Synthesis and evaluation of a platinum-rare earth alloy catalyst for PEM-fuel cells

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Introduction

The major kinetic challenge with Proton Exchange Membrane Fuel Cells (PEMFCs) is the oxygen reduction reaction (ORR) occurring at the cathode. Currently, large amount of platinum (Pt) is used in order to reach reasonable efficiency. Since Pt is a rare earth metal and accounts for half of stack cost, a reduction in Pt would enable a large-scale commercial breakthrough of fuel cells. Experiments on Pt alloys showed higher specific activity than pure Pt. The alloying elements yttrium (Y), gadolinium (Gd), and terbium (Tb) were identified to be promising both in terms of activity and stability [1] .

Project Descricption

A thin film of Pt_3Y was first synthesized by magnetron sputtering in ultra-high vacuum on glassy carbon pellets. The electrochemical surface area (ECSA) and the kinetic current density was calculated by cyclic voltammetry (CV). By comparing the results from Pt thin films produced in the same way, the potential of the metals as catalysts for PEM-fuel cells is evaluated.

Methodology

Magnetron Sputtering

Sputtering is a deposition process in which energetic ions are accelerated towards a target. The ions strikes the target and atoms are ejected from the surface. The sputtered atoms travel towards the substrate and incorporate into growing films. Magnetron sputtering utilizes electromagnetic fields to confine particles near the surface of the target, increasing the ion density and resulting in a high rate of sputtering.

Working pressure: 0.01 mbar
Base pressure: 8.3 x 10^{-8} mbar
Working gas: Argon
Sputtering time: 1 min
Distance between target and substrate: 8 cm

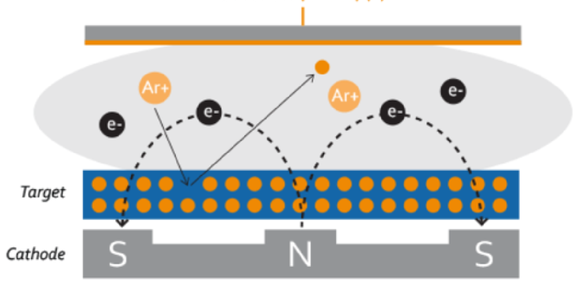

Figure 1: Schematic diagram of Magnetron Sputtering [2].

Rotating Disk Electrode (RDE)

RDE technique is a widely used method to study the Oxygen Reduction Reaction (ORR) mechanism by controlling and determining reactant transportation near electrode surface and its effect on the electron transport kinetics.

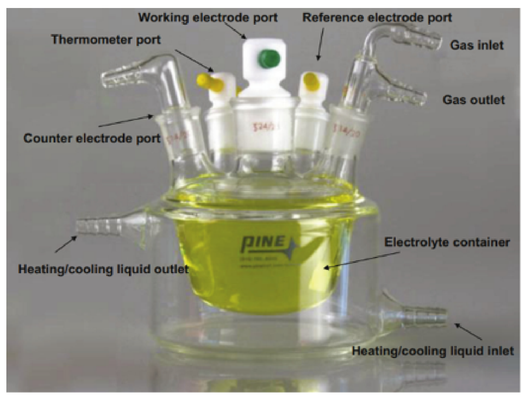

Figure 2: Schematic of the three-electrode cell for RDE measurements [3].

Results

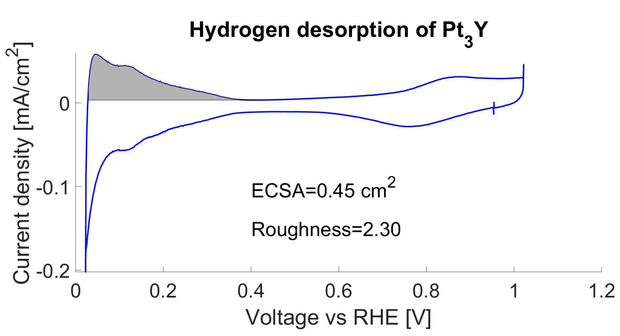

Figure 3: CV of Pt_3Y with the hydrogen desorption peak shown in gray.

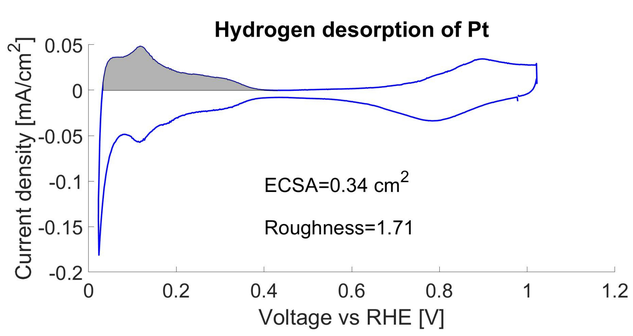

Figure 4: CV of Pt with the hydrogen desorption peak shown in gray.

