Characterizing Protective Coatings for PEMFC Bipolar Plates : Transitioning from Stainless Steel to Aluminum Substrates

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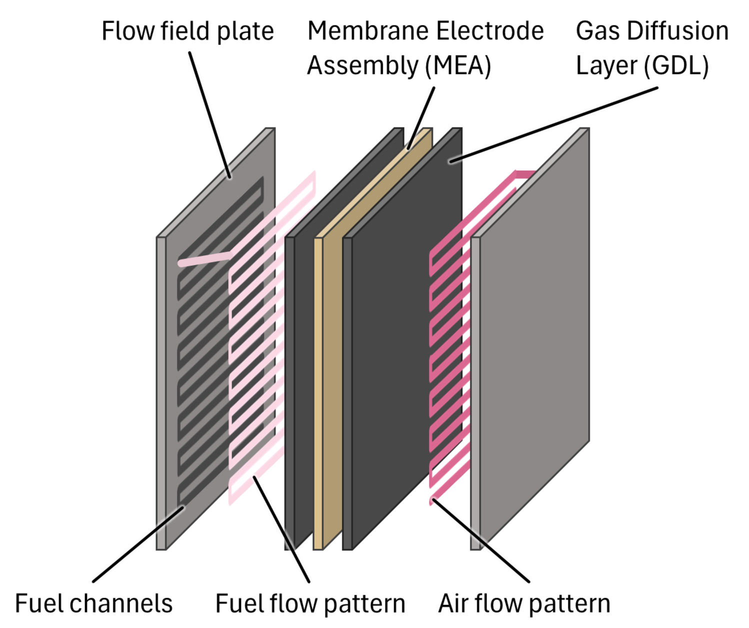
Context

Proton Exchange Membrane Fuel Cells (PEMFCs) convert hydrogen and oxygen into electricity and water. They are compact, efficient, and can participate to decarbonizing transport and stationary power. The PEMFC stack consists of a membrane-electrodes assembly (MEA), where the electrochemical reactions occur, gas diffusion layers, and bipolar plates. The latter are essential components, responsible for gas distribution, current conduction, and water management, and can account for up to 80% of the stack's total weight. Stainless steel is widely used for bipolar plates due to its strength and corrosion resistance. However, to lower both the weight and the production costs, aluminum emerges as an attractive alternative thanks to its low density and affordability. One of its major drawbacks is its poor corrosion resistance in the acidic and humid environment of the fuel cell. This poster presents the characterization of a protective coating, originally effective on stainless steel, now applied to aluminum substrates.

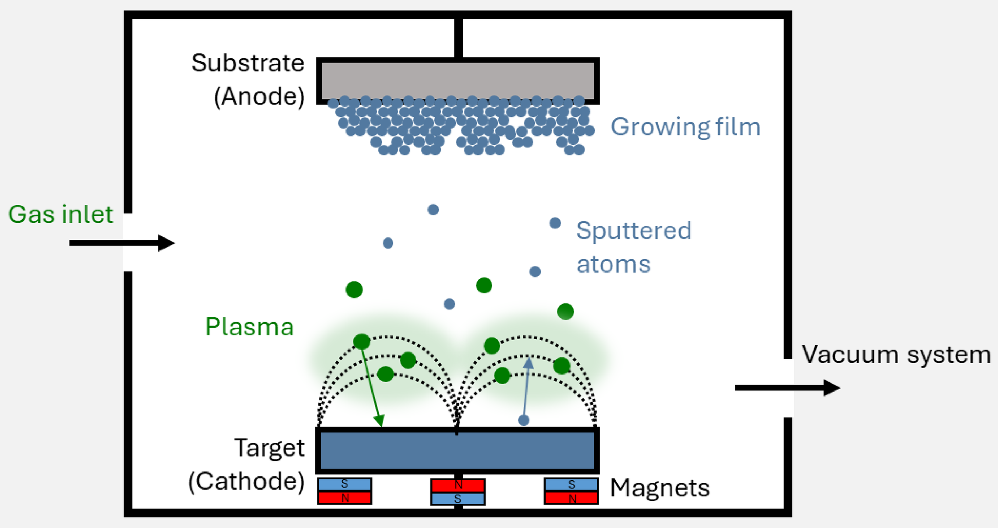


Coating Deposition

A Cr/C coating was deposited by magnetron sputtering on aluminum AA1100 and stainless steel 316L.

