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TRA275 Fuel Cell Systems

Rotating Disk Electrode Evaluation of Catalyst Materials for PEM-Fuel Cells

INTRODUCTION

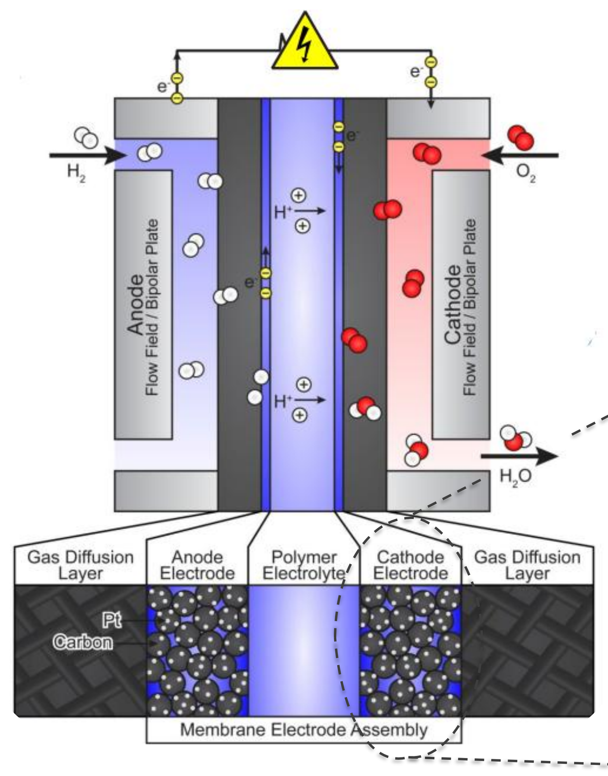
This study aimed to investigate how fuel cell catalyst ink formulation affects performance by preparing three inks with varying platinum concentrations (20 wt% Pt, 40 wt% Pt, and 50 wt% Pt). The ink contains the catalyst used on the electrodes in the membrane electrode assembly (MEA) and consists of Pt/C, a solvent, and an ionomer. The inks were evaluated using a rotating disk electrode (RDE) setup, analyzing the electrochemically active surface area (ECSA) through cyclic voltammetry (CV) and via linear sweep voltammetry (LSV) the kinetic activity and diffusion coefficient were evaluated for the oxygen reduction reaction (ORR).

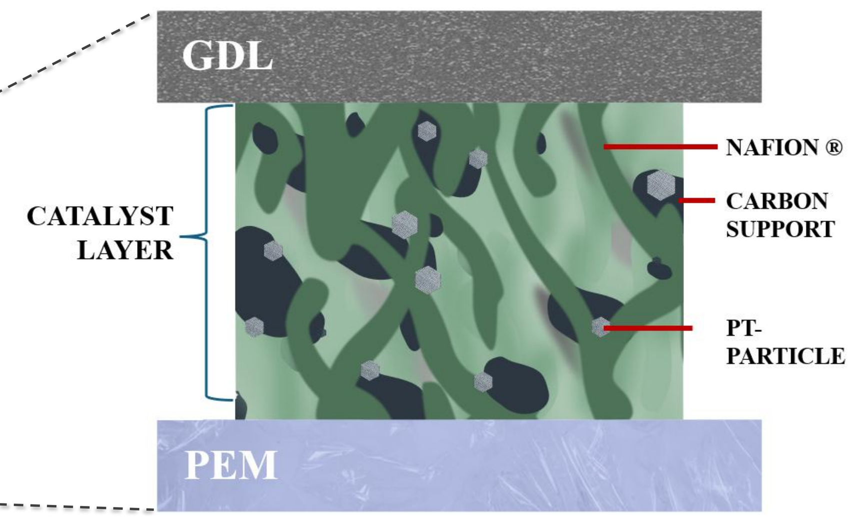
METHOD

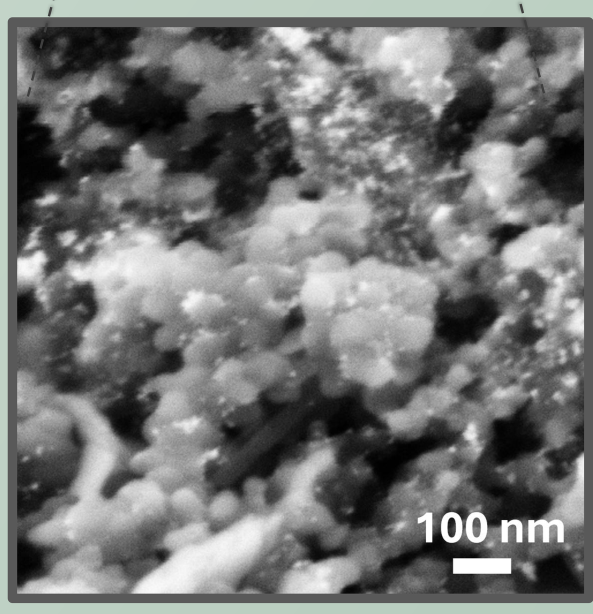
1. The ink was prepared by mixing 6.6 mg Pt/C-catalyst with 6 ml MilliQ water, 2 ml isopropanol (IPA), and 60 µl Nafion ® Solution (0.1 M).
2. Glassy carbon electrodes were thereafter prepared by drop casting 10 µl of the prepared ink onto the electrode surface, followed by spin-drying while heat-curing using convective heating. This was repeated twice for each electrode. This gave a Pt-loading of 16.23, 32.81, 42.15 µg/cm², respectively.

