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Integrating biomolecules with electrodes: From electrochemical analysis to proof-of-concept biotechnological applications

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Electrochemical processes involving the transfer of electrons and the build-up of potential differences across interfaces are central processes in life. The study of redox proteins at the interface with electrode materials allows us to address fundamental biological questions. Through this understanding we can also make use of biological elements for the fabrication of hybrid electrode materials with different biotechnological applications. Among others, relevant examples include the development of biofuel cells for clean energy generation, and novel catalytic materials used in bioelectrosynthesis aiming at the conversion of surplus residues into valuable products. In particular, the photosynthetic protein complexes are highly abundant in nature and have an exceptionally high quantum yield, close to 100%, for the photon-to-electron conversion. As a result, there is a great interest in the coupling of these biomolecules with electrode materials for the development of semi-artificial biodevices that will enable the conversion of solar light energy into electrical power as well as the synthesis of valuable products. In addition, redox enzymes are highly active and selective biological catalysts, able to perform catalytic conversions with high yields under mild conditions, such as aqueous solutions, near-neutral pH, and ambient temperature and pressure. As will be shown, we can fabricate functional bioelectrodes that consist of electrically conductive materials and integrate isolated enzymes or photosynthetic complexes. Taking advantage of relatively simple but powerful electrochemical characterization tools, the biohybrid materials are investigated to assess electrochemical communication at the biotic/abiotic interface, ensuring appropriate immobilization and productive interaction between the biological entities and the electrode surface. Examples will be shown highlighting the possibility of performing electrochemical characterizations at the microscale using micro(bio)sensors for direct local analysis of chemical reactions with higher spatial and temporal resolution and our latest developments in hybrid biomaterials for energy conversion and carbon dioxide valorization.

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