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RF Magnetron Sputtered Nanometric Pd-Ag Coatings for Corrosion Protection of Titanium and Stainless Steel Bipolar Plates in PEM Fuel Cells

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INTRODUCTION

Proton Exchange Membrane (PEM) fuel cells efficiently convert hydrogen energy into electricity with zero emissions. In these devices, bipolar plates perform vital functions, including gas distribution, current collection, heat management, and water removal.

While traditionally made of graphite for its chemical stability, metallic substrates like Stainless Steel (AISI 316L) and Titanium are increasingly preferred to reduce thickness, weight, and costs via precision stamping. However, in the harsh PEM environment, uncoated metals suffer from corrosion and oxide layer growth, leading to high Interfacial Contact Resistance (ICR). To overcome this challenge, this study presents the production, by Radio Frequency Magnetron sputtering, and comprehensive characterization of protective Pd-Ag alloy coatings on AISI 316L and titanium substrates, evaluating their potential to enhance stack durability and performance.

EXPERIMENTAL

Substrate: AISI 316L and Titanium **Coating**: Pd-Ag alloy (23 wt.% Ag)

Radio Frequency Magnetron Sputtering techniques:

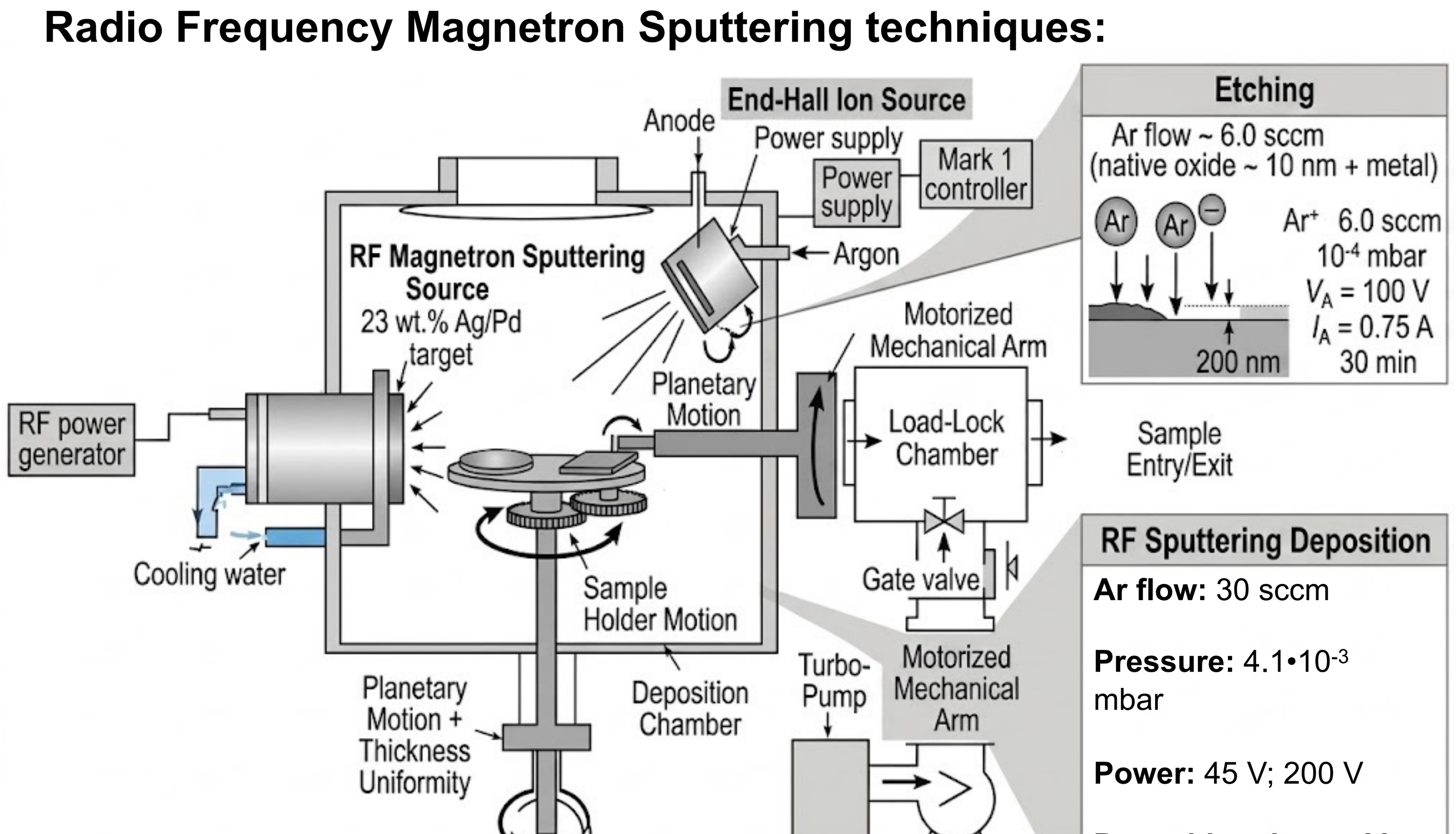

Figure 1 – Schematic of the system and deposition process

STRUCTURAL AND MORPHOLOGICAL CHARACTERIZATIONS

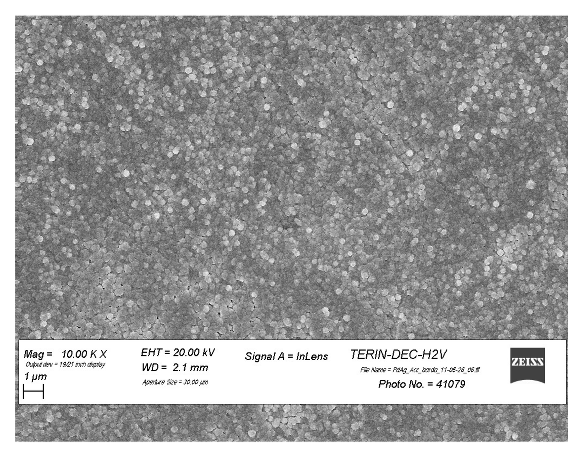

Figure 2 – Micrograph of the Pd-Ag 66nm sample on AISI316L

SEM micrographs show that the Pd-Ag coatings obtained at higher voltage (and thus higher radio frequency power) are denser and more compact. The morphology of the films grown on the Ti substrate differs from that of the coatings on steel, As shown in the micrographs in Figures 2 and 3.

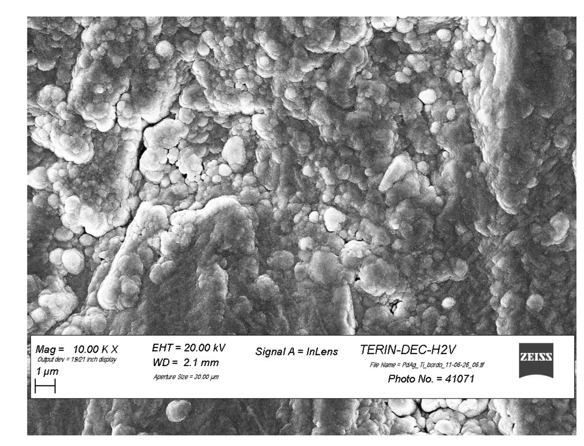

Figure 3 – Micrograph of the Pd-Ag 66nm sample on Ti

Figure 4 – XRD pattern overlay of the AISI316L substrate and the 66 nm Pd-Ag coated samples pre- and post-preliminary corrosion testing

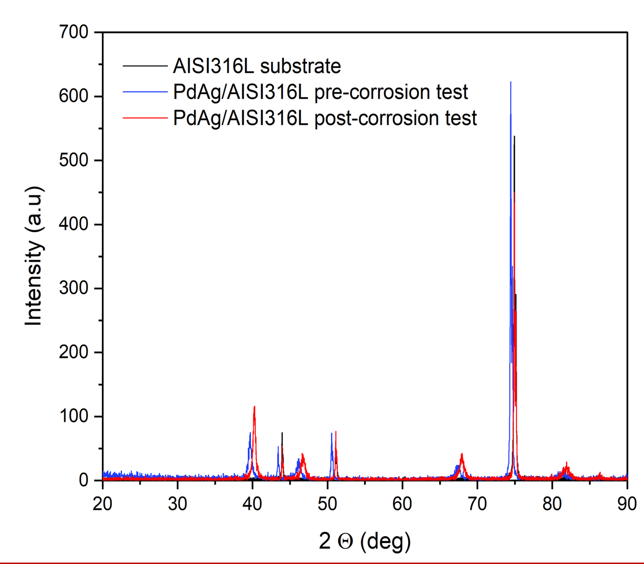

Figure 4 confirms the chemical stability and acid resistance of the Pd-Ag coating on AISI 316L steel. Pre- and post-corrosion test XRD pattern overlays show identical 2θ peak positions with no new oxidation or degradation phases.

