



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

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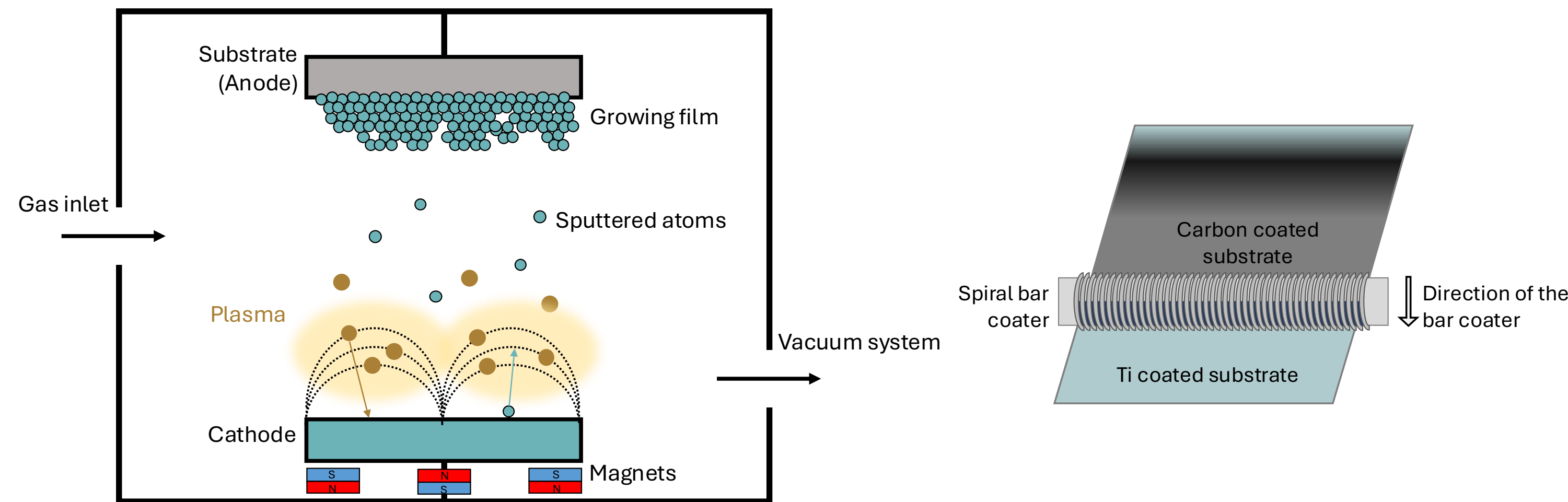
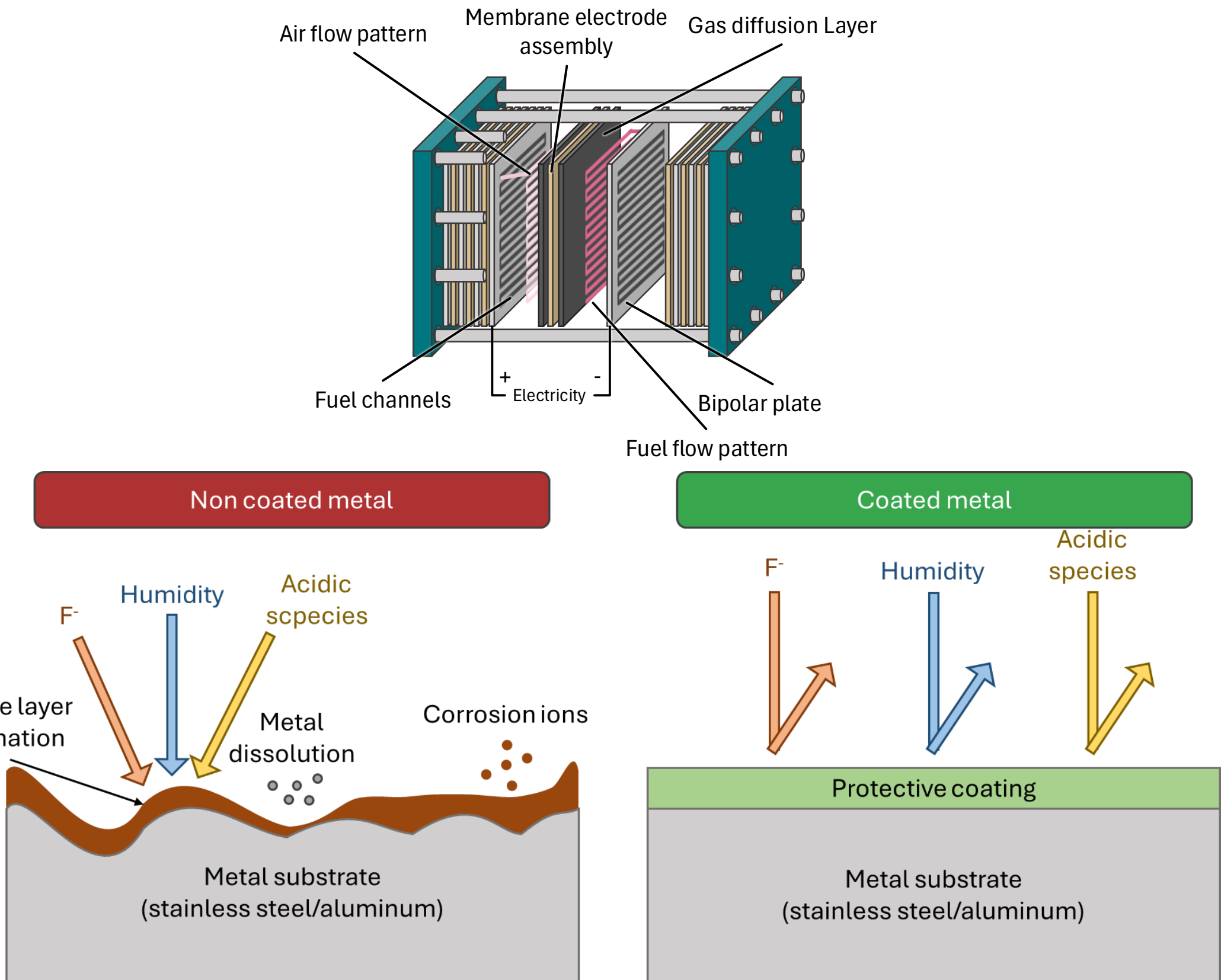
INTRODUCTION

