Preparation of CNT-PPy-SnNi/Pt Catalyst for Enhancing the Oxidation of Organic Compounds in Alkaline Conditions.

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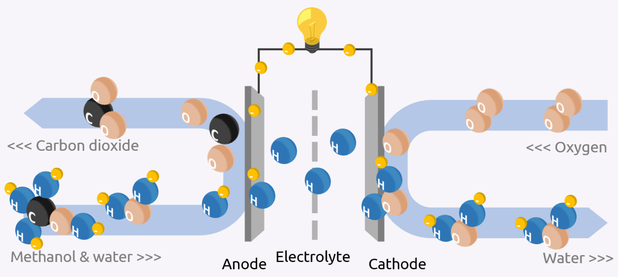
ABSTRACT

The development of highly efficient and durable electrocatalysts for alcohol oxidation is crucial for direct alcohol fuel cell (DAFC) applications. This research focuses on the design and fabrication of an advanced electrocatalyst to enhance oxidation performance for both methanol (MeOH) and glucose in alkaline media. Specifically, CNT-PPy-SnNi/Pt catalysts were synthesized using carbon nanotube (CNT)-modified polypyrrole (PPy) as a supporting material to accelerate oxidation reactions in MeOH and glucose. The key advantage of this catalyst lies in its high surface area and enhanced electron transport, which significantly improves reaction efficiency. Cyclic voltammetry (CV) analysis indicates that the CNT-PPy-SnNi/Pt catalysts exhibit outstanding electrocatalytic activity in both methanol and glucose oxidation, delivering high current density at a lower potential, confirming its superior efficiency. The incorporation of tin (Sn) and nickel (Ni) enhances the electronic properties of the system, facilitating more efficient charge transfer and oxidation activity. Additionally, the presence of platinum (Pt) provides excellent catalytic activity and stability, further boosting the oxidation kinetics of methanol and glucose. The CNT-PPy hybrid support structure is crucial in preventing nanoparticle aggregation, enhancing electrical conductivity, and promoting uniform metal dispersion on the surface. These characteristics suggest that a CNT-PPy-SnNi/Pt is a highly promising electrocatalyst for the electrochemical oxidation of alcohols in alkaline fuel cell applications.

INTRODUCTION

Direct alcohol fuel cells (DAFCs) generate electricity through the oxidation of alcohols at the anode, producing electrons that travel through an external circuit to the cathode, where oxygen reduction occurs. This process provides a clean and efficient energy source. However, conventional catalysts face challenges such as poor stability and high cost. To overcome these issues, this study develops a CNT-PPy-SnNi/Pt catalyst, which enhances electron transfer, improves oxidation efficiency, and ensures better catalytic stability for DAFC applications.



(Siqens. (n.d.). Methanol fuel cell [Digital image]. Retrieved from https://siqens.de/en/methanol-fuel-cell/)

Anode:

$$CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$$

Cathode:

$$3/2\ O_2 + 6H^+ + 6e^- \rightarrow 3H_2O$$

Overall:

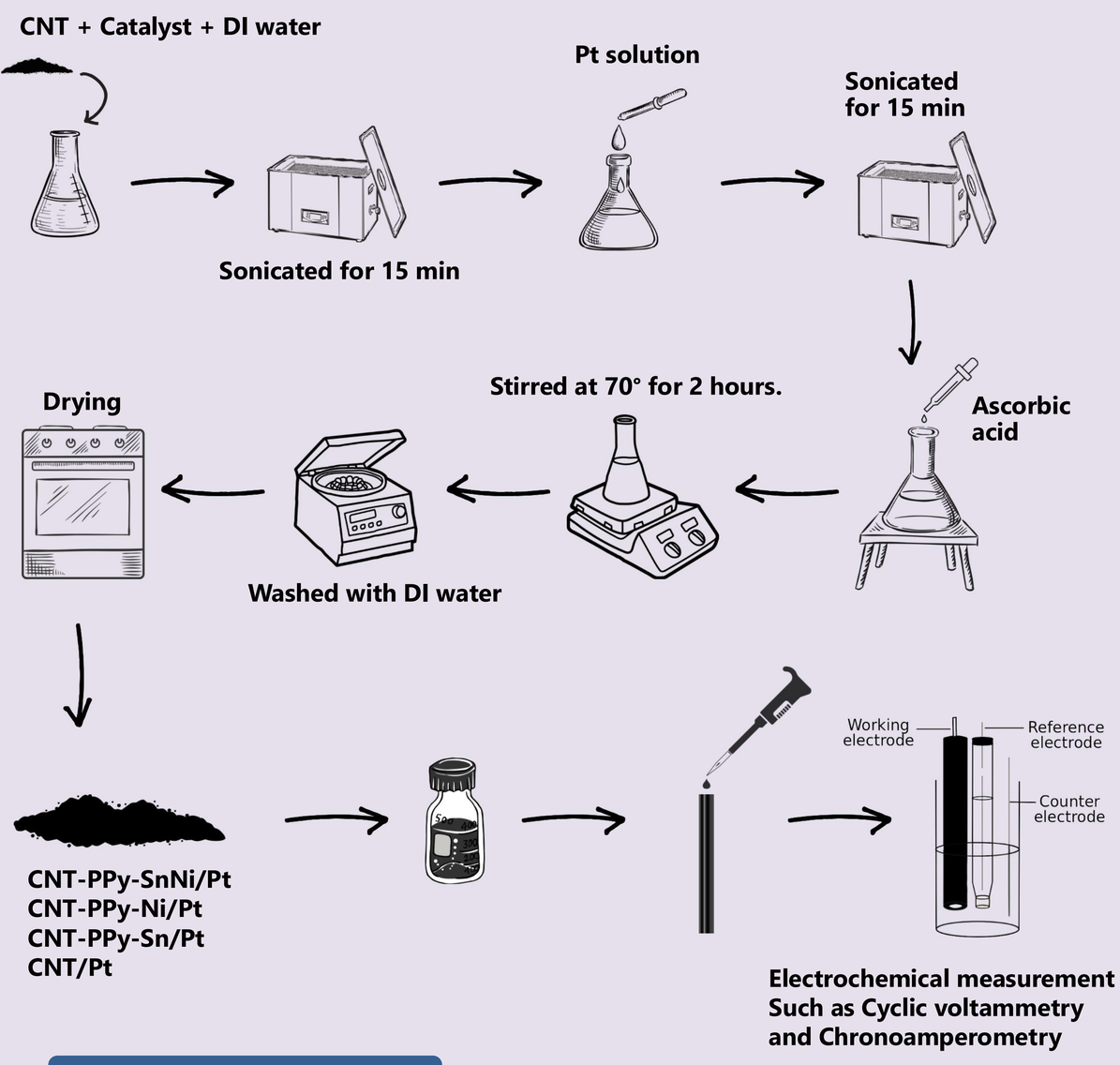
$$CH_3OH + H_2O + 3/2O_2 \rightarrow CO_2 + 3H_2O$$

Figure 1 : Scheme of a direct alcohol fuel cell

OBJECTIVES

- To improve the efficiency of the Pt based-catalyst and carbon nanotube to enhance performance.
- To study the electrocatalytic activities and stabilities of the synthesized catalysts towards oxidation of organic compounds

METHODOLOGY



RESULTS AND DISCUSSION

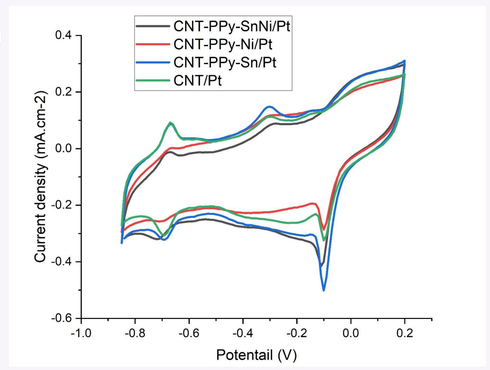


Figure 2 : CVs of CNT-PPy-SnNi/Pt , CNT-PPy-Ni/Pt ,CNT-PPy-Sn/Pt and CNT/Pt electrocatalyst were analyzed in 0.5 M KOH solution by the potential range of -0.85V to 0.2V at scan rate of 50 mVs^{-1}

Table 1 : QH and ECSA of Catalyst in 0.5 M KOH solution

Catalysts	KOH	
	QH (μC)	ECSA ($cm^2\ mg^{-1}$)
CNT-PPy-SnNi/Pt	1.36	12.95
CNT-PPy-Ni/Pt	1.96	18.67
CNT-PPy-Sn/Pt	1.28	12.20
CNT/Pt	1.02	9.71

The ECSA values in Table 1 indicate that CNT-PPy-Ni/Pt has the highest ECSA (18.67 m^2/g), followed by CNT-PPy-SnNi/Pt (12.95 m^2/g), CNT-PPy-Sn/Pt (12.20 m^2/g), and CNT/Pt (9.71 m^2/g). Incorporating Ni significantly enhances the electrochemically active surface area, providing more active sites for oxidation reactions. This increase in ECSA suggests that CNT-PPy-Ni/Pt has the highest potential for catalytic activity due to its larger available surface for electrochemical reactions. The presence of Sn and Ni in CNT-PPy-SnNi/Pt also contributes to an improved ECSA compared to CNT/Pt, indicating enhanced catalytic efficiency.

