IOCEN 2026 Conference

The 3rd International Online Conference on Energies

12–15 May 2026 | Online

MDPI

Exploring Platinum recycling methods towards a sustainable and more cost-effective PEM technologies

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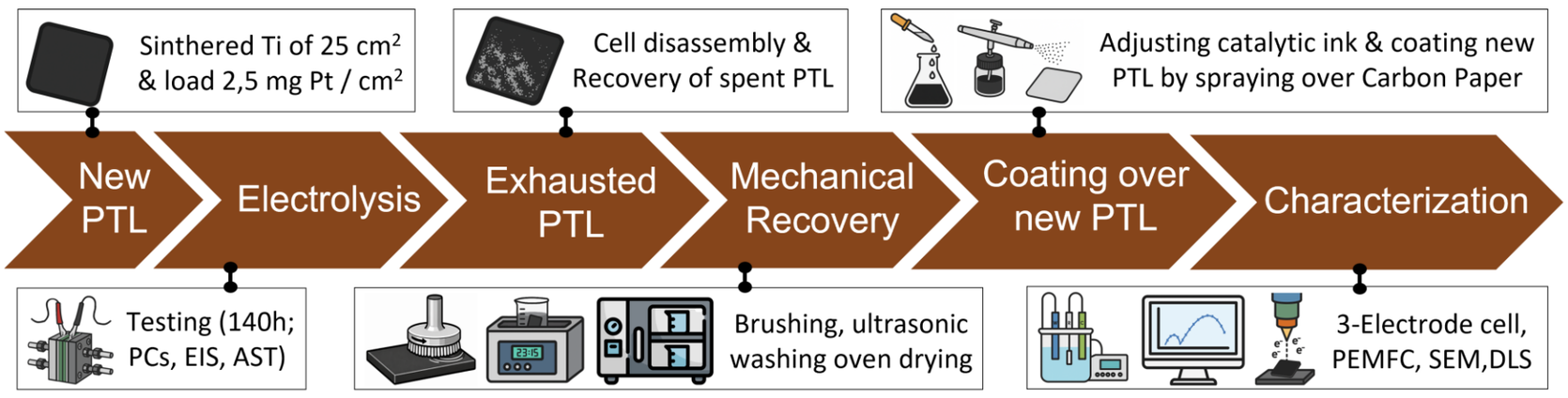
INTRODUCTION & AIM

The large-scale deployment of PEM-based hydrogen technologies is essential for global decarbonization. However, their cost and scalability are limited by the reliance on platinum group metals (PGMs), particularly platinum. This challenge has driven growing interest in strategies that not only reduce catalyst loading, but also enable the recovery and recycling of critical raw materials from end-of-life components.

- Recovery and reuse of Pt-based catalysts from exhausted PTLs (PEM electrolysers)
- Development of a novel mechanical method for Pt/C recovery
- Direct reuse of catalyst with no Pt isolation
- Sustainable and more cost-effective alternative to conventional recycling methods

MATERIALS & METHODS

Mechanical recovering method



Our Proposal: **1. Mechanical recovery method (Mr)** reported 95% efficiency for catalyst recovery

