Abstract

A biosensor produces readable signals proportional to the concentration of an analyte (e.g., biomolecules) in a reaction to identify the biological or chemical processes. There are several uses for biosensors, including disease monitoring (e.g., cancer), drug research, detection of contaminants, pathogens (e.g., food pathogens), and disease (e.g., COVID-19) indicators in physiological fluids (blood, urine, saliva, sweat). Due to its vast range of applications related to health and the environment, the design and development of high-performance biosensors have captured the considerable attention of researchers and scientists in the last ten years. The biosensor market is expected to double in the coming 10 (ten) years. Among biosensors, many biosensing technologies are available, including electrochemical, optical, plasmonics, etc. However, 80% of the market is dominated by electrochemical biosensors alone. Among electrochemical biosensors, the efficient capture of biorecognition signals and their conversion into electrochemical signals (transduction process), improving transducer performance (i.e., increasing sensitivity, reducing response time, reproducibility, and lowering the detection limits even to detect trace level or individual molecules), and miniaturization of the biosensing devices are the main challenges involved in the development of biosensors. The performance of the electrochemical biosensors highly depends on the material platform used to immobilize the bioreceptors. The advancement of the materials at the nanoscale has allowed the production of highly accurate electrochemical biosensors. The combination of sensing technologies with nanomaterials—which can be zero to three-dimensional, have a high surface-to-volume ratio, and strong conductivities, can address the issues that are being generally faced with respect to the sensitivity, repeatability, and selectivity. Numerous nanomaterials have been used in biosensing technologies, out of which carbon dots (CDs) have emerged as an intriguing contender for immobilizing biomolecules and building biosensors due to its low cost, strong affinity, surface functionalities, high surface area, superior intracellular solubility, and nontoxicity. CDs are the result of limiting carbon material's physical dimension, which can deliver the new physical and chemical properties usually absent in the bulk counterparts.

Further deriving these carbon dots from the biowaste (BWCDs) is highly appreciable, targeting the waste to wealth. However, still creating a single material platform for a wide range of biomolecules is a challenge that demands the control of material characteristics (surface functionalities, redox centers, surface area, stability, conductivity, and diffusion properties) at the nanoscale. To address this issue, producing desirable out-of-plane functionalities (will enhance the functional group density)and covalent bridges with highly porous and tunable host structures could be an ideal platform for biosensing. Coming to the porous materials, recently developed metal organic frameworks (MOFs) structure allow the myriads of metal clusters and organic linkers combination to tune the porosity and chemical/physical properties. In this project we propose the hybrid structures of BWCDs and MOF as a base platform to immobilize wide range of bioreceptors just by changing functionalities at the base material (functional groups at BWCDs, metal centers for MOF, and the spatial distribution of BWCDs in MOF crystals). The developed material is expected to have easy structural modification for different types of bioreceptors with high performance. Further, in order to enhance the performance of the biosensors based on the developed material, a new technique, wiz scanning electrochemical microscopy, will be explored, which can allow for the extension of the limit of detection by studying the electrochemical reactions at a micro-scale dimension, could allow detecting the minute concentration of target biomolecules which is one of the main challenges in the biosensor industries.