Fuel cells are devices that are promising for clean energy transition, as they produce electricity from hydrogen and oxygen with water as by-product. Among the different technologies, Proton Exchange Membrane Fuel Cells (PEMFC) are particularly attractive for transportation applications due to their compact design and low operating temperature.

Bipolar plates are key components of PEMFC, as they ensure gas distribution, electrical conductivity, heat management, and water removal. Metallic bipolar plates, commonly based on coated stainless steel or titanium, must withstand the acidic and humid fuel cell environment, while maintaining low weight and good mechanical resistance. Aluminum could be a good alternative material to further reduce both cost and mass, as its density is three times lower than that of stainless steel and its cost is also lower than the commonly used stainless steel alloy (316L).

However, the **corrosive operating conditions inside PEMFC** can lead to metal dissolution and oxide formation on bipolar plates. These degradation phenomena may increase the interfacial contact resistance, decrease electrical conductivity, and contaminate the membrane-electrode assembly, ultimately reducing fuel cell performance and durability. For this reason, **protective coatings** are investigated to improve corrosion resistance while preserving electrical properties.

This work evaluates the corrosion behavior of uncoated and coated stainless steel and aluminum substrates under conditions designed by the US Department of Energy (DOE) to mimic a fuel cell environment. The protective coating was compared to non-coated materials through electrochemical measurements and surface characterization to assess its suitability for metallic bipolar plate applications.



PRODUCTION OF THE COATING

The coating is deposited on AA1100 and SS316L substrates by a **combination of two techniques** :

- Physical Vapor Deposition (PVD)** of a titanium layer. This project specifically uses magnetron sputtering. In a vacuum chamber, a gas is ionized to form a plasma under an applied electric field between the target and the substrate. The resulting ions bombard the target, ejecting atoms that then travel and deposit onto the substrate, forming a thin film.
- Wet chemistry** deposition of a carbon containing mixture via bar coating. A thin coating of about 10 microns will be obtained after the solvent evaporation.
- 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.

