Engineering Biomolecule–Material Interfaces for Next-Generation Bioelectronic Devices

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The advanced interfacing of biomolecules with functional materials has emerged as a powerful strategy for developing high-performance bioelectronic devices for sensing and energy conversion. Over the past several years, my research has focused on investigating and advancing biomolecule–material interactions to create biosensing platforms capable of detecting a wide range of biomarkers and harvesting the electricity from sustainble resource including biological fluid [1-5]. Among various biomolecules, enzymes are uniquely valuable due to their high specificity and ability to transfer electrons during catalysis. This dual functionality makes them useful not only as biorecognition elements in biosensors but also as biocatalysts in biofuel cells and self-powered sensing devices. However, enzymes typically require redox mediators to enable efficient electron transfer to the electrode. The effective immobilization of redox mediators capable of facilitating efficient enzyme-mediated electron transfer (MET) is therefore essential. Building on this foundation, I employed coordination chemistry to immobilize redox-active molecules onto the high-surface-area, porous structures of MOF-based materials [1-2]. This rational design approach allowed for high loading and controllable redox site coverage, with favorable molecular spacing and orientation to enable efficient electron transfer even for enzymes with deeply buried active sites. This breakthrough led to the development of a versatile electrode platform for exploring complex bioelectrocatalytic processes, including multi-enzyme cascade reactions [4]. Looking ahead, this research will expand to applying biomolecules for gas-phase biosensors, developing novel biorecognition elements and innovative sensing approaches, stabilizing biocatalysts and enhancing bio-energy harvesting efficiency, and using bioelectrochemistry to investigate the origin of life, with the dual aim of advancing fundamental science and creating technologies with strong practical potential to improve quality of life.

References:

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