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Editorial

Synthesis and Applications of Metal-Derived Catalysts on Semiconductor Materials for Photoelectrocatalytic Processes

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Photoelectrocatalysis combines photovoltaic and electrocatalytic processes. Based on the application of a biased potential on a photoelectrode in which a catalyst is deposited, this technology provides an effective solution to (i) overcome kinetic barriers in traditional electrochemical conversion by catalytic materials with the assistance of solar power ; (ii) inhibit the recombination of the photogenerated electron-hole pairs in typical photocatalytic systems [1]. Significant advances in materials science and nanomaterials have vastly increased the efficiency, versatility, and applicability of photoelectrocatalytic devices in different fields such as hydrogen generation [2,3], air and water depollution [2,4], CO₂ recycling [5], and electricity generation [6].

Recently, new composite photoelectrodes, based on metal-derived catalysts, have started to appear. They exhibit high photoelectrocatalytic activity (in terms of photocurrent densities and onset potentials), as well as high selectivity and stability. This has been achieved through novel engineering of their structural, architectural and compositional features. Different catalyst configurations (molecular, supramolecular, plasmonic NPs, metal oxides, MOFS) are currently being explored. Some examples are described in the following.

Wang et al. recently demonstrated that NiMoO₄ nanosheets deposited onto TiO₂/g-CN heterojunctions form a stable TiO₂/g-CN/NiMoO₄ 3D photoelectrocatalyst that was able to provide a photocurrent density for water oxidation as high as 1.8 mA/cm² under 1 sun at 1.23 V versus RHE (two times higher than pristine TiO₂) with a faradaic efficiency, *FE*, of 93.6% for 12 h [7]. The improved performance was ascribed to the original hybrid assembly, with an expansion of the photoresponse to a visible range by the g-CN/TiO₂ heterojunction alongside the highly catalytic surface provided by NiMoO₄ for OER. Another example of metal TiO₂ functionalization has been given by Chen et al. for application in environmental remediation [8]. They proposed Au-Pd/TiO₂ nanobelts synthesized by bimetallic Au-Pd electrodeposition as a super-reusable photoelectrocatalyst for the degradation of the antibiotic levofloxacin (LEV) in an aqueous solution (demonstrating enhanced visible light absorption, low recombination, and a photoelectrochemical degradation efficiency of 95%).

Molecular catalysts based on transition metal complexes are well-known for their selectivity. Kamata et al. recently presented a novel route to synthesize a hybrid supramolecular photoelectrocatalyst for CO₂-to-CO reduction: poly-RuRe/NiO [9]. The poly-RuRe/NiO showed increased activity in an aqueous solution and improved stability vs. simple RuRe/NiO (the total *FE* of 85% against 57%, respectively).

Finally, plasmonic metal nanostructures have gained attention in the quest for efficient solar-to-fuel energy conversion. Deng et al. showed that the strongly coupled Cu-Pt core-shell nanoparticle (fabricated by combining top-down lithography and solution-based chemistry) deposited on an ITO possesses exceptional photoelectrocatalytic activity for HER (the current density of c.a. 2 mA/cm² under the white light of 450 mW/cm² at -0.2 V vs. RHE), with a two-fold activity enhancement of the surface lattice resonances compared to localized surface plasmons [10].

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This *Special Issue* aims to cover recent advances in developing metal-derived catalysts on semiconductor materials and their applications in photoelectrocatalytic processes. Synthesis and assembling processes and insights on electronic, geometrical, and compositional effects in the photoresponse and photo-electrocatalytic cell conception and implementation are all encouraged—but not restrictive—topics. This Special Issue aims to bring together expertise, concepts, and ideas in the field of metal catalyst-based photoelectrodes to strengthen the current state of knowledge, highlight the latest advances, and bring forth anticipated applications relating to energy transition and environmental sustainability. With their remarkable tuning possibilities, metal-derived catalysts on semiconductor materials will be part of the next era of photoelectrocatalysts for the energy transition.

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