Literature: **2. Leaching with aqua regia (AR) 90-99% efficiency and:**

2.1. Classic Impregnation (H2) 85-95% efficiency / 2.2. Ethylene glycol (EG) >95% efficiency

Experimental set-up

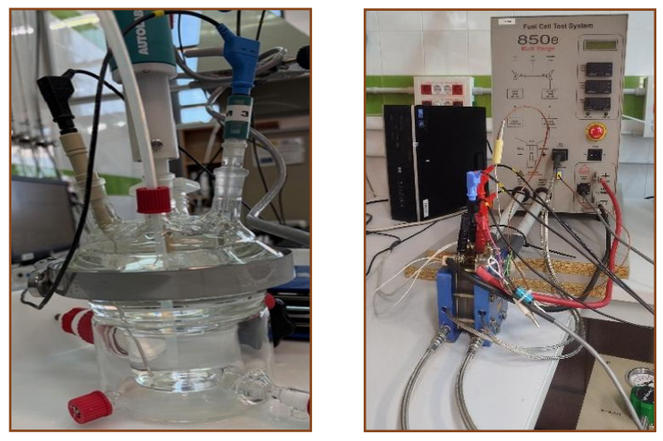


Fig.1 (Left) Three-electrode cell setup for cyclic voltammetries and LSV performance & (right) PEMFC 100kwTest Bench to perform PCs and EIS.

RESULTS & DISCUSSION

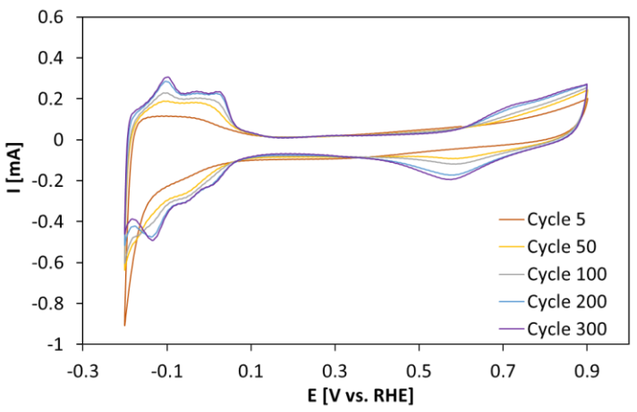


Fig.2 - Cyclic Voltammetries for recovered catalyst activation

Characterization for exhausted catalyst mechanically recovered

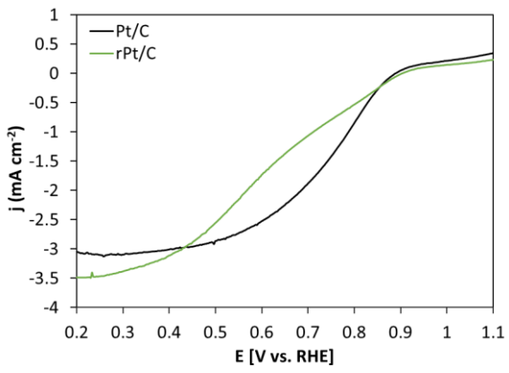


Fig.3 – LSVs for Oxygen Reduction Reaction (ORR) study.

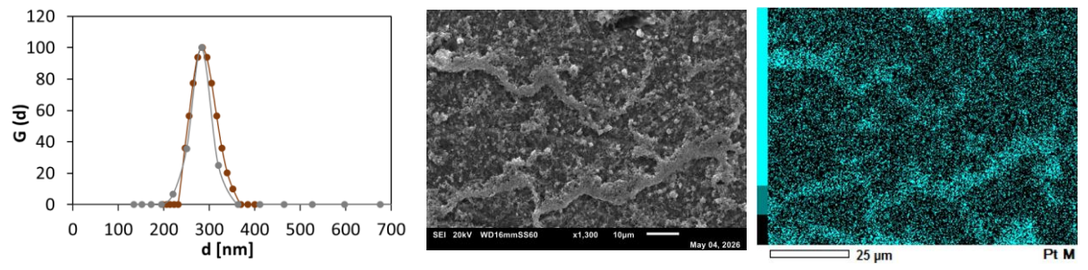


Fig.5 - Particle size distribution and SEM image for Fresh catalytic ink morphology and Pt distribution.