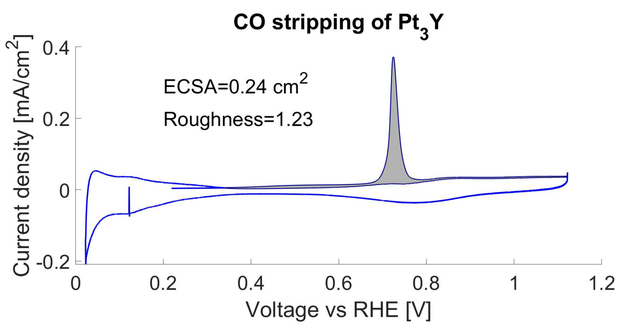

Figure 5: CV of Pt_3Y with the CO stripping peak shown in gray.

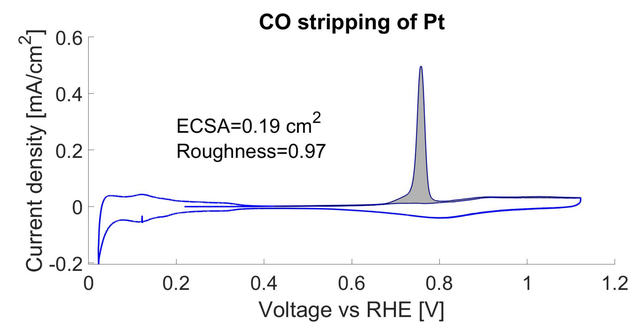

Figure 6: CV of Pt with the CO stripping peak shown in gray.

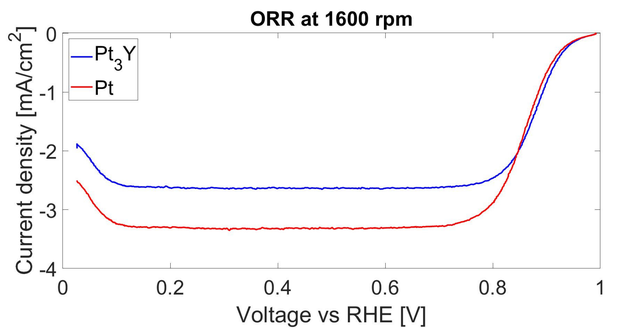

Figure 7: CV of Pt_3Y and Pt in oxygen saturated electrolyte.

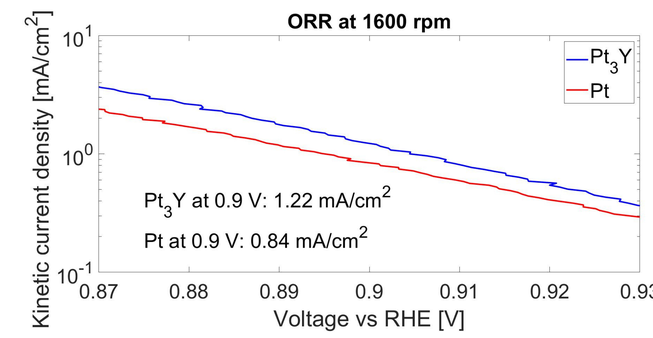

Figure 8: The kinetic current density during CV of Pt_3Y and Pt in oxygen saturated electrolyte.

Discussion

Based on the results, it shows that ECSA is larger for Pt_3Y than for Pt with both hydrogen desorption and CO stripping. ECSA for a sample is expected to be similar when using hydrogen desorption and CO stripping but these results give a much lower ECSA for CO stripping than for hydrogen desorption. The roughness is greater than 1.0, since the thin film is not flat, so it has an area that is larger than the glassy carbon pellet area.

The kinetic current density, which is the current density that is produced if mass transport is not limiting the reaction rate, is higher for Pt_3Y than for Pt. This indicates that Pt_3Y is more active than Pt as a catalyst for the ORR. Obtaining a higher kinetic current density for Pt_3Y is consistent with the article [1], but the values reported in the article are approximately 10 times bigger.

The results indicate that Pt_3Y is a better catalyst for the ORR than Pt but there is a need for repetition of experiments to confirm results. A possible explanation for the ECSA measurements by hydrogen desorption and CO stripping giving different values, and the kinetic current density being 10 times smaller than the value in the article [1], is the presence of contaminants in the electrolyte.

References

[1] Lindahl et.al, "High Specific and Mass Activity for the Oxygen Reduction for Thin Film Catalyst of Sputtered Pt3Y", Advance Materials Interfaces, vol. 4, no. 13, 2017.
[2] "Denton Vacuum", 2022. [Online]. Available: https://www.dentonvacuum.com/products/discovery/. [Accessed 28 February 2023].
[3] Du, C. et. al, "Rotating Disk Electrode Method", in Rotating Electrode Methods and Oxygen Reduction Catalysts, Massachusetts , USA, Elsevier B.V., 2014, p.186.