Solar-Driven Photocatalysis for Hydrogen Production and Carbon Dioxide Conversion

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The persistent global dependence on fossil fuels has led to severe environmental challenges, largely driven by the rapid rise in greenhouse gas emissions. Developing cost-competitive, low-carbon technologies based on renewable energy is therefore essential. Among all renewable sources, solar energy holds the highest potential for large-scale sustainable deployment. Hydrogen, a zero-emission energy carrier, represents an attractive alternative to carbon-based fuels, particularly when produced photocatalytically from water. Likewise, the photocatalytic conversion of CO_2 into value-added chemical fuels offers a promising route to both mitigate emissions and generate useful products. Inspired by natural photosynthesis, a wide range of artificial photocatalytic systems based on porphyrinoids have been designed and evaluated over the last years.[1]

In this presentation, I will discuss our recent progress in the development of photocatalytic systems for hydrogen evolution and CO_2 reduction that employ porphyrin derivatives as chromophores or as molecular catalysts. I will highlight several homogeneous systems, focusing on strategies for enhancing photosensitizer performance and catalytic efficiency through molecular design. Furthermore, I will present our advances in heterogeneous photocatalysis, including the use of self-assembled supramolecular porphyrinoid nanostructures[2] and dye-sensitized photocatalytic systems (DSPs).[3] Finally, I will address our efforts to improve the overall sustainability of these processes by replacing conventional sacrificial electron donors with productive oxidation reactions, specifically the photocatalytic oxidation of alcohol derivatives.[4]

References:

[1] E. Nikoloudakis, I. López-Duarte, G. Charalambidis, K. Ladomenou, M. Ince, A.G. Coutsolelos, *Chem. Soc. Rev.*, **2022**, *51*, 6965.

[2] E. Triantafyllou, E. Nikoloudakis, S. Psilodimitrakopoulos, D. Kavalieros, G. Landrou, E. Stratakis, G. Charalambidis, A. Mitraki, A.G. Coutsolelos, *ChemSusChem*, **2025**, *18*, e202501251.

[3] V. Nikolaou, E. Nikoloudakis, G. Charalambidis, A. G. Coutsolelos, *Chem. Commun.*, **2025**, *61*, 10086.

[4] D. Romito, C. Govind, V. Nikolaou, R.J. Fernández-Terán, A. Stoumpidi, E. Agapaki, G. Charalambidis, S. Diring, E. Vauthey, A.G. Coutsolelos, F. Odobel, *Angew. Chem. Int. Ed.*, **2024**, *63*, e202318868.