Using biochar as a support material for the preparation of anode catalysts for low-temperature fuel cells.

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ABSTRACT

Pt-based electrocatalysts for methanol oxidation were developed using biochar derived from corn stover as a sustainable carbon support. Pt/biochar exhibited acceptable electrocatalytic activity with onset potentials comparable to Pt supported on commercial carbon black (CB), demonstrating the feasibility of biochar as an alternative support. To improve performance, CB was mixed with biochar to form composite supports. The addition of CB enhanced both activity and stability compared to Pt/biochar alone, with Pt/1CB–3Biochar showing the best overall performance among the biochar-based catalysts. Nevertheless, all biochar-containing catalysts displayed lower current densities than Pt/CB, mainly due to the limited electrical conductivity of biochar. Chronoamperometric measurements confirmed stable operation over 3600 s. FT-IR analysis revealed abundant oxygen-containing functional groups on biochar, which facilitate Pt nanoparticle anchoring and contribute to catalyst stability. These results indicate that biochar is an acceptable and sustainable catalyst support for methanol oxidation, and that performance can be improved through conductive additives, although further modification is required to match commercial carbon black.

INTRODUCTION

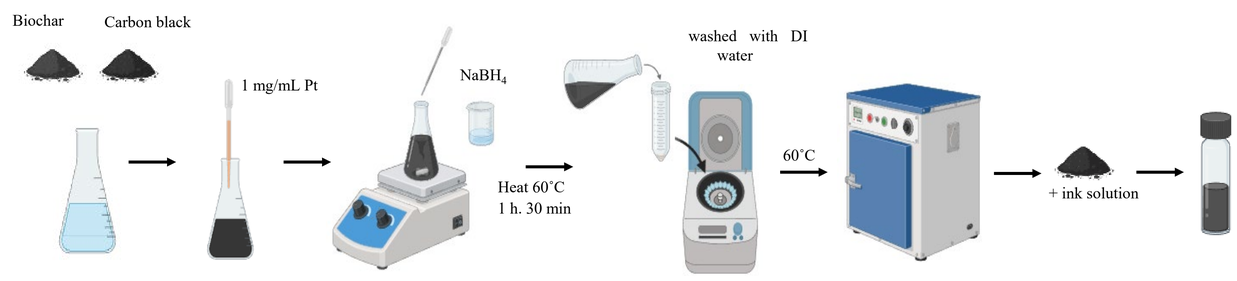
Direct methanol fuel cells (DMFCs) are promising energy devices due to high energy density and low operating temperature, but their commercialization is limited by the high cost and durability of Pt catalysts. Catalyst supports play a key role in improving activity, stability, and Pt utilization. Carbon black (CB) is widely used because of its high conductivity and surface area, but its production relies on non-renewable resources. Biochar derived from agricultural waste, such as corn stover, offers a sustainable, low-cost alternative with tunable surface chemistry and functional groups that can anchor Pt nanoparticles. However, its lower electrical conductivity can limit catalytic performance. Hybrid supports combining biochar with CB can enhance conductivity and stability while maintaining sustainability. In this work, Pt nanoparticles were supported on biochar, CB, and biochar–CB composites, and their performance toward methanol oxidation was evaluated to explore biochar as an acceptable sustainable support and assess improvements from CB addition.

OBJECTIVES

- To explore the feasibility of corn-stover-derived biochar as a sustainable and low-cost support for Pt catalysts
- To evaluate the stability and durability of Pt catalysts supported on biochar
- To assess the potential of biochar as an alternative support material for methanol oxidation in fuel cells

EXPERIMENTAL

Synthesis of Carbon black-Biochar/$NaBH_4$



Electrochemical measurements



Electrochemical measurements were conducted using a standard three electrode system for Cyclic voltammetry (CV), Linear Sweep voltammetry (LSV) and Chronoamperometric (CA) measurements.

RESULTS AND DISCUSSION

Characterization

FT-IR

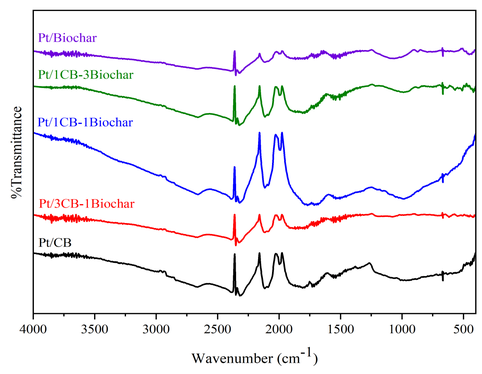


Fig. 1 FTIR Spectra of Pt/CB, Pt/3CB-1Biochar, Pt/1CB-1Biochar, Pt/1CB-3Biochar and Pt/Biochar

Fig.1 shows the FT-IR spectra of the catalysts, where similar peaks are observed in all samples. The peak at 1600 cm^{-1} corresponds to the C=C stretching, while the peak at 1750 cm^{-1} is attributed to the C=O stretching. In addition, a band around 2000 cm^{-1} is related to CO adsorption on the Pt surface. These results confirm that both carbon black and biochar supports possess similar fundamental carbon structures.