CHARACTERIZATION OF THE COATING

Corrosion characterization

- Aqueous H₂SO₄ solution (pH = 3) at 60 °C, N₂ bubbling to simulate the anode side of a PEMFC. Size of the working electrode : 10 cm²
- Potentiodynamic polarization is performed starting from OCV, sweeping to -0.6 V, up to +0.8 V, and back to -0.6 V vs Ag/AgCl, at a scan rate of 15 mV/s. Cycle is repeated 3 times. Parameters are based on DOE’s requirements.
- Higher corrosion potential (E_{corr}) → less tendency to corrode → better corrosion resistance
- Lower corrosion current density (I_{corr}) → slower corrosion rate → better corrosion resistance

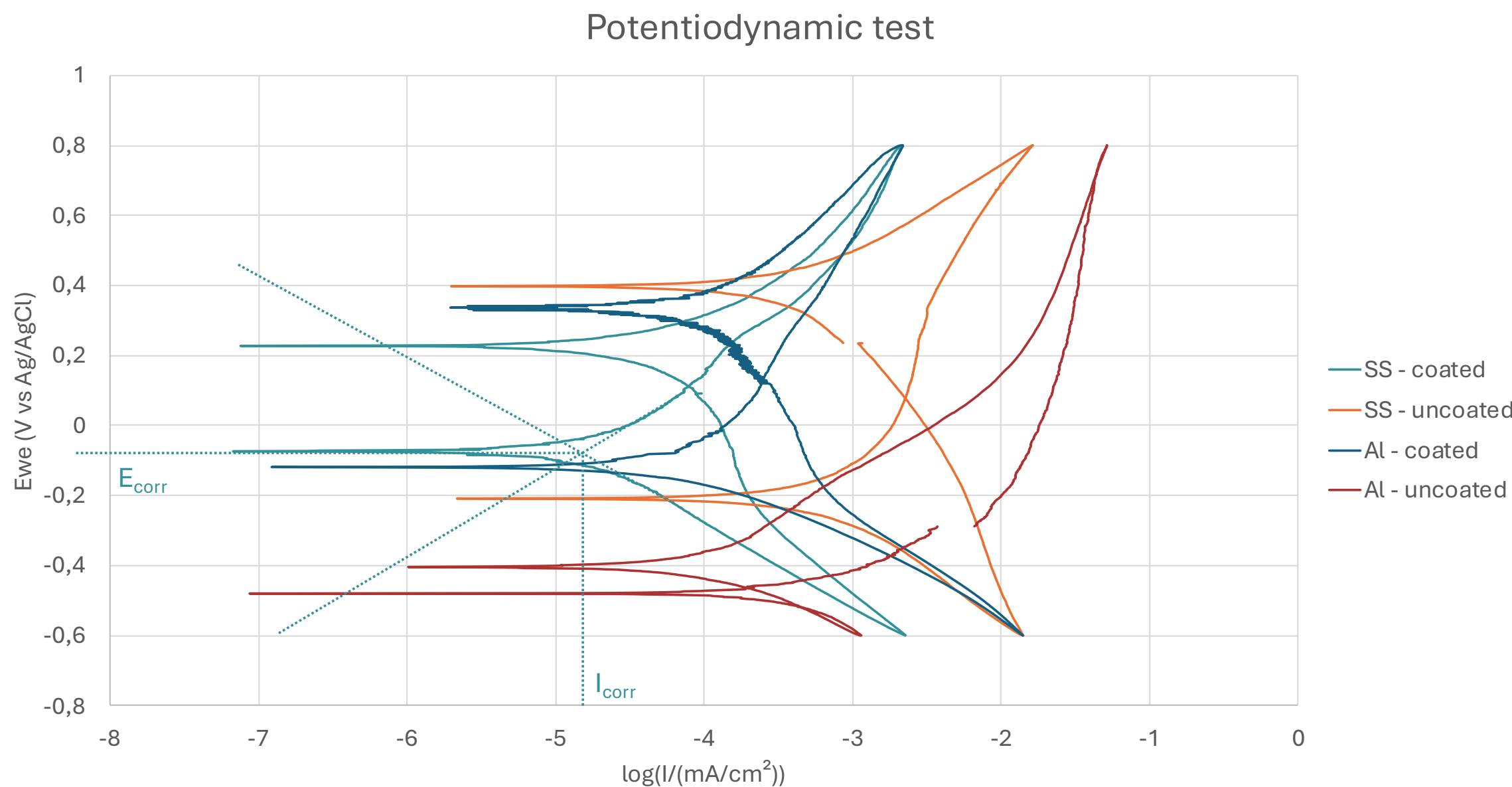
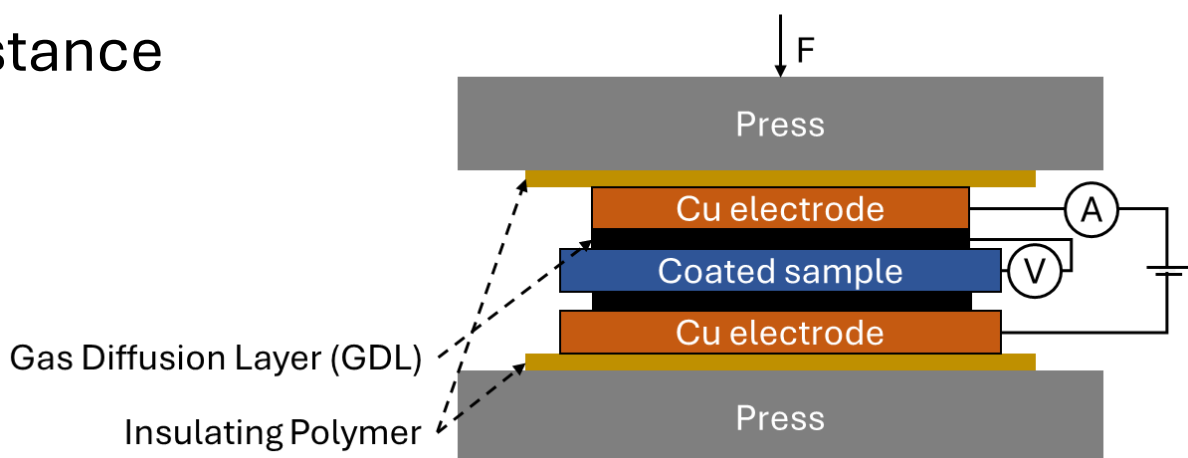
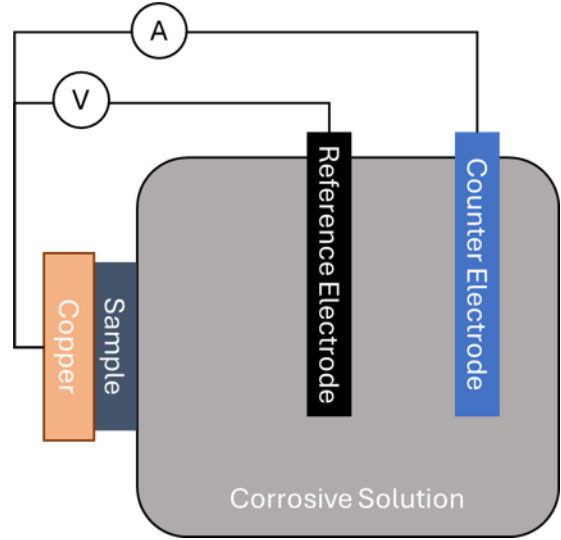
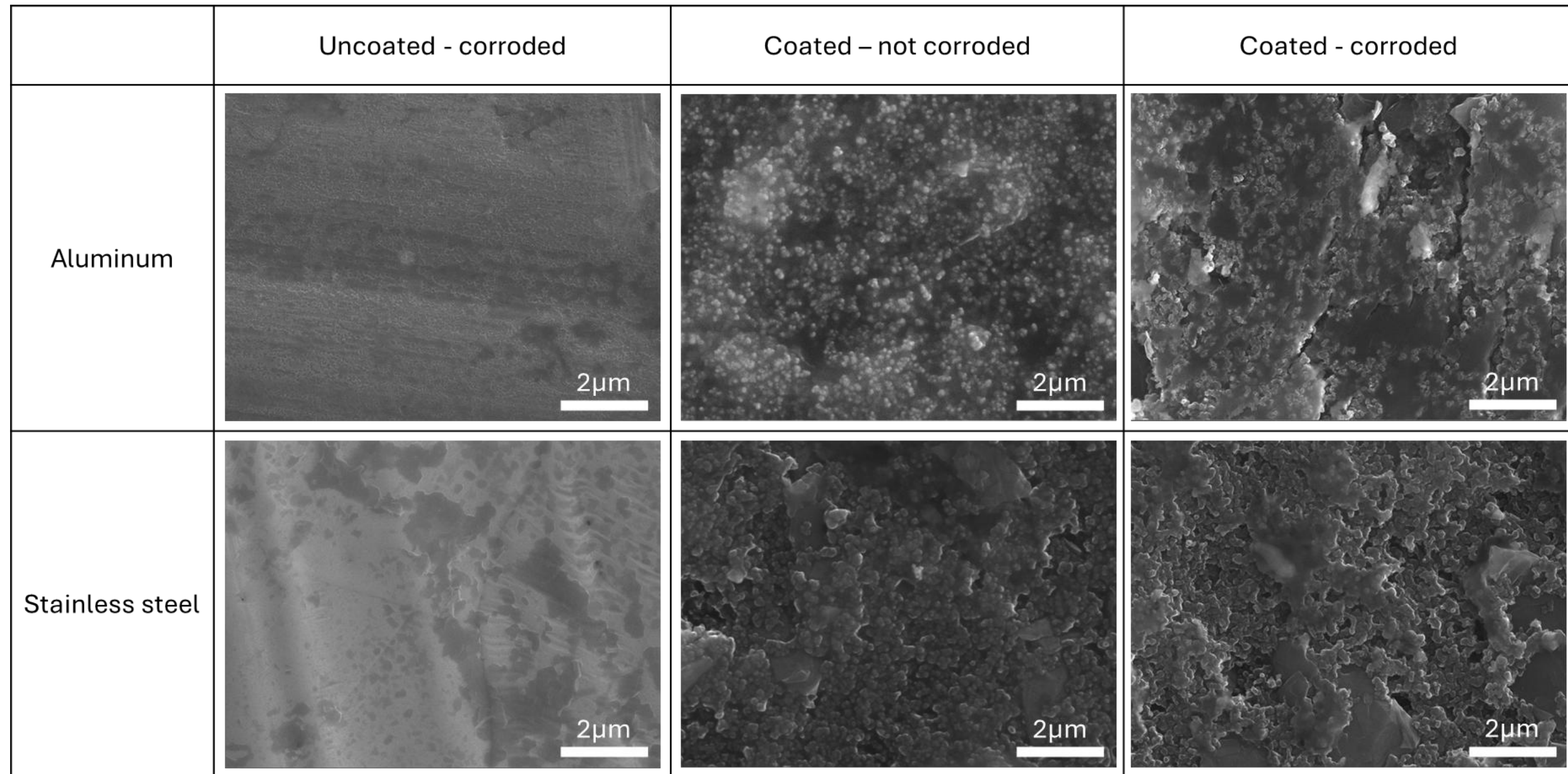
Interfacial Contact Resistance (ICR)

