DTU Energy Conversion
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Corrosion behaviour of construction materials for high temperature PEM water electrolysers

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Introduction

Elevated working temperatures in PEM water electrolysis involve increased demands for corrosion resistance of catalysts and current collectors. High temperature PEM cells cannot be built from the same materials as a cell working below 100 °C. Elevated temperatures create severe corrosion media for components in the cell. The anodic compartment of electrolyser is expected to have stronger corrosive conditions than cathodic due to high positive polarization in combination with presence of evolving oxygen. This demands further development of all materials from which electrolyser cells are built.

Experimental part

In this work different types of corrosion resistant stainless steels, Ni-based alloys as well as titanium and tantalum were evaluated as a possible metallic bipolar plate and construction material in terms of corrosion resistance in simulated conditions of high temperature proton exchange membrane (PEM) water electrolyser (HTPEMWE).

The experiments were performed in the cell (Figure 1), simulating the conditions of high temperature PEM water electrolysis cell.

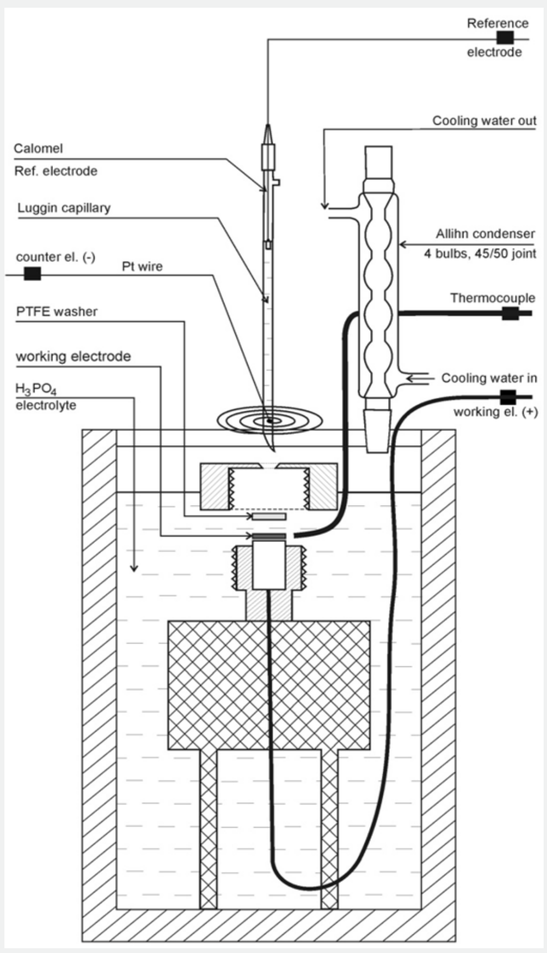

Figure 1. A cell, used to estimate the corrosion resistance of materials[1].

All samples were proned to anodic polarization in 85% phosphoric acid electrolyte solution. Platinum and gold plates were tested for the valid comparison. Steady-state voltammetry was used in combination with scanning electron microscopy and energy-dispersive X-ray spectroscopy[2].

Discussion and conclusions

Corrosion resistance of materials was assessed using the special case of the Butler-volmer equation of kinetics of electrode reactions, which was applied to corrosion (scan speed 1 mV/s)[3].

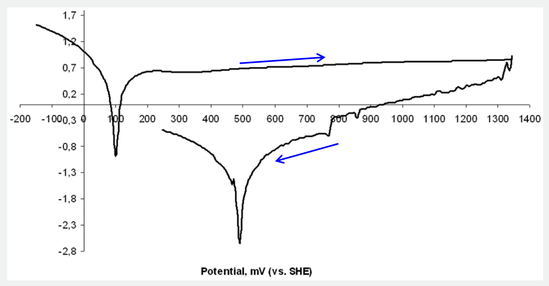

Figure 2. A Tafel plot for Inconel625, 120 °C.

Results show that stainless steels are the most exposed to corrosion under strong anodic polarization.

Among alloys, Ni-based showed the highest corrosion resistance in the simulated media.

However, among all tested materials, Ta-CVD coating on SS316L had the best stability. It was also found that Ti can not be used in phosphoric acid doped electrolytes (in contrast to Nafion-based systems).

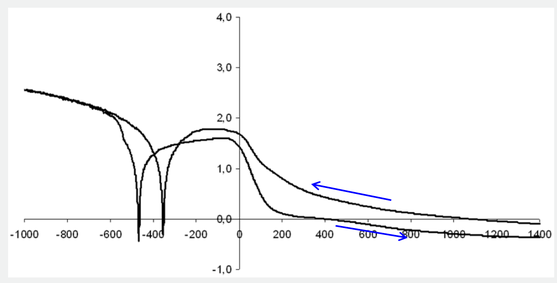

Figure 3. A Tafel plot for Ti, 120 °C.

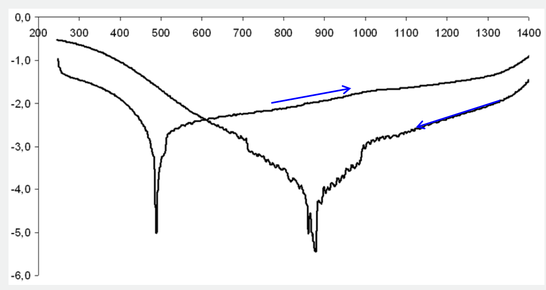

Figure 4. A Tafel plot for Ta, 120 °C.

Alloy type	Ni	Co	Cr	Mo	W	Fe	Si	Mn	C	Al	Ti	Other	Nb+Ta
AISI 316L	10.0-13.0	-	16.5-18.5	2.0-2.5	-	Bal.	1.0	2.0	0.03	-	-	N<0.11	-
AISI 321	9.0-12.0	-	17-19	-	-	Bal.	1.0	2.0	0.08	-	0.4-0.7	-	-
AISI 347	9.0-13.0	-	17-19	-	-	Bal.	1.0	2.0	0.08	-	-	-	0.8
Incoloy®825	44	-	21.5	3.0	-	27	0.3	1.0	0.05	0.1	1.0	Cu: 2.0	-
Hastelloy®C-276	57	2.5	15.5	16.0	3.75	5.5	0.08	1.0	0.02	-	-		-
Inconel®625	62	1.0	21.5	9.0	-	5.0	0.5	0.5	0.1	0.4	0.4	-	3.5

Table 1. Chemical composition of the tested alloys (elements, wt.%).

Table 2. Corrosion rates at 80 and 120 °C (calculated from the backward polarization slope).

Sample	i_{corr}, mA/cm² (CR, mm/year) 80 ˚C	120 ˚C
Stainless steel AISI 316L	6.3×10^{-2} (0.73)	1.3×10^{-1} (1.46)
Stainless steel AISI 321	1.0×10^{-2} (0.12)	4.0×10^{-2} (0.46)
Stainless steel AISI 347	2.5×10^{-2} (0.29)	7.9×10^{-2} (0.92)
Incoloy®825	2.0×10^{-2} (0.23)	3.2×10^{-2} (0.37)
Hastelloy®C-276	4.0×10^{-3} (0.05)	2.4×10^{-2} (0.28)
Inconel®625	5.3×10^{-4} (<0.01)	2.0×10^{-2} (0.23)
Titanium		6.3 (73.3)
Tantalum		6.3×10^{-5} (<0.001)

Corrosion stability increases in the following row:

Ti < AISI316L < AISI347 < AISI321 < Incoloy®825 < Hastelloy®C276<Inconel®625 < Ta

References

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3. Annual book of ASTM standarts 10.05, g3-89, p. 42-47.