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Platinum-Decorated Transition Metal Phosphides for High-Efficiency Renewable Hydrogen Production

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INTRODUCTION & AIM

- Hydrogen is a clean and sustainable energy carrier with immense potential for replacing fossil fuels.
- Overall water splitting (OWS), which involves both the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER), is an efficient route for sustainable hydrogen production. The development of earth-abundant, bifunctional electrocatalysts capable of efficiently driving both the HER and OER within a single system is imperative for the advancement of alkaline water electrolyzer technologies.
- Transition metal phosphides (TMPs) are recognized as highly effective electrocatalysts due to their abundance of active surface sites, excellent electrical conductivity, and strong chemical stability. These characteristics are derived from the intrinsic high electrocatalytic activity of the metal (M) centers and phosphorus (P) sites. To further enhance their performance, platinum (Pt) nanoparticles can be anchored onto TMPs, creating composite materials with superior catalytic properties.
- **Research Objective:** This research aims to develop Pt-decorated CoP and CoFeP coatings on copper (Cu) substrate via electroless deposition and galvanic displacement method, and to evaluate their bifunctional electrocatalytic activity for overall alkaline water splitting using Linear Sweep Voltammetry (LSV).

METHODS

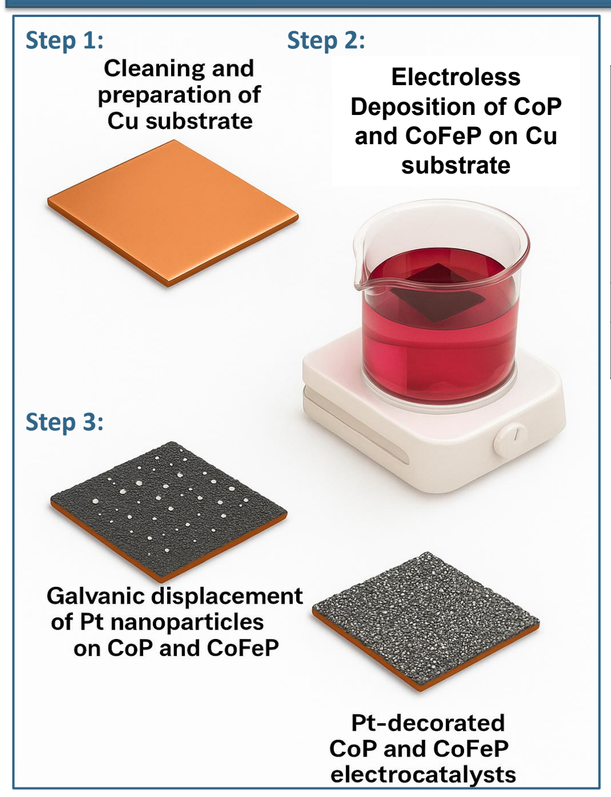

Table 1. Composition of plating baths and deposition parameters.

Coatings	Composition of the plating bath, mol L^{-1}				Deposition conditions		
	$CoSO_4 \cdot 7H_2O$	$NaH_2PO_2 \cdot H_2O$	$FeSO_4 \cdot 7H_2O$	Glycine	T, °C	*t*, min	pH
CoP/Cu	0.1	1.50	-	0.6	80	30	10.5
CoFeP/Cu	0.1	1.50	0.01	0.6	80	30	10.5

Table 2. Elemental composition of Co-based and Pt-decorated coatings deposited on copper substrates, as determined by EDX analysis.