- Cr deposition with Ar/C_2H_2 atmosphere
- Substrate cleaning in ultrasonic baths + plasma etching

➤ No parameter optimization was performed in this study, although deposition parameters significantly affect coating adhesion, morphology, and performances.
Instead, parameters previously validated for stainless steel were directly applied to assess their transferability to aluminum.



X-ray Photoelectron Spectroscopy & Optical Microscopy

Experimental Conditions

- Corroded coating on aluminum and on stainless steel;
- XPS K_α (Thermo Scientific), spot size 250 µm, snapshot mode, pass energy 151.2 eV.

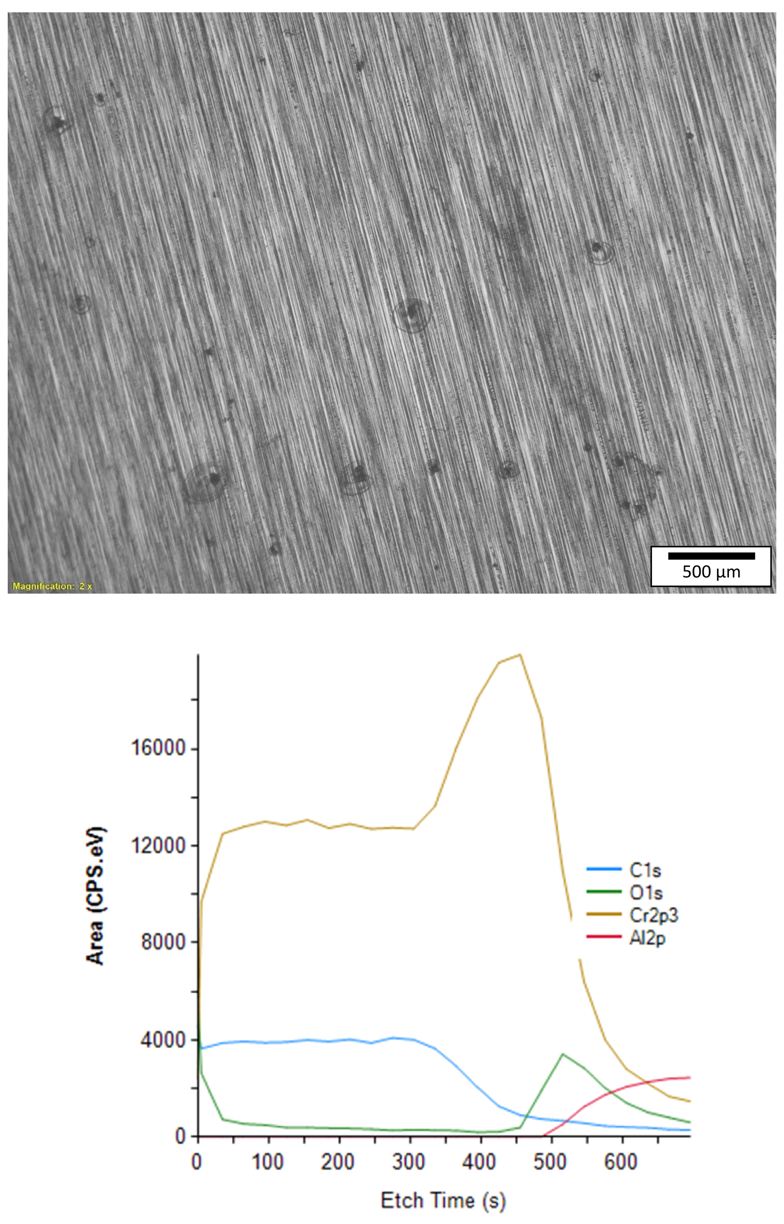
Observations - Aluminum

- Visible localized pitting corrosion;
- XPS depth profile shows high oxygen concentration at coating/substrate interface;
- Indicates poor corrosion resistance.