Electrochemical analysis

Cyclic voltammetry; CV

Linear Sweep voltammetry; LSV

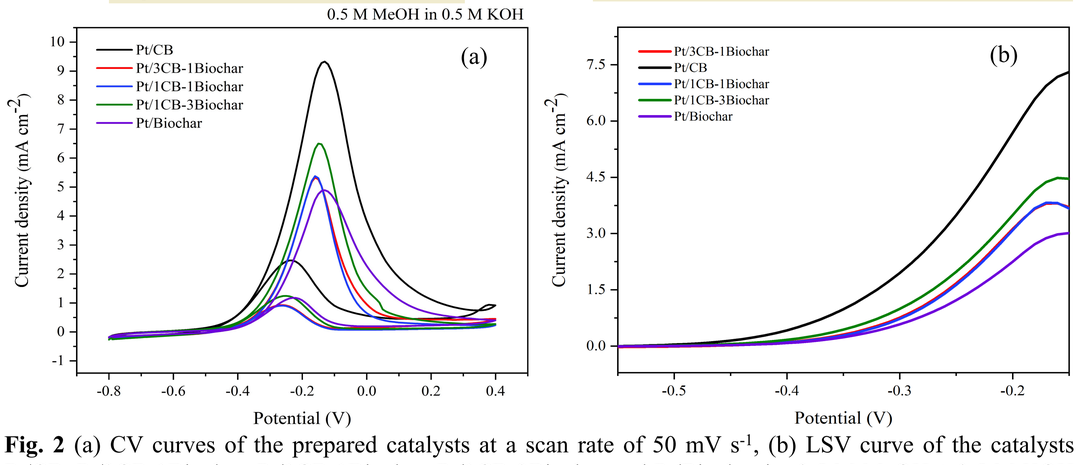


Fig. 2 (a) CV curves of the prepared catalysts at a scan rate of 50 mV s^{-1}, (b) LSV curve of the catalysts Pt/CB, Pt/3CB-1Biochar, Pt/1CB-1Biochar, Pt/1CB-3Biochar and Pt/Biochar in 0.5 M MeOH + 0.5 M KOH at a scan rate of 5 mV s^{-1}

Table 1 Electrochemical performance parameters

Catalyst	E_{onset} (V)	Anodic scan		Cathodic scan		I_f/I_b ratio
		I_f (mA cm^{-2})	E_f (V)	I_b (mA cm^{-2})	E_b (V)	
Pt/CB	-0.40	9.33	-0.13	2.23	-0.23	4.18
Pt/3CB-1Biochar	-0.33	5.33	-0.16	0.93	-0.26	5.73
Pt/1CB-1Biochar	-0.33	5.37	-0.16	0.91	-0.26	5.90
Pt/1CB-3Biochar	-0.35	6.50	-0.15	1.24	-0.25	5.24
Pt/Biochar	-0.32	4.89	-0.13	1.17	-0.22	4.18

Fig.2 and **Table 1** show that Pt/CB exhibits the highest catalytic activity for methanol oxidation, showing the highest current density and the lowest onset potential. In contrast, Pt/Biochar shows the lowest catalytic performance. However, all Pt/CB-biochar composites present lower maximum current density than Pt/CB but exhibit lower E_f and higher I_f/I_b ratio, indicating lower activation energy for methanol oxidation and better removal of adsorbed CO on the Pt surface.

Chronoamperometry; CA

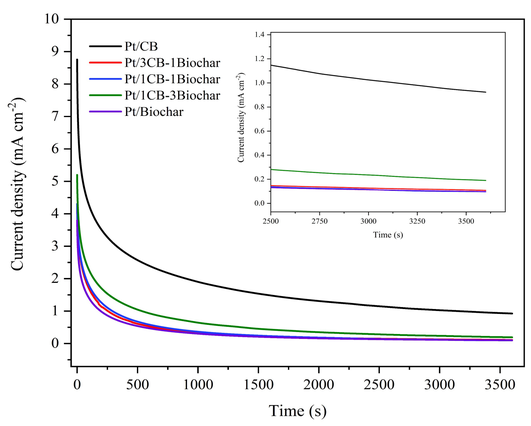


Fig. 3 CA curves of Pt/CB, Pt/3CB-1Biochar, Pt/1CB-1Biochar, Pt/1CB-3Biochar and Pt/Biochar at E_f for 3600 s in 0.5 M MeOH + 0.5 M KOH

Table 2 Residual current density at 3600 seconds of the catalyst.

Catalyst	Stability at 3600 s. (mA cm^{-2})
Pt/CB	0.923
Pt/3CB-1Biochar	0.108
Pt/1CB-1Biochar	0.096
Pt/1CB-3Biochar	0.190
Pt/Biochar	0.097

Fig.3 show that Pt/CB maintains the highest current intensity after 3600 s. While Pt/1CB–3Biochar displays relatively high current retention among the composites. The rapid current decay during the initial ~250 s is attributed to double-layer charging and the formation of adsorbed intermediates on Pt active sites. After this period, a stable current is established, reflecting sustained catalytic performance.

CONCLUSIONS

- CV & LSV: Pt/CB shows the highest current density and lowest onset potential, confirming superior methanol oxidation activity
- Biochar composites: Pt/biochar–CB catalysts have slightly higher onset potentials and lower currents due to biochar's limited conductivity.
- Optimal ratio: Pt/1CB–3Biochar achieves the best balance between activity and onset potential among the composites
- Stability (CA): Chronoamperometry confirms good durability over prolonged operation.
- Surface properties (FT-IR): Oxygen-containing functional groups on biochar facilitate Pt anchoring and contribute to catalyst stability

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