PhD position (October 2024 – October 2027)

Synthesis of Electrocatalysts based on non-noble metals for water splitting

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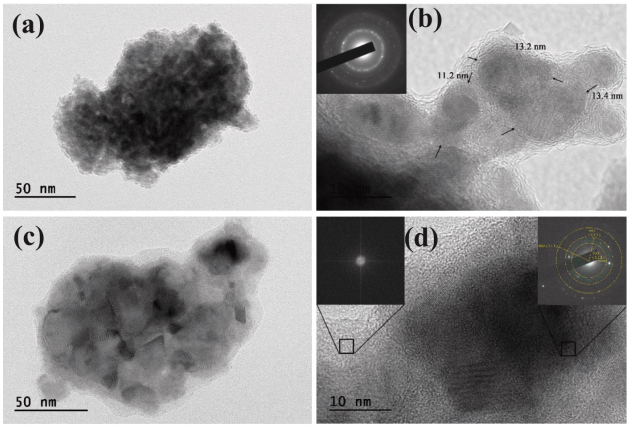
***Keywords**: Co-electrodeposition; Alloys; Ionic liquids; Electrocatalysis*
***Application deadline**: 20th April 2024*

Today, water-splitting is considered one of the most promising solutions for hydrogen preparation. Pt-group metals offer excellent electrocatalytic performance for the hydrogen evolution reaction (HER) and the oxygen evolution reaction (OER), but their high cost limits their use. As a result, the preparation of non-noble metal catalysts, which are highly efficient for HER and OER, remains a key avenue to explore.
In recent years, the use of alloys has proved to be a promising approach to enhancing the catalytic activity of the electrode. Transition metal alloys, such as Ni, Fe and Co-based intermetallics, have been extensively studied as efficient bifunctional electrocatalysts, but their performance remains to be improved.
The main objectives of this project are to develop a new, low-cost way of synthesizing multi-element alloys for the preparation of catalysts, and to study their reactivation in terms of reaction mechanism and active sites, as well as their ageing with respect to water-splitting. The approach we propose is based on the use of concentrated ionic media such as ionic liquids, their mixtures with molecular solvents or deep-eutectic solvents (DES), which are suitable solvents for various electrochemical applications [1, 2]. They already have shown interesting physicochemical properties (relatively high ionic conductivity, wide electrochemical potential window), enabling them to be used in a wide variety of applications. In recent years, these ionic media have been used as solvents for the electrodeposition of various metals [3-5]. The use of electrodeposition to prepare alloys on the electrode surface represents an original approach to modulating alloy composition, as recently demonstrated for the preparation of alloys of two or three elements (Figure) [6].



TEM images of different electrodeposited alloys in NEA (a,b) C-$Ni_{88.7}Co_{11.3}$, (c,d) C-$Ni_{64.4}Co_{35.6}$

We therefore propose to develop a multi-scale design strategy for electrocatalysts via their synthesis by electrodeposition of transition metal alloys (Fe, Ni, Co...). By controlling the deposition conditions (temperature, concentration, potential...), the composition and morphology of the alloys will be mastered. Two main approaches will be developed to obtain a large specific surface area for catalysts:
- Electroplating on a conductive foam;
- Electroplating a thin film followed by selective electrochemical dissolution of the alloy's most active metal to form a porous material.

***Knowledge and skills**: The candidate must have a Master degree or equivalent in chemical sciences, chemical engineering or electrochemistry. In the motivation letter, the candidate must show a high motivation, curiosity, scientific rigor, as well as both autonomy and teamwork abilities. Good writing skills and oral expression in English are also required*

[1] A.P. Abbott, K.J. McKenzie, Phys. Chem. Chem. Phys., 8 (2006) 4265-4279.
[2] F. Endres, Phys. Chem. Chem. Phys., 12 (2010) 1648.
[3] F. Liu, Y. Deng, X. Han, W. Hu, C. Zhong, J. Alloys Compd., 654 (2016) 163-170.
[4] Q. Zhang, Q. Wang, S. Zhang, X. Lu, X. Zhang, Chemphyschem, 17 (2016) 335-351.
[5] B. Meenatchi, V. Renuga, A. Manikandan, Journal of Inorganic and Organometallic Polymers and Materials, 26 (2016) 423-430.
[6] Y. Xie, A. Miche, V. Vivier, M. Turmine, Appl. Surf. Sci., 635 (2023).