ELECTROCHEMICAL CHARACTERIZATIONS

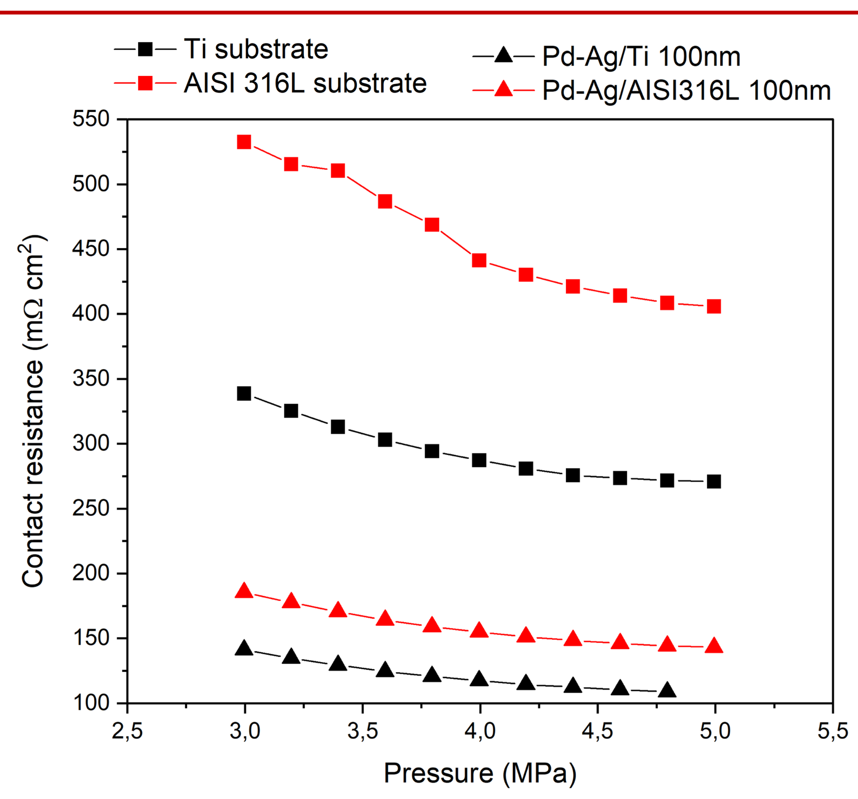

Figure 5 – Comparison of ICR measurements for substrates and 100 nm samples

ICR measurements of the samples showed that, for both substrates, the Pd-Ag coated samples exhibit lower contact resistance compared to the bare substrate (Figure 5). Between the two substrates, contact resistance values were lower for samples deposited on titanium than for those deposited on steel.