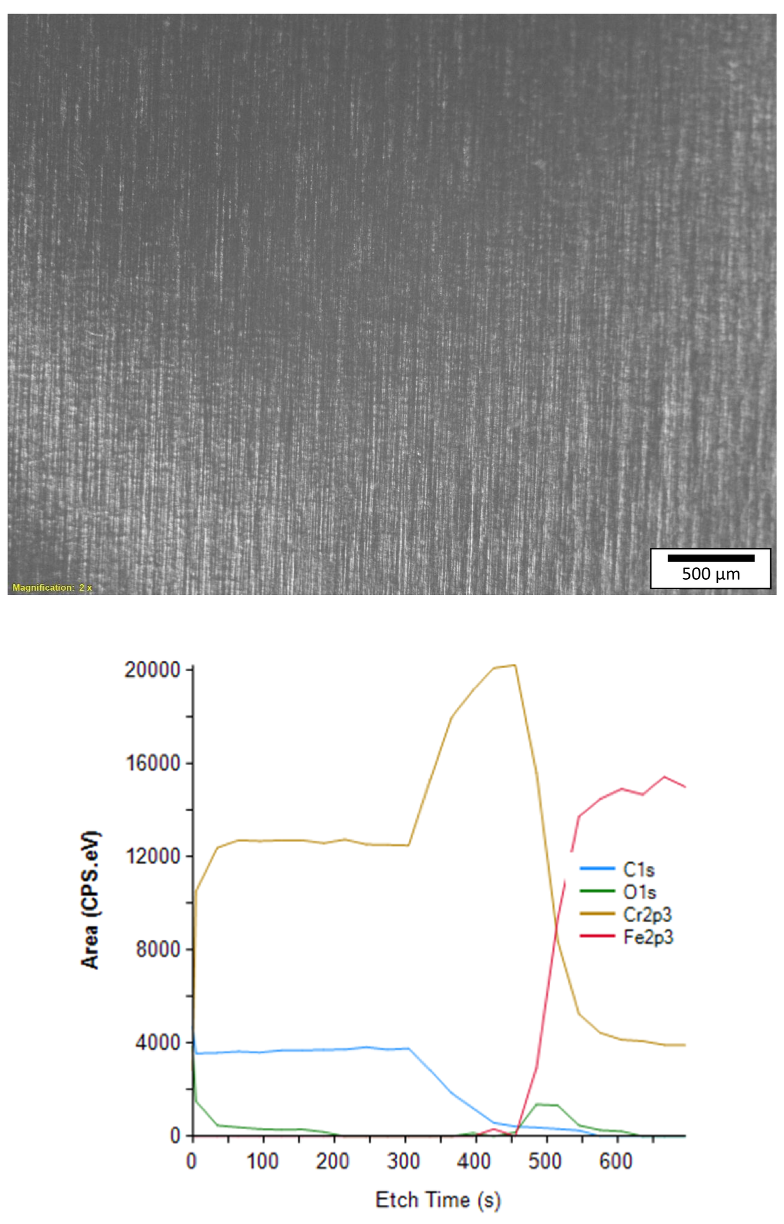
Observations - Stainless Steel

- No significant surface degradation;
- Lower oxygen signal at interface;
- Suggests better interfacial stability and corrosion resistance.