3. A rotating disk electrode (RDE) setup was used to study the oxygen reduction reaction (ORR), while cyclic voltammetry (CV) was performed to determine the electrochemically active surface area (ECSA). The same system was used for both measurements, consisting of a spin-head glassy carbon (GCE) working electrode coated with the ink sample (WE), a platinum counter electrode (CE), and an $Hg/HgSO_4$ reference electrode (RE). For ORR studies, the rotation speed was varied (600, 1600, and 3000 rpm) to separate kinetic and diffusion-limited currents.

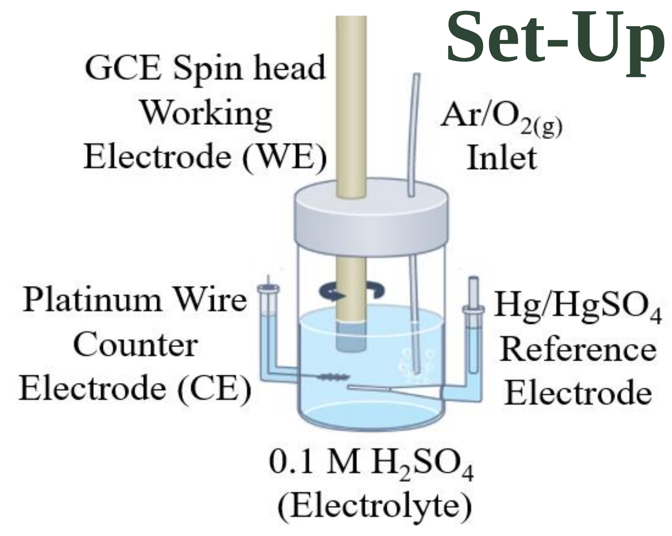
Cross-Section of a PEM Fuel Cell [1]



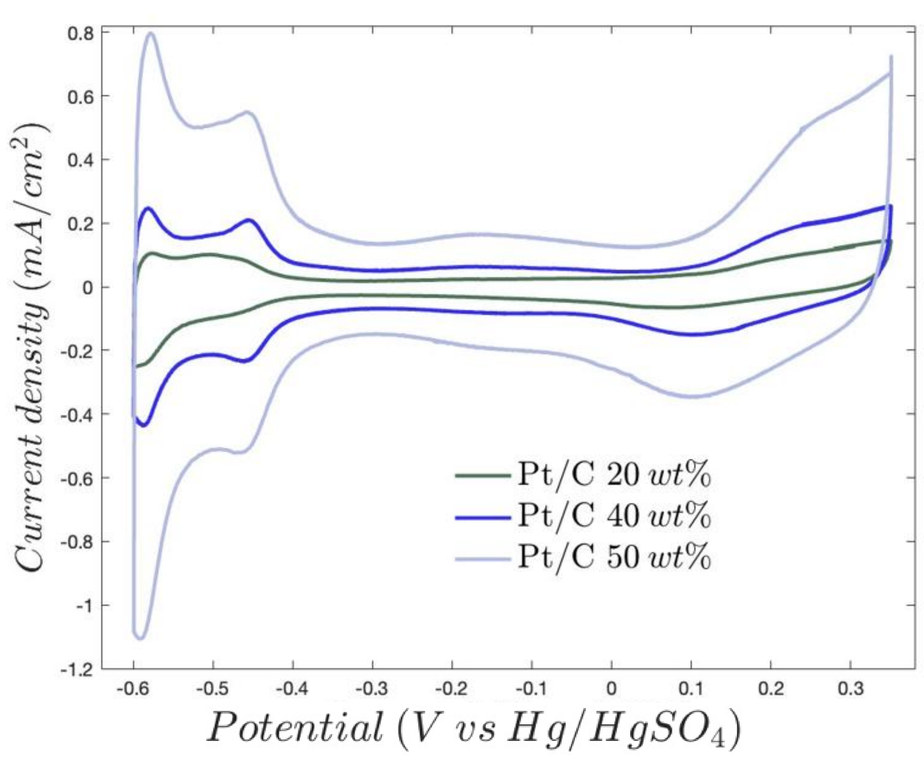




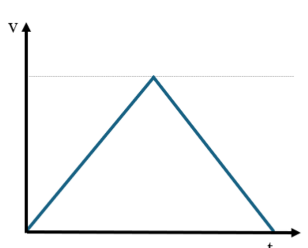
Rotating Disk Electrode Set-Up [2]



