

# PLATINUM-MODIFIED COBALT-IRON PHOSPHIDE ELECTROCATALYSTS FOR EFFICIENT OVERALL WATER SPLITTING AT INDUSTRIAL TEMPERATURES

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The production of green hydrogen using electrocatalytic water splitting, driven by renewable electricity, has emerged as a promising approach. Unlike conventional strategies of developing electrocatalysts for the two half-reactions of water splitting (e.g., the hydrogen and oxygen evolution reactions, HER and OER) separately, there has been a growing interest in designing bifunctional electrocatalysts that can efficiently catalyze both reactions simultaneously. These catalysts are essential for bridging the gap between laboratory-scale research and industrial-scale alkaline water electrolysis. In this study, cobalt phosphide (CoP) and cobalt-iron phosphide (CoFeP) were directly fabricated on copper substrates via an electroless deposition method. Sodium hypophosphite ( $\text{NaH}_2\text{PO}_2$ ) was utilized as both the phosphorus source and reducing agent. Subsequently, platinum (Pt) nanoparticles were introduced through a galvanic displacement process. The morphology, elemental composition, and crystal structure of the catalysts were characterized by scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), inductively coupled plasma optical emission spectroscopy (ICP-OES), X-ray diffraction (XRD), and X-ray photoelectron spectroscopy (XPS). The bifunctional electrocatalytic performance toward overall water splitting was evaluated in a two-electrode setup in 1 M KOH electrolyte. Among the synthesized catalysts, Pt-CoFeP demonstrated superior bifunctional activity, with a low Pt loading of only  $1.4 \mu\text{g cm}^{-2}$ , achieving a low cell voltage of 1.62 V at  $10 \text{ mA cm}^{-2}$ . This is attributed to synergistic interactions between Pt, Co, and Fe that enhanced HER and OER kinetics by improving charge transfer, stabilizing active sites, and optimizing the electronic structure, thus enhancing the utilization efficiency of Pt. It is imperative to assess the performance of electrocatalysts in the context of hydrogen generation under industrially relevant temperatures, as this evaluation is instrumental in substantiating their practical applicability. Remarkably, the electrolyzer employing Pt-CoFeP as the anode and Pt-CoP as the cathode requires only 1.54 V to achieve a current density of  $10 \text{ mA cm}^{-2}$  at an industrially relevant temperature of 75 °C. Furthermore, the cell voltage demonstrates a consistent decline from 1.62 V at 25 °C to 1.54 V at 75 °C. This indicates that the operational stability and efficacy of the system are enhanced across the temperature range of 25–75 °C, thereby confirming the robustness and industrial viability of the system. This present research offers a scalable strategy for the design of platinum-modified transition metal phosphides as efficient bifunctional electrocatalysts for industrial alkaline water electrolysis and sustainable hydrogen production.

## Acknowledgements

This research was funded by a grant (No. P-MIP-23-467) from the Research Council of Lithuania.

**Keywords:** platinum nanoparticles, transition metal phosphides, Industrial temperature, overall water splitting, alkaline electrocatalysis