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INVESTIGATIONS OF OXYGEN EVOLUTION REACTION CATALYSTS FOR PROTON EXCHANGE MEMBRANE WATER ELECTROLYZER

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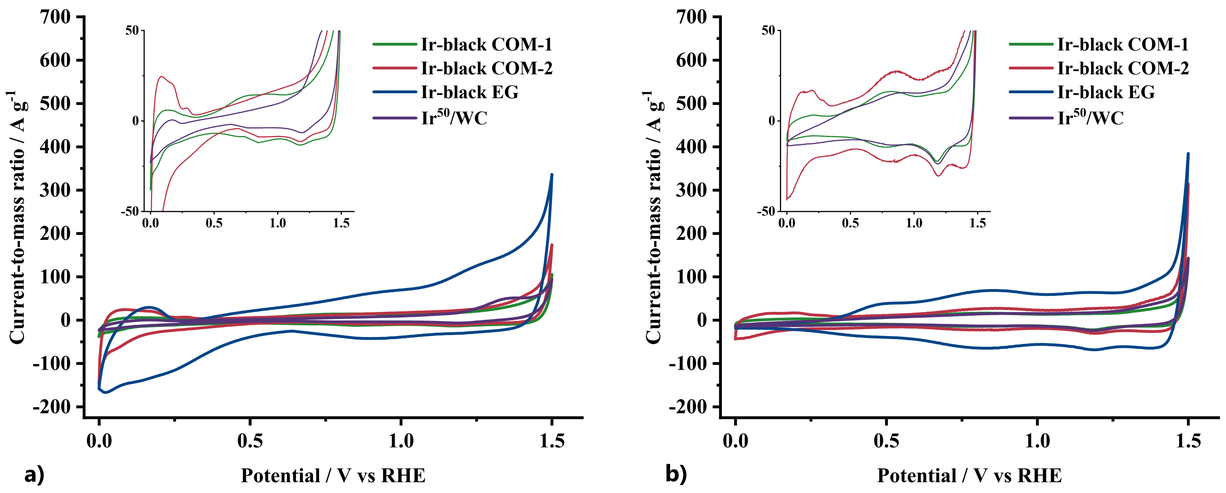
INTRODUCTION

The rapid development of renewable energy sources necessitates efficient energy storage and transport, with hydrogen emerging as a promising energy carrier due to its high-energy content and eco-friendly combustion. Proton exchange membrane water electrolysis (PEMWE) is a key technology for producing green hydrogen, where the oxygen evolution reaction (OER) plays a crucial role in determining efficiency. While RuO_2 exhibits higher OER activity, its instability limits industrial applications, making Ir-based catalysts the preferred choice due to their balance of activity and durability. However, the scarcity and high cost of iridium drive the need for more efficient utilization and reduced loading in PEMWE systems. This study focuses on synthesizing and characterizing Ir-based OER catalysts, examining the impact of morphology and structure on performance to enhance their future application in membrane-electrode assemblies.

EXPERIMENTAL PART

- **Synthesis** of WC-supported Ir nanoparticles and Ir-black (EG) were synthesized by a modified polyol reduction approach [1].
- **The catalyst inks** was prepared by mixing of Ir-black or Ir^{50}/WC with a solvent mixture of IPA and DI water, with addition of an aqueous Nafion® emulsion. The mixture was then ultrasonically dispersed using a probe sonicator for optimal duration which depends on catalysts morphology.
- **The conditioning** of Ir catalysts in liquid electrolyte was performed using the following protocol: CV in the range of 0–1.5 V vs. RHE (15 cycles), followed by 1.2–1.8 V (50 cycles), and again 0–1.5 V (15 cycles) at a sweep rate of 100 mV/s.
- **The activity** was performed using the CV measured at 1.2 – 1.65 V at a sweep rate of 20 mV/s.
- **The accelerated stress testing (AST)** was studied using a square potential wave method in the range of 1.4–1.6 V (vs. RHE), with each potential held for 3 seconds.