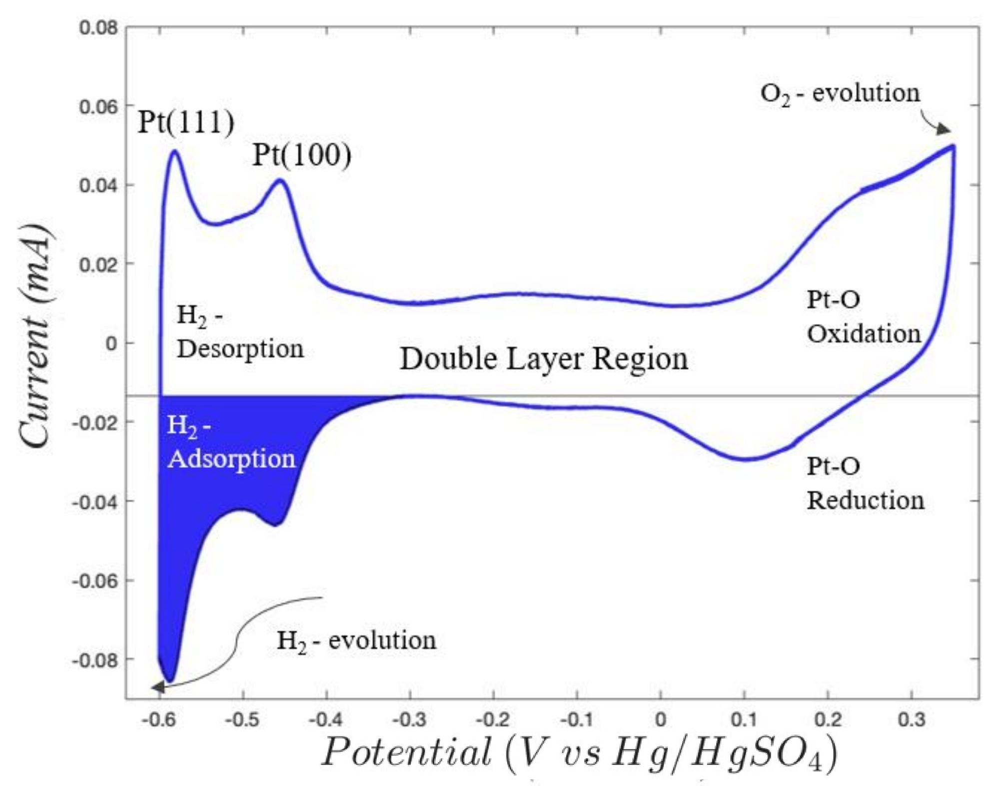
CYCLIC VOLTAMMETRY (CV)



Cyclic voltammetry (CV) is used to determine the electrochemically active surface area (ECSA) of the electrode with catalyst ink. By analyzing the hydrogen adsorption region in the CV curve, the active surface area could be quantified.

