

Highly Dispersed Pt–Fe–Ru Nanoparticles on Mesoporous Bio-Based Hydrochar for Effective Oxygen Reduction Reactions in Acidic and Alkaline Electrolytes

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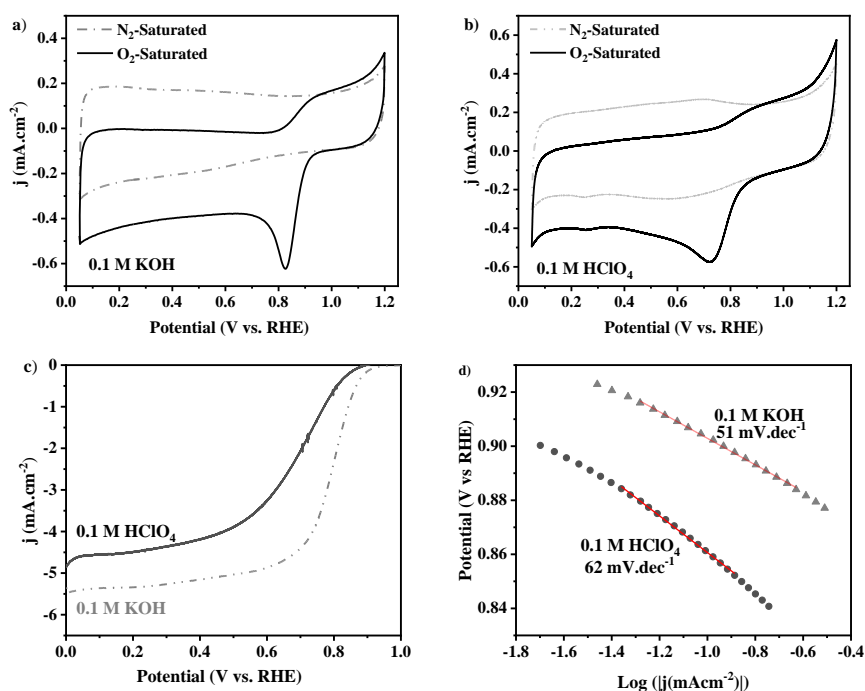
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Abstract

Proton exchange membrane fuel cells (PEMFCs) and anion exchange membrane fuel cells (AEMFCs) represent a promising clean energy solution due to their high efficiency and zero emissions. However, their widespread implementation is limited by the high cost of platinum-based catalysts required for the oxygen reduction reaction (ORR). This study addresses this challenge by developing a cost-effective, high-performance electrocatalyst using a mesoporous bio-derived hydrochar support. The hydrochar was synthesized from cellulose through hydrothermal carbonization followed by H_3PO_4 activation, yielding a material with a high specific surface area ($1137 \text{ m}^2\text{g}^{-1}$), mesoporosity ($537 \text{ m}^2\text{g}^{-1}$), abundant defect sites ($I_D/I_G = 1.9$), and diverse surface functionalities. These properties enabled the uniform dispersion of low-load ($\leq 2 \text{ wt}\%$) platinum, iron, and ruthenium nanoparticles through wet impregnation and thermal reduction, forming synergistic alloy nanoparticles on the hydrochar surface.

Electrochemical evaluations demonstrated exceptional ORR activity of the catalyst in both acidic and alkaline media. In 0.1 M HClO_4 , the catalyst exhibited an onset potential of 0.88 V and a Tafel slope of 62 mVdec^{-1} , while in 0.1 M KOH , the onset potential and Tafel slope improved to 0.95 V and 51 mVdec^{-1} , respectively, highlighting its versatility across different electrolytes.

Overall, this work provides a pathway to significantly reduce PEMFC costs while maintaining high catalytic performance, offering a sustainable and economically viable solution for the advancement of fuel cell technologies.



36 **Figure 1.** CV curves of Pt-Fe-Ru/hydrochar in (a) 0.1 M KOH and (b) 0.1 M HClO₄, generated with a scan rate
37 of 5 mVs⁻¹. (c) LSV curve of Pt-Fe-Ru/hydrochar generated in 0.1 M HClO₄ and 0.1 M KOH, with a scan rate of
38 5 mVs⁻¹ and rotation speed of 1600 rpm. (d) ORR Tafel plots of Pt-Fe-Ru/Hydrochar generated under O₂-
39 saturated atmosphere with a rotation speed of 1600 rpm.

40 **Acknowledgements.** This work has been funded by the French National Research Agency
41 (ANR) through the InnOxiCat project ANR-20-CE05-0010.