Characterization of enzymatic catalysis by microscopy and electrochemistry: application to H_2/O_2 bio-fuel cells

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Enzymes are macromolecules whose structure results from evolution over millions of years to optimize biocatalysis processes enabling growth of the host microorganism. Their activity and their specificity overcome by far those of organic or inorganic catalysts. Among them, redox enzymes catalyze electron transfer reactions that are crucial to the metabolism. They are promising catalysts in various biotechnological domains such as medical diagnostic, depollution or renewable energies. Advances in these fields require multidisciplinary approaches that combine biochemistry, material chemistry and electrochemistry. This thesis project relies on this multidisciplinary approach to investigate, determine and bring a solution to the main problems limiting the performances of redox enzymes as biocatalysts in devices such as biofuel cells. At the end of the project, a demonstrator based on specifications required by the partner Hyseas-Energie will be built. Bio-fuel cells work like conventional ion-exchange membrane fuel cells, that do not emit lighthouse gases. They display the further advantage that they use enzymes instead of the expensive and sparse platinum-based catalysts. Moreover, enzyme huge specificity compared to that of platinum allows to use non-purified gases like hydrogen from biomass. Last results obtained in our lab have shown that catalytic currents can reach amperes per mg of enzyme, *i.e*. very competitive values compared to platinum. However, several bottlenecks limit the understanding and thus the optimization of bio-fuel cells. At the level of individual electrodes that compose the two poles of the fuel cell, the question of homogeneity of enzyme immobilization and catalysis distribution can be raised. The penetration of enzyme inside porous materials indispensable to improve performances is also an important issue. At the level of the entire device, mechanisms of proton transfers linked to current circulation have to be clarified. The originality of this thesis project will be to use an innovative method relying on coupling electrochemistry and fluorescence microscopy to study theses aspects in the frame of biocatalysis of H_2 oxidation and O_2 reduction by new resistant enzymes immobilized on planar electrodes or at (nano)porous conductive materials.

Candidate profile: M2 in analytical chemistry, electrochemistry, biochemistry or physico-chemistry.

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