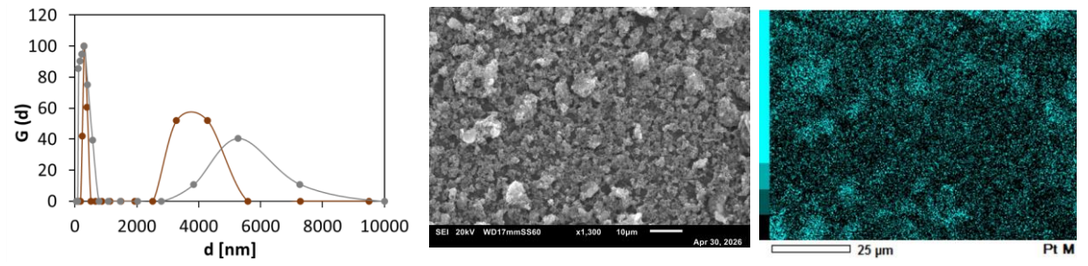


Fig.6 - Particle size distribution and SEM image for Recycled catalytic ink morphology and Pt distribution.

- Recycled catalyst need around 300 cycles of activation. Done at 100 mV · s^{-1}
- LSVs for ORR done at 1600 rpm. Previous purging with O_2 for 15-20 minutes

PEM Fuel Cell tests for exhausted catalyst mechanically recovered

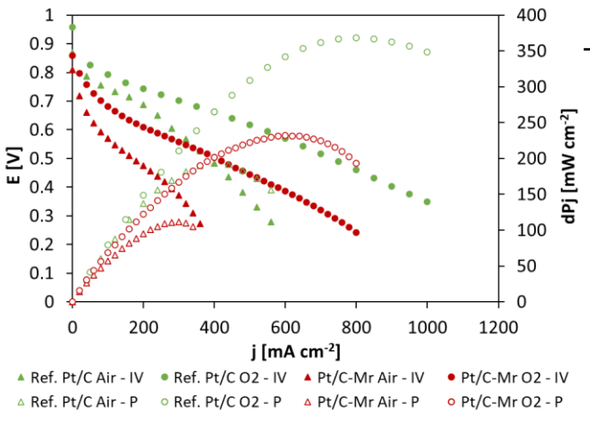


Fig.4 - IV and power curves for fresh catalyst and exhausted catalyst mechanically recovered

Sample	E (V)	mW/cm²)	kW/g Pt)
Ref. Pt/C	0.57	181.53	1.16
Pt/C-Mr	0.34	109.93	0.43
Pt/C-Mr HL*	0.50	160.10	0.63

*Table.1 - Fuel cell performance data. All values given under Air conditions and j = 320 mA/cm² . * High catalytic load.*

- Reference, Recovered : Total Pt load 0.15 mg · cm^{-2} & Recovered HL: 0.25 mg · cm^{-2}
- Recovered catalyst load (cathode) doubled to match nominal reference performance

Comparative with other recovery methods

Sample	$ECSA_{HUPD}$ (m^2 g^{-1})	$E_{1/2}$ (V)	Tafel slope (mV dec^{-1})
Ref. Pt/C	44.8	0.746	70
Pt/C-Mr	43.7	0.609	92
Pt/C-AR-H2	13.2	0.568	101
Pt/C-AR-EG	35.0	0.683	79

Table.2 - Electrochemical parameters: fresh catalysts (green) fresh catalyst recovered via 2 methods (black) and exhausted catalyst mechanically recovered .

- Higher ORR activity with Pt/C-AR-EG despite lower ECSA
- Lower ECSA with Pt/C-AR-H2, likely due to poorer Pt distribution

CONCLUSION

- High-efficiency mechanical Pt/C recovery method developed
- Mechanically recovered catalyst achieved ECSA values close to fresh Pt/C after electrochemical activation, despite higher particle size and lower Tafel slope
- Recovered exhausted catalyst has lower PEMFC performance than fresh catalyst, but is promising for cost reduction and PEM circularity
- Other conventional literature methods showed similar ORR activity but less ECSA

FUTURE WORK

- Optimize mechanical recovery process & improve method reproducibility
- Adapt in-situ activation procedure to improve PEM Fuel Cell electrochemical performance
- Use the recycled catalyst for the selected recycling methods
- Extend the comparison with other conventional chemical recycling methods

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