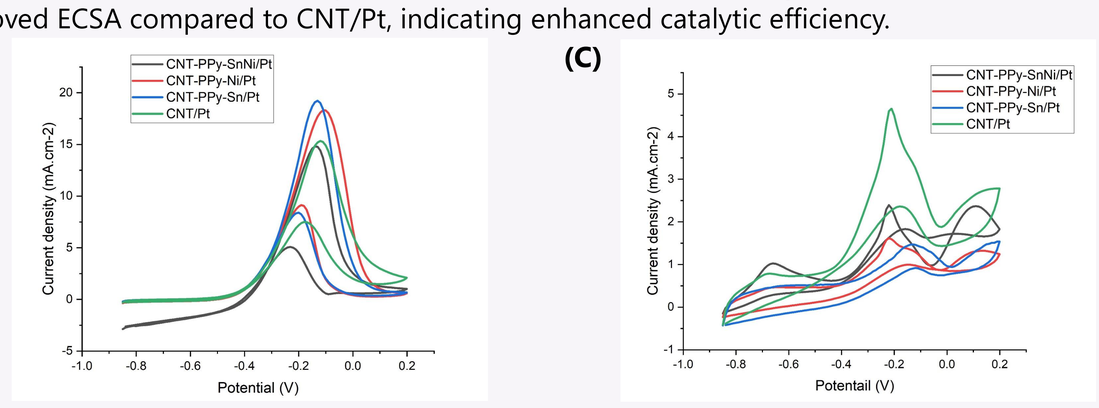


Figure 3 : CVs of CNT-PPy-SnNi/Pt , CNT-PPy-Ni/Pt , CNT-PPy-Sn/Pt and CNT/Pt electrocatalyst were analyzed in (b) 0.5 M MeOH + 0.5 M KOH and (c) 0.1 M Glucose + 0.5 M KOH by the potential range of -0.85V to 0.2V at scan rate of 50 mVs^{-1}

The CV curves in Figure 3 demonstrate that CNT-PPy-Ni/Pt and CNT-PPy-Sn/Pt exhibit higher current densities than CNT/Pt, indicating enhanced oxidation kinetics for methanol and glucose. The CNT-PPy-Ni/Pt catalyst shows the highest peak current density, suggesting that Ni plays a crucial role in boosting electrocatalytic activity. Additionally, CNT-PPy-SnNi/Pt exhibits superior performance compared to CNT/Pt, further confirming the beneficial effects of Sn and Ni incorporation.

The CA curves in Figure 4 show that CNT/Pt initially exhibits the highest current density but experiences a rapid decline over 3600 seconds, indicating poor stability. In contrast, CNT-PPy-SnNi/Pt, CNT-PPy-Ni/Pt, and CNT-PPy-Sn/Pt demonstrate more stable current retention, suggesting improved durability. The incorporation of Sn and Ni not only enhances catalytic activity but also reduces catalyst degradation, leading to a longer lifespan for the electrocatalyst.

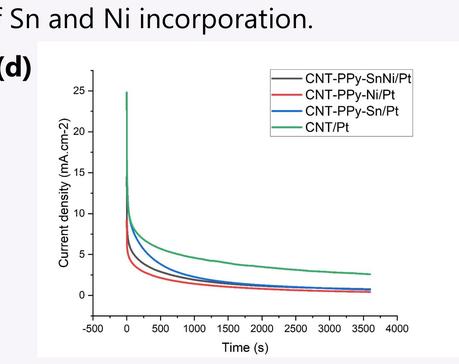


Figure 4 : Chronoamperogram of selected catalysts at E_{max} for 3600s in 0.5 M MeOH + 0.5 M KOH

CONCLUSIONS

The results indicate that CNT-PPy-SnNi/Pt is the most efficient electrocatalyst, exhibiting the highest ECSA and current density in CV measurements, confirming its superior electrocatalytic activity for methanol and glucose oxidation. Moreover, CA results show that CNT-PPy-SnNi/Pt possesses enhanced stability compared to CNT/Pt, making it a promising catalyst for direct alcohol fuel cells (DAFCs). The combination of Sn and Ni improves electron transfer, prevents Pt nanoparticle aggregation, and enhances the overall catalytic performance in alkaline conditions. Therefore, CNT-PPy-SnNi/Pt is a highly promising candidate for DAFC applications.

Acknowledgements

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