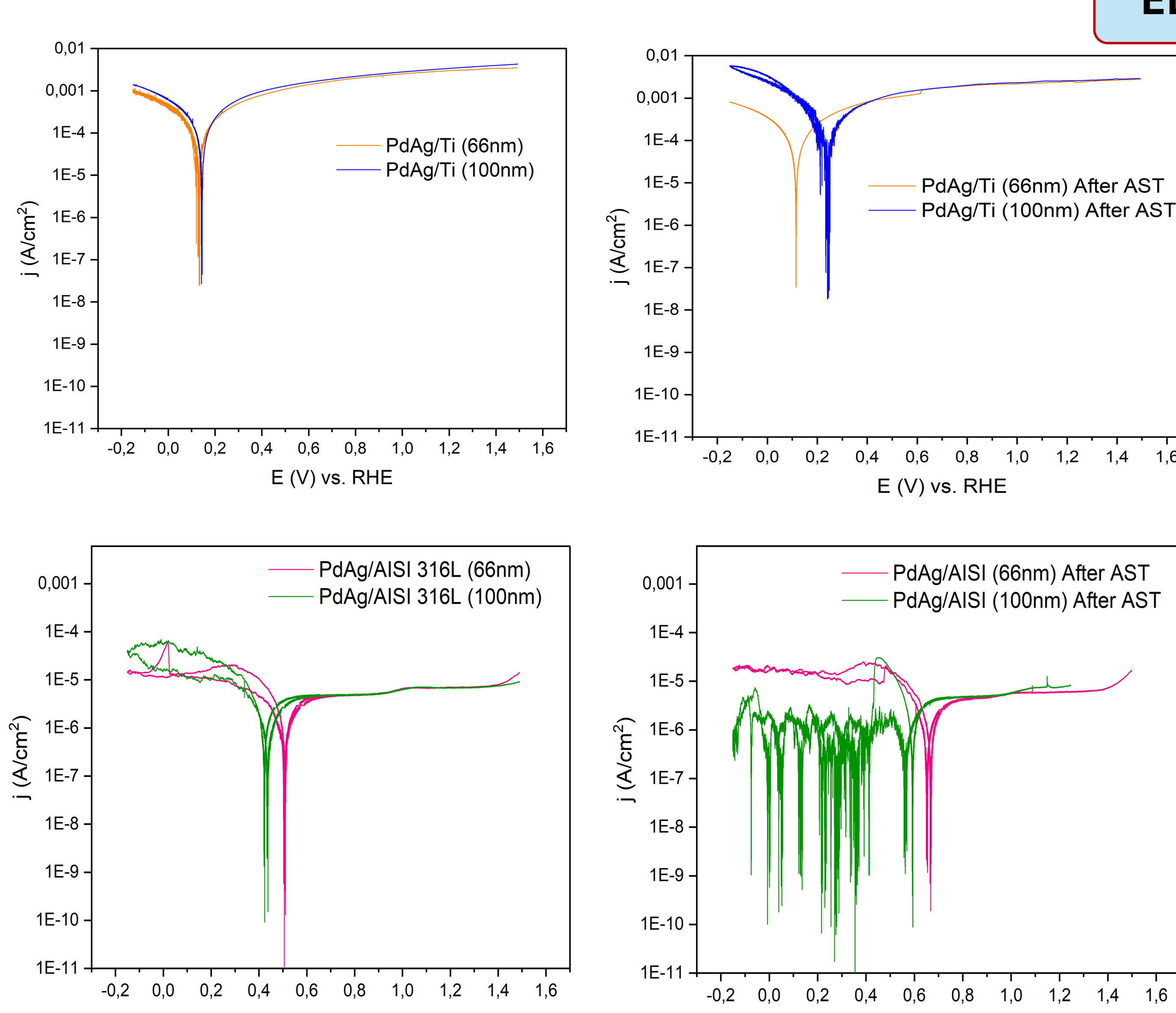

Figure 6 – Potentiodynamic curves of the coated samples: pre-accelerated stress test (AST) curves (left) and post-AST curves (right)

Potentiodynamic measurements were performed before and after the actual corrosion test (potentiostatic test). As shown in Figure 6, the thinner samples (66 nm) obtained at higher radio frequency power exhibit greater stability and resistance to the simulated PEM cell environment, despite their lower thickness. Table 1 shows that the 66 nm coating performs better on the AISI 316L steel substrate, yielding superior corrosion potential and current values.

Table 1 – Corrosion potential (E_{corr}) and corrosion current density (J_{corr}) values pre- and post-accelerated stress test (AST)

	E_{corr} (V) Pre-AST	E_{corr} (V) Post-AST	J_{corr} (mA/cm^2) Pre-AST	J_{corr} (mA/cm^2) Post-AST
PdAg/Ti (66nm)	0.0039	0.0046	0.594	0.487
PdAg/Ti (100nm)	0.110	0.2266	0.489	0.984
PdAg/AISI 316L (66nm)	0.5619	0.7131	0.0038	0.0035
PdAg/AISI 316L (100nm)	0.5097	0.4919	0.0043	0.0036

CONCLUSION

The obtained results confirm the effectiveness of the RF Magnetron Sputtering technique, integrated with ion etching, in depositing homogeneous and strongly adherent Pd–Ag alloy coatings on metallic substrates. Morphological and electrochemical characterizations in a simulated PEMFC environment highlighted the importance of deposition parameters: coatings obtained at a higher bias potential exhibit better corrosion resistance, particularly on the AISI 316L steel substrate. Furthermore, these coatings showed good stability in an acidic environment and an improvement in contact resistance. Among the analyzed configurations, the 66 nm Pd–Ag sample deposited on AISI 316L steel demonstrated the best electrochemical performance, with a corrosion current density of 0.0035 mA/cm^2 and a corrosion potential of approximately 0.71 V vs. RHE. These results demonstrate that such coatings are highly promising for application in metallic bipolar plates for PEMFCs.

Acknowledgements

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