RESULTS AND DISCUSSION



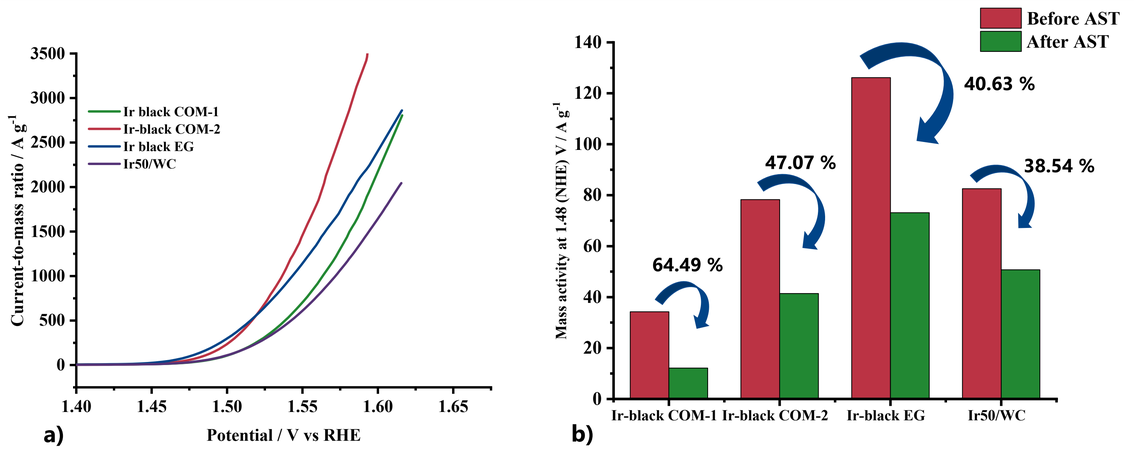
Cyclic voltammograms (CVs) of catalysts obtained before (a) and after conditioning (b) in Ar saturated 0.1 M $HClO_4$; sweep rate of 100 mV s^{-1} at 30 °C.

Before conditioning, all samples showed characteristic peaks of iridium oxidation and reduction, but their intensity are different. After conditioning, the Ir-black EG showed the most pronounced increase in the double layer capacity, indicating its developed surface and high availability of active sites. At the same time, the Ir-black COM-1 showed the least changes, which may indicate a denser structure or limited activation. The Ir^{50}/WC also showed stable behaviour, confirming that the support helps to preserve the active surface and slow down degradation processes.

CONCLUSION

The analysis of catalytic activity showed that the Ir-black EG has the highest initial activity, however, the Ir^{50}/WC catalyst shows better stability after AST, which confirms its potential for long-term use. Thus, the choice of an optimal synthesis method and the use of a suitable support are key factors in the development of efficient and stable iridium electrocatalysts.

RESULTS AND DISCUSSION



(a) Oxygen evolution reaction (OER) activity of all compared catalysts at 1.48 V. The scanning rate, temperature and rotation speed are 5 mV s^{-1}, room temperature and 2500 rpm, respectively. The measurements were performed in Ar saturated 0.1 M $HClO_4$; b) Decrease in catalysts' OER activity after AST.

Mass activity, A g^{-1}	Ir-black COM-1	Ir-black COM-2	Ir-black EG	Ir^{50}/WC
at 1.48 V, before AST	34.24	78.27	126.13	82.53
at 1.48 V, after AST	12.16	41.43	73.11	50.73
at 1.55 V, before AST	702.25	1838.94	1142.52	1214.83
at 1.55 V, after AST	247.91	842.91	738.53	1114.25

The Ir-black EG showed the highest activity prior to the AST, which is attributed to its unique structure providing greater availability of active sites. In contrast, the Ir^{50}/WC catalyst using a tungsten carbide-based support showed much greater stability. It retained most of its activity after AST, indicating that the support effectively prevents the aggregation of iridium particles and helps to maintain the catalyst's stability.

