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Porous silicon optical biosensors for rapid environmental monitoring of trace heavy metals

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The objective of this research is to develop a generic integrated biosensing platform for detection of heavy metal pollutants in aqueous solutions. Heavy metals are one of the most serious pollution problems of our time, which threatens global sustainability as being non-biodegradable. Increasing industrial activity and the use of metallic constituents of pesticides leads to the accumulation of heavy metals in the food chain. Long-term exposure to these highly toxic pollutants may result in severe physiological and neurological damage and may even cause cancer. Consequently, growing environmental awareness has resulted in strict regulations for reducing heavy metals presence in the environment. Thus, we have designed and fabricated a simple optical biosensing platform based on porous Silicon (PSi) nanostructures that allows for real-time monitoring of heavy metal pollutants in aqueous solutions by enzymatic activity inhibition. An oxidized PSi optical nanostructure, a Fabry-Pérot thin film, is synthesized and used as the optical transducer element. First, we show a general detection assay by immobilizing horseradish peroxidase (HRP) within the oxidized PSi nanostructure and monitor its catalytic activity in real-time by reflective interferometric Fourier transform spectroscopy. Optical studies reveal high specificity and sensitivity of the HRP-immobilized PSi towards three metal ions (Ag+>Pb2+>Cu2+), with LOD of 56 ppb. Next, we demonstrate the concept of specific detection of Cu2+ ions (a model heavy metal) by immobilizing Laccase, multi-copper oxidase, within the PSi. The resulting biosensor allows for specific detection and quantification of copper ions in real water samples by monitoring the Laccase relative activity. The optical biosensing results are found to be in excellent agreement with those obtained by the gold standard analytical technique (ICP-AES) for all water samples. The main advantage of the presented biosensing concept is the ability to detect heavy metal ions, at environmentally relevant concentrations, using a simple and portable experimental setup.

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