- Assess coating’s electrical conductivity and its effect on the bare substrate’s ICR.
- Lower ICR = better electrical conductivity.

Scanning Electron Microscope

- Comparison of surface morphology before and after corrosion.

	DOE requirements	Stainless steel - uncoated	Stainless steel - coated	Aluminum - uncoated	Aluminum - coated
E _{corr} (mV vs Ag/AgCl)	-	-210	-74	-334	-118
I _{corr} (μA/cm ²)	< 1	0,6	0,02	0,2	0,1
ICR before corrosion (mΩ.cm ²)	< 10	17,6	10,1	51,7	22,8



RESULTS

- Surface coatings significantly improve corrosion resistance for both aluminum and stainless steel. Stainless steel shows superior electrochemical stability compared to aluminum.
- Coated samples show lower ICR values than their uncoated counterpart. 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).
- Localized pitting corrosion on some samples. Visible change in the coating’s structure after corrosion.

PERSPECTIVES

- Coatings exhibit **improved performances in corrosion resistance** for both aluminum and stainless-steel substrates.
- Performance can be further enhanced through targeted **optimization of deposition parameters** (sputtering power, pressure, coating thickness).
- Ongoing and future work extends to long-term potentiostatic testing and **cathode-side corrosion studies** to validate durability under realistic operating conditions.
- Advanced microstructural characterization (SEM, EDS, XRD) will enable direct correlations between coating structure, composition, and corrosion behavior.
- The goal is the development of robust multifunctional coatings combining :
 - high corrosion resistance
 - low electrical resistance
 - long-term operational stability

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