Corroded coating on aluminum



Corroded coating on stainless steel



Electrochemical Characterization

Corrosion Characterization

Experimental Conditions

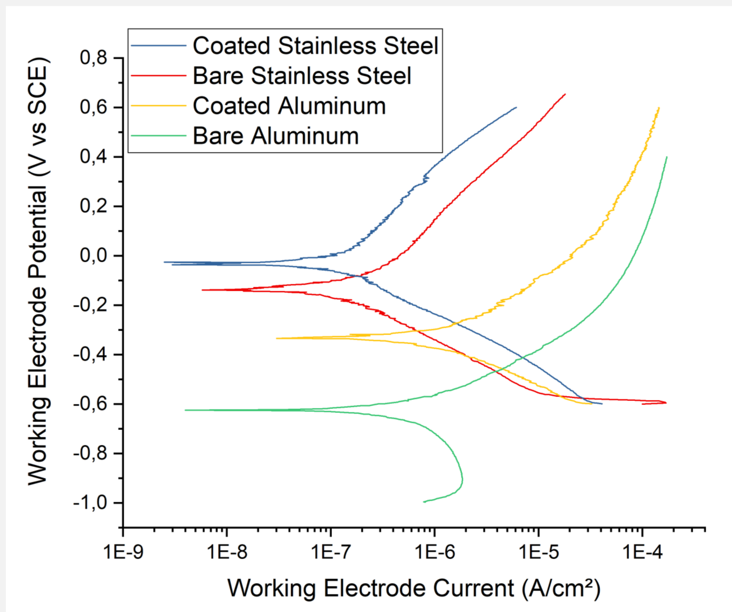
- Aqueous H_2SO_4 solution (pH = 3) at 60 °C, N_2 bubbling to simulate the anode side of a PEMFC. Size of the working electrode : 10cm².
- Potentiodynamic polarization performed from –0.6 V to +0.6 V vs. SCE.

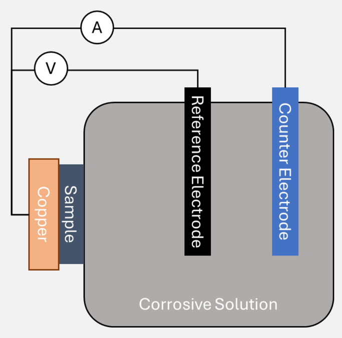
Indicators

- Higher corrosion potential (E_{corr}) → more noble behavior → better corrosion resistance.
- Lower corrosion current density (I_{corr}) → slower corrosion rate → better corrosion resistance.

Results

Surface coatings significantly improve corrosion resistance for both aluminum and stainless steel. Stainless steel shows superior electrochemical stability vs. aluminum.





Sample	Corrosion		ICR
	E_{corr} (V)	I_{corr} (µA/cm²)	R_{mean}(mOhm.cm²)
Coated Stainless Steel	-0.05	0.12	9 +/- 2.7
Stainless Steel	-0.19	0.18	18 +/- 1.7
Coated Aluminum	-0.36	1.07	38 +/- 2.0
Aluminum	-0.62	0.31	52 +/- 11.0

Interfacial Contact Resistance (ICR)

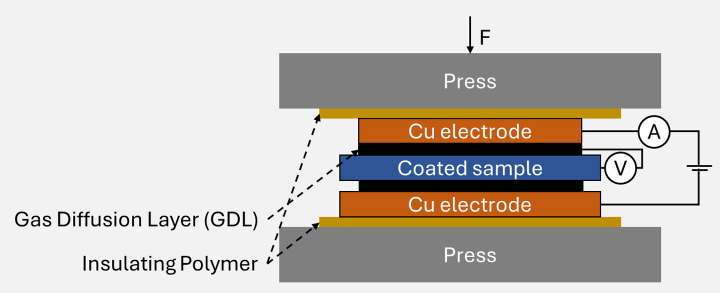
Goals

- Evaluate Interfacial Contact Resistance (ICR) between Gas Diffusion Layer (GDL) and coating before and after coating deposition (pre-corrosion);
- Assess coating's electrical conductivity and its effect on the bare substrate's ICR.

Indicator : Lower ICR = better electrical conductivity.

Results

- Coated samples show lower ICR values;
- Coated stainless steel sample shows lower ICR : consistent with expectations, as the coating was previously optimized for stainless steel;
- Aluminum samples exhibit ICR values above DOE target (< 10 mΩ·cm²).



Conclusion

- A protective Cr/C coating deposited by magnetron sputtering was transferred from stainless steel 316L to aluminum AA1100 substrates.
- Corrosion characterization indicates that coated aluminum is not resistant enough to corrosion.
- Optical microscopy and XPS showed clear differences in corrosion behavior : coated stainless steel remained stable whereas coated aluminum displayed localized pitting and interfacial degradation.
- ICR measurements show that coated aluminum does not yet meet the DOE target for electrical conductivity.
- Further optimization of deposition and cleaning parameters is required to improve adhesion, corrosion…

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