Catalyst	Wt. %			
	Pt	Co	Fe	P
CoP/Cu	-	94.90	-	5.10
CoFeP/Cu	-	83.52	13.11	3.37
PtCoP/Cu	0.39	94.40	-	5.21
PtCoFeP/Cu	19.26	59.58	9.54	11.62

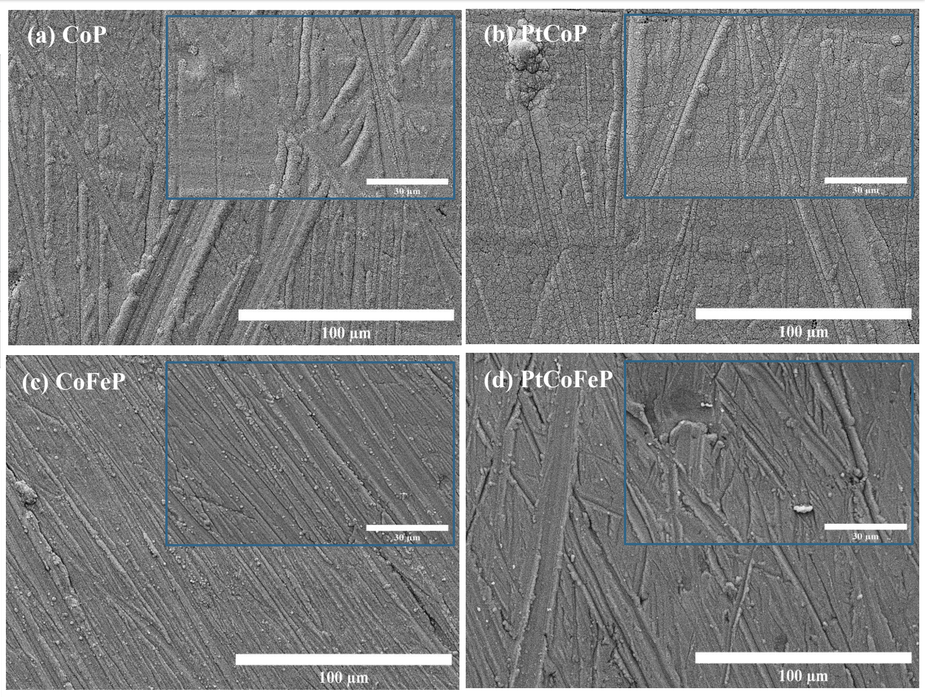

Fig. 1. The SEM views of CoP (a), PtCoP (b), CoFeP (c), and PtCoFeP (d) catalysts.

