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

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Heavy metals are one of the most serious environmental pollution problems of our time, threatening global sustainability as being non-biodegradable. Heavy metal exposure causes serious health effects, including reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death. Consequently, growing environmental awareness has led to strict regulations on the maximum metal concentrations allowed in natural waters. Traditional methods to analyze heavy metals with high sensitivity include diverse spectroscopy techniques: cold vapor atomic absorption spectroscopy, inductively coupled plasma – mass spectroscopy/atomic emission spectroscopy (ICP-MS/AES), UV-VIS, X-ray and others. Although these methods have high precision (as low as part per-trillion concentrations), these techniques are expensive, require sophisticated instrumentation, and can only be performed in a centralized lab. Thus, the objective of this research is to develop a generic integrated biosensing platform for rapid and on-site detection of heavy metal pollutants in water. Our sensing strategy is based on general detection of heavy metals by utilizing the binding affinity of diethylenetriaminepentaacetic acid molecule modified within oxidized porous Si (PSi) nanostructure and monitoring its chelator activity in real-time by reflective interferometric Fourier transform spectroscopy (RIFTS). The sensing concept is demonstrated for the detection of four model ions: Pb^{+2}, As^{3+}, Cu^{+2}, and Cd^{+2}. Next, specific detection and quantification is performed through specific interaction with aptamer-modified PSi with metal targets. The resulting biosensor allows for specific detection in real water samples (e.g., surface and ground water) by monitoring the binding activity of the aptamers to these ions. Overall, 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. While the specific biosensor design can be tailored by varying the immobilized molecule on the PSi.

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