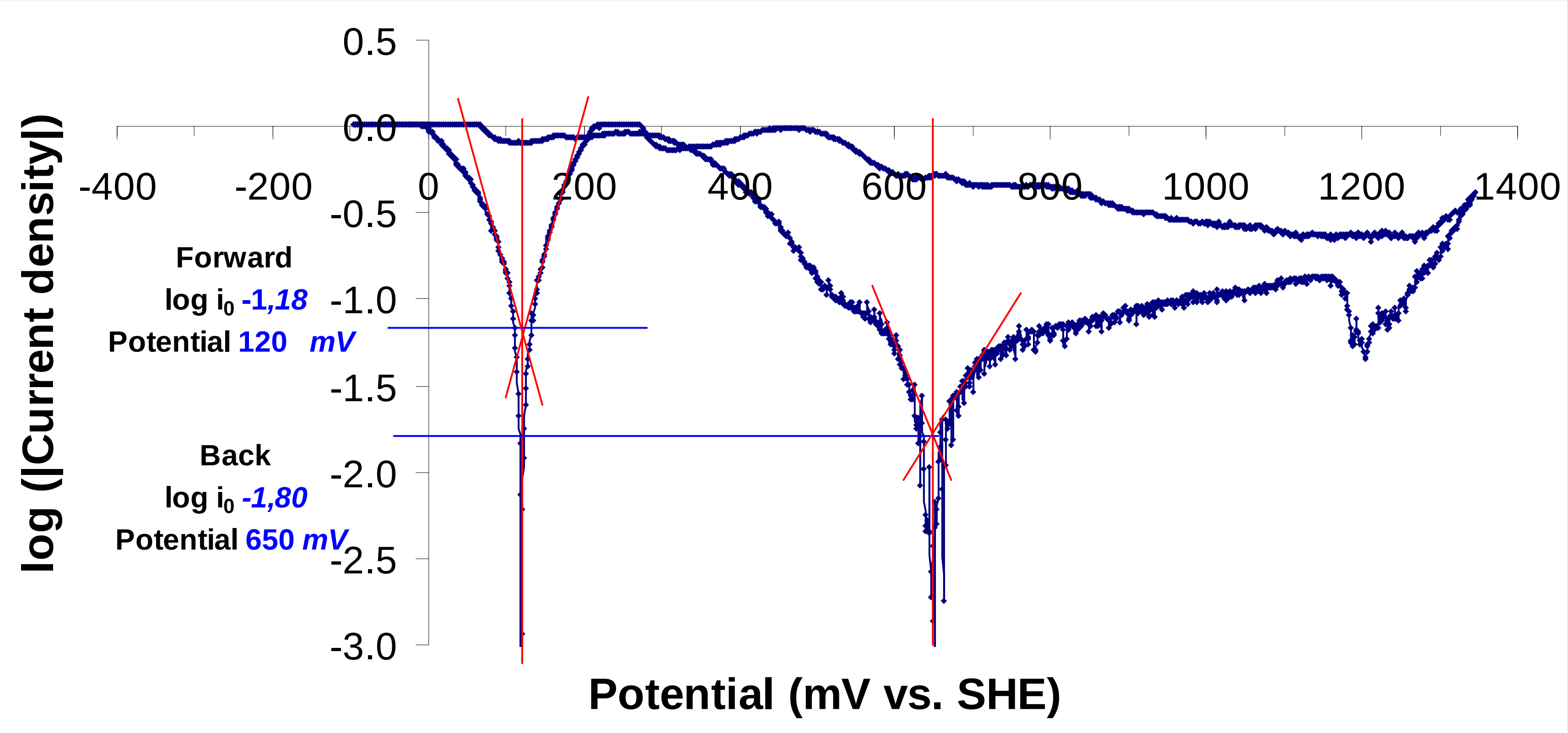


Figure 3: Tafel plot for Incoloy® (Alloy 825), temperature 120°C, scan rate 1mV/s

Figure 3 shows a typical Tafel plot for the tested alloys. In Table 1 the corrosion currents are listed for the tested alloys. It is shown that the most corrosion resistant alloy is Hastelloy® (Alloy C276)

	T=80°C	T=120°C
	i_{corr} mA/cm²	
Stainless steel AISI 316L	6.166×10^{-2}	1.778×10^{-1}
Stainless steel AISI 321	5.623×10^{-2}	1.122×10^{-1}
Stainless steel AISI 347	1.778×10^{-1}	3.981×10^{-1}
Inconel® (Alloy 625)	1.778×10^{-2}	1.122×10^{-1}
Incoloy ® (Alloy 825)	1.259×10^{-2}	6.607×10^{-2}
Hastelloy® (Alloy C276)	1.122×10^{-3}	5.623×10^{-2}

Table 1: Corrosion currents for different alloys at 80°C and 120°C

Corrosion resistance at T=120 °C increases in the following sequence: AISI 347<AISI 316L<AISI 321<Inconel® Alloy 625<Incoloy® Alloy 825 <Hastelloy® Alloy C276.