RESULTS & DISCUSSION

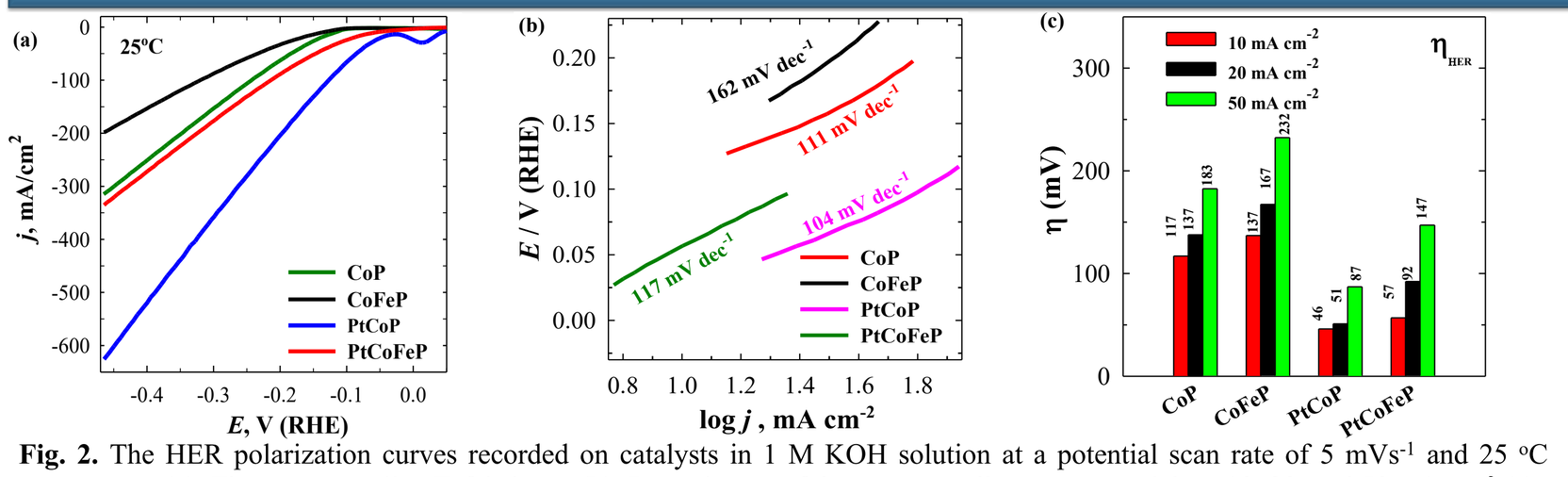

Fig. 2. The HER polarization curves recorded on catalysts in 1 M KOH solution at a potential scan rate of 5 mVs^{-1} and 25 °C temperature **(a)**. The corresponding Tafel slopes **(b)**. Bar columns of the corresponding overpotentials at 10, 20, and 50 mA cm^{-2} **(c)**.

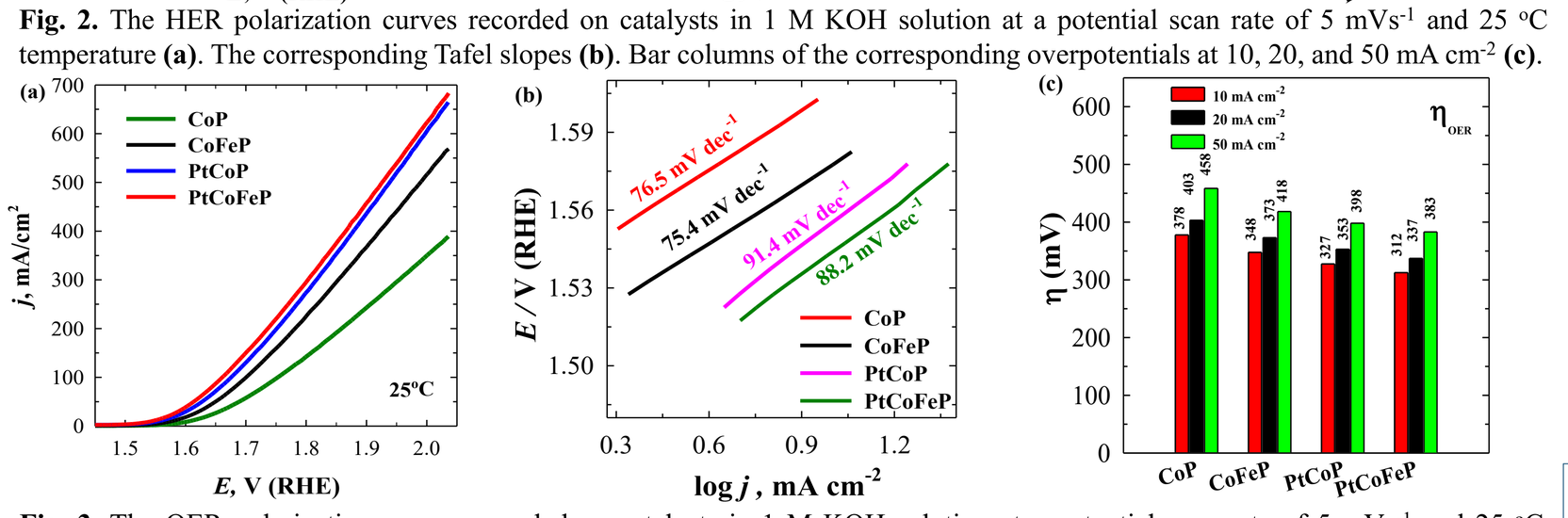

Fig. 3. The OER polarization curves recorded on catalysts in 1 M KOH solution at a potential scan rate of 5 mVs^{-1} and 25 °C temperature **(a)**. The corresponding Tafel slopes **(b)**. Bar columns of the corresponding overpotentials at 10, 20, and 50 mA cm^{-2} **(c)**.