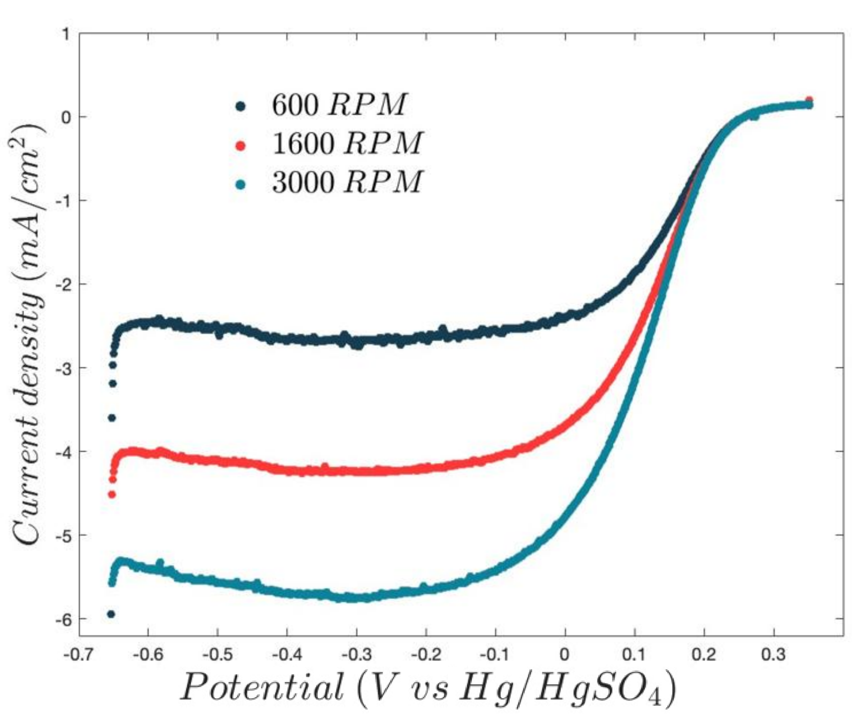


	20 wt-%	40 wt-%	50 wt-%
ESCA (cm²/µg-Pt)	0.120	0.135	0.261
Q_{ads} (mC/cm²)	0.313	0.714	1.779

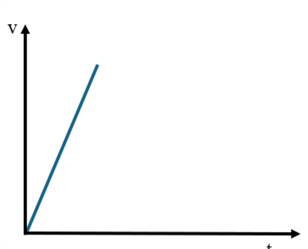


LINEAR SWEEP VOLTAMMETRY (LSV-ORR)

Linear sweep voltammetry (LSV) was used to evaluate the kinetics and mass transport of the half-cell reaction oxygen reduction reaction (ORR) occurring at the cathode in hydrogen fuel cells. By measuring the current at varying overpotentials, the diffusion coefficient and reaction rate could be determined.



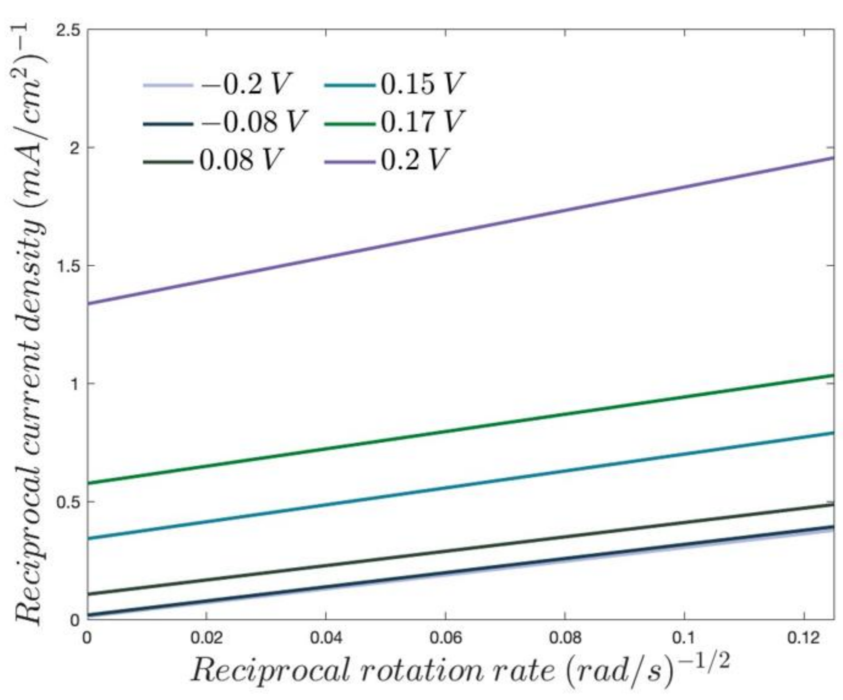
KOUTECKÝ–LEVICH EQUATION



$$\frac{1}{j} = \frac{1}{j_k} + \frac{1}{j_d}$$

$$\frac{1}{j} = \frac{1}{j_k} + \frac{1}{B}\omega^{-\frac{1}{2}}$$

Overpotential (V)	Diffusion Coefficient (cm²/s)	Reaction Rate (cm/s)
-0.08	8.0728e-06	0.0897
0.08	7.8837e-06	0.0152
0.2	3.7985e-06	0.0012



CONCLUSION

- A larger electrochemically active surface area (ECSA) leads to an increased catalytic activity, as more active platinum sites are available with a higher platinum to carbon ratio.
- An increasing overpotential results in slower kinetics and a lower diffusion coefficient.
- By increasing the rotational speed the pure kinetics can be isolated.
- This investigation examined parts of the PEM fuel cell, which makes this study useful to compare different catalyst inks and their catalytic activity, but is not directly applicable to a full PEM fuel cell system.

References: [1] Adapted from "Introduction to Fuel Cell Systems," Björn Wickman, Chalmers University of Technology (2025). Slide 38. [2] Adapted from Figure 1 in "Efficient hydrogen oxidation on monolayer Pt-modified tungsten carbide" by C. Yang, A. Bagger, J. Rossmeisl, & C. Langhammer, published in Nature Catalysis (2022).