Development of Nafion® based composite membranes

Nafion® membranes loaded with zirconium phosphate (ZrP) is known to have better performance in PEM fuel cells operating above 100°C compared to pure Nafion® membranes[6]. H_3PO_4 doped polybenzimidazole (PBI) has emerged as another promising electrolyte system for PEM fuel cells operating at high temperatures[7]. In the development of a composite membrane for a PEM steam electrolyser these two concepts have been combined. A four component composite membrane of Nafion®, PBI, ZrP and H_3PO_4 is under active development in our laboratory. A Nafion®-PBI membrane is prepared by solution casting. The choice of Nafion® counter cation significantly affect the appearance of the resulting blend membrane. Subsequently, zirconium(IV) is loaded by ion exchange followed by precipitation of ZrP and H_3PO_4 doping. The prepared composite membrane has reasonable conductivity even at very low H_3PO_4 contents at 120°C, see Figure 4.

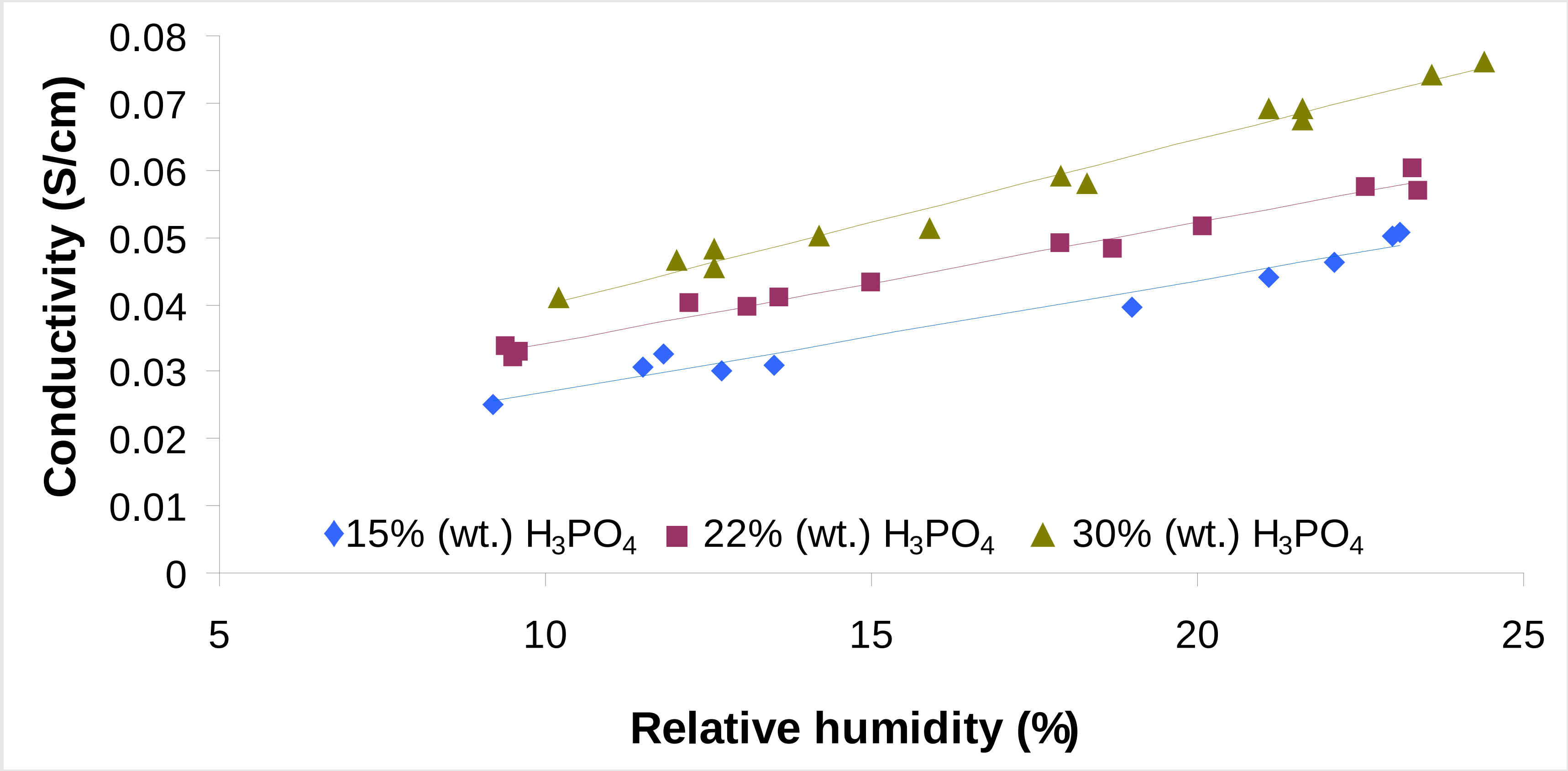


Figure 4: Nafion®, PBI, ZrP (wt. ratio 77:10:13) composites Conductivity at 120°C

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WELTEMP project partners

Technical University of Denmark (Project coordinator)	Denmark
Institute of Chemical Technology Prague	Czech Republic
The Norwegian University of Science and Technology	Norway
IHT Industrie Haute Technologie SA	Switzerland
Acta S.p.A.	Italy
Tantalum Technologies A/S	Denmark
Danish Power Systems ApS	Denmark
Institute of Macromolecular Chemistry ASCR	Czech Republic

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