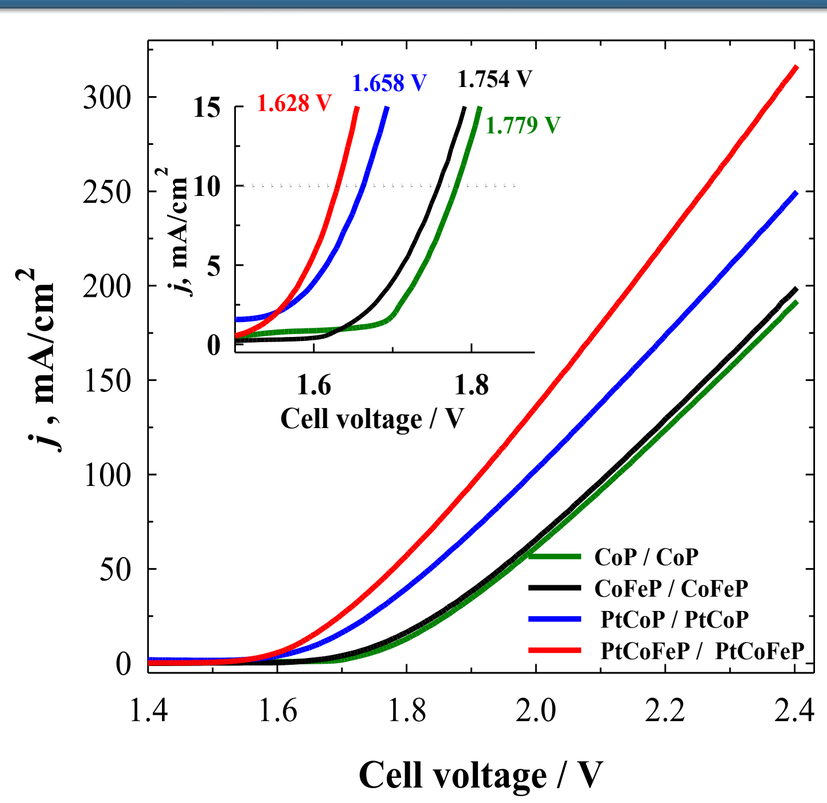

Fig. 4. Polarization curves of different Co-based catalysts as both anode and cathode for overall water splitting performance in the two-electrode setup at the scan rate of 5 mV s^{-1}.

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CONCLUSION

- **Characterization:** The morphology and composition of the catalysts were analysed using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS).
- **HER activity:** PtCoP/Cu demonstrated the lowest overpotential, 46.46 mV at a current density of 10 mA cm^{-2} at 25 °C, thereby confirming its superior HER activity.
- **OER activity:** PtCoFeP/Cu exhibits the lowest overpotential, 312.46 mV at a current density of 10 mA cm^{-2} at 25 °C, thereby establishing itself as the most viable catalyst in the series.
- **Overall water splitting:** The assembled electrolyser with PtCoFeP as the cathode and anode has been identified as the most effective bifunctional catalyst, requiring a minimal voltage of 1.628 V to achieve 10 mA cm^{-2}, surpassing the performance of PtCoP due to synergistic interactions between Co, Fe, and Pt.
- **Summary:** The fabricated Pt-decorated CoP and CoFeP catalysts exhibit remarkable bifunctional electrocatalytic performance, with high activity toward both HER and OER. Their superior efficiency, low overpotentials, and stable performance establish them as highly promising materials for overall water splitting. This offers significant potential for practical applications in sustainable hydrogen production and clean energy technologies.