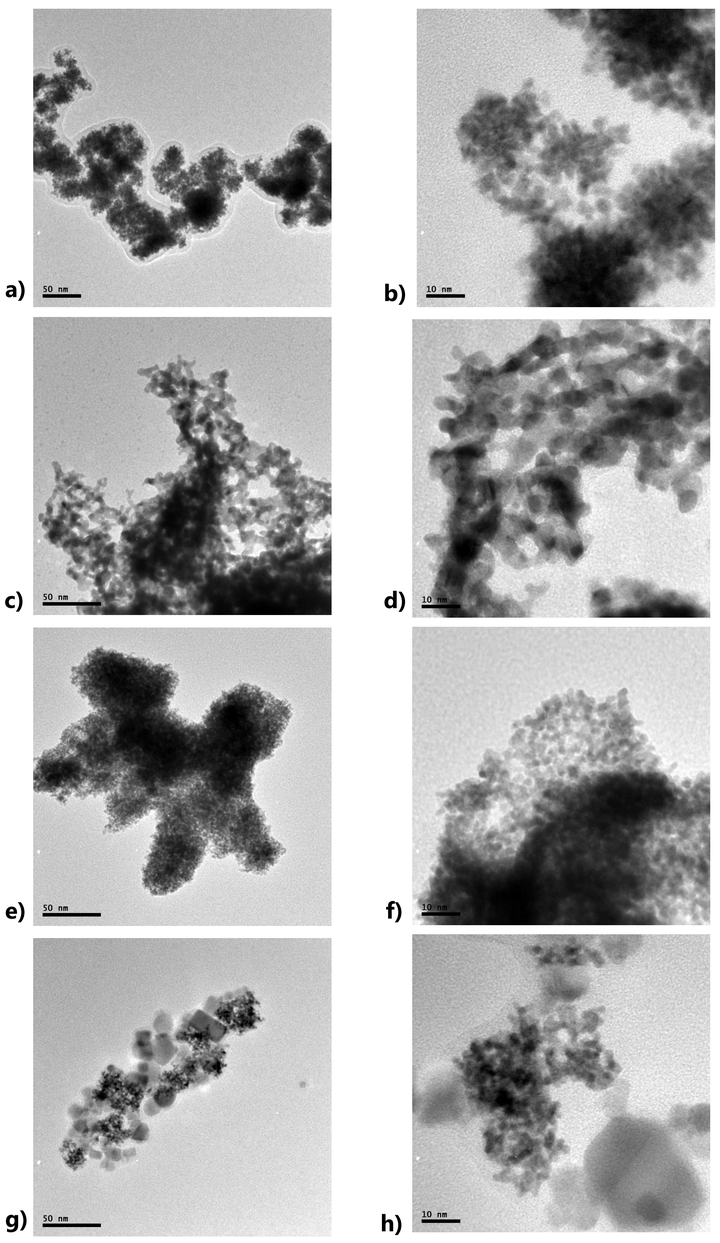


Figure 4 — Transmission electron microscopy (TEM) images of Ir-black COM-1 (a,b), Ir-black COM-2 (c,d), Ir-black EG (e,f) and Ir^{50}/WC catalysts.

All samples contain particles of 2-2.8 nm in size, but their degree of agglomeration varies. Ir-black catalysts exhibit pronounced aggregates, which may limit the availability of active sites and reduce the catalyst efficiency. In the Ir^{50}/WC catalyst, the iridium particles are deposited on a support, which helps prevent excess agglomeration and may contribute to improved stability under operating conditions.

The observed differences in morphology indicate the influence of the synthesis method and the presence of support on the structure of the catalysts, which may further affect their activity and stability.

[1]. *A. Pushkarev et al. 2020 J. Phys.: Conf. Ser.* ***1683*** *052022*