Corrosion issues of bipolar plate materials used in proton exchange membrane water electrolysers

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Renewable hydrogen obtained by water electrolysis is foreseen to have a major role in transitioning from an entirely fossil fuel-based economy to zero-emission technologies, with the goal of decarbonizing the transport and energy sector [1,2]. Amongst different technologies, proton exchange membrane (PEM) electrolysis is a promising technology for producing sustainable hydrogen, however its critical limitation is the usage of expensive electrocatalysts and construction materials, resulting in high hydrogen production costs [3]. The U.S. Department of Energy has established technical targets for PEM electrolysis, including stack-level capital costs, which should decrease from 450 to 100 \$/kW by 2026, with a final target of 50 \$/kW [4]. To meet these targets, low-cost alternative materials, particularly for bipolar plates (BPPs) and porous transport layers (PTLs) are urgently required. Yet, corrosion issues occurring especially at the anode side, restrict the use of more affordable alternatives to titanium. To address this issue, it is proposed to use stainless steel protected by Ti coatings. However, austenitic steels are expensive due to their high nickel content, and our research has thus focused on the high chromium ferritic stainless steels used as a support for BPPs.

In our study, we used scanning electrochemical microscopy (SECM) to investigate the localized corrosion behaviour of ferritic stainless steel AISI 446 and Ti-coated AISI 446, as candidate materials to replace titanium in BPPs construction for PEMWE. Typically, corrosion resistance is assessed using conventional electrochemical methods, which can only provide a macro-scale view of the corrosion process, as opposed to SECM, which allows for high sensitivity localization of corrosion sites. We used the SECM feedback mode with a redox mediator to evidence the passive layer formed at open-circuit potential on the surface of bare and Ti-coated AISI 446. Since BPPs experience high anodic potentials during operation, the samples were also anodically polarized to evidence the localized corrosion phenomena.
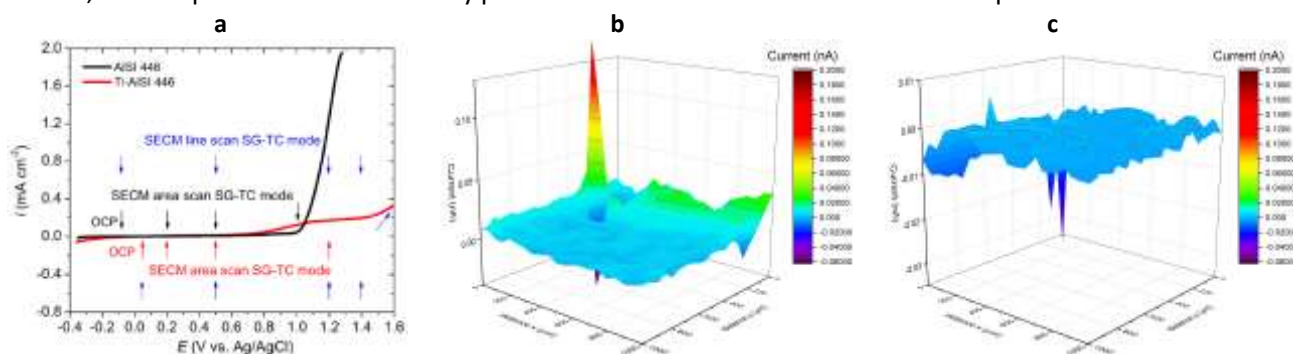

Figure 1. Potentiodynamic polarization curves at 1 mV/s scan rate (a); SECM area scans of uncoated AISI 446 at 1.0 V vs. Ag/AgCl (b) and of Ti-coated AISI 446 at 1.2 V vs. Ag/AgCl (c) in 0.1 M Na_2SO_4

The uncoated AISI 446 substrate is corrosion resistant in Na_2SO_4 solution up to an anodic potential of 1.0 V vs. Ag/AgCl, where the onset of localized corrosion is detected simultaneously with oxygen evolution reaction. The Ti-coated AISI 446 sample exhibits improved corrosion resistance, with no indication of iron (II) ion generation, even at anodic potentials of 1.2 V vs. Ag/AgCl, where only oxygen formation is observed. The results show that AISI 446 is susceptible to localized corrosion at lower anodic potentials than previously detected by conventional electrochemical methods. A thin Ti coating, deposited by magnetron sputtering, provides excellent corrosion resistance, allowing AISI 446 to be used for manufacturing BPPs.

References
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