Development of Electrochemical Sensor and Biosensor Platforms: Detection of Therapeutic Drugs and Heavy Metal Ions

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Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt förvar i KB.E3.01 (Lilla hörsalen), KBC-huset, Umea Universitet, fredagen den 13 december, kl. 10.00.
Avhandlingen kommer att förvaras på engelska.

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Abstract

Electrochemical sensors and biosensors combine the sensitivity of electroanalytical methods with the selectivity of a sensor or biosensor surface. The chemical or biochemical component (receptor) in the sensor recognizes an analyte and produces an electrical signal which is proportional to the analyte concentration. Some of these sensors are routinely used in clinical applications and are known for their simplicity, portability, cost-effective, and miniaturization. The glucose sensor used in the management of diabetes is a good example of such biosensors.

This thesis deals with the development of electrochemical biosensor and sensor platforms for the detection of therapeutic drugs, demonstrated using methotrexate (MTX) which is the most common drug used for the treatment of cancer patients, and heavy metal ions (Pb²⁺ and Cd²⁺).

The biosensor surfaces were generated by immobilization of antibody (anti-MTX) on chemically modified gold electrodes using different surface modification protocols. Self-assemble monolayer (SAM) using alkanethiol (cysteamine) or electrografting with diazonium salt (4-carboxybenzenediaonium tetrafluoroborate, 4-CBD) was used for surface modification. The surface modification was monitored and characterized using electrochemical immittance spectroscopy (EIS) and cyclic voltammetry (CV) along with other complementary technique such as X-ray photoelectron spectroscopy (XPS). The biosensing surfaces were used for the detection of MTX in an electrochemical flow cell (paper I) and in a batch system (paper II). The detection was based on non-faradaic electrochemical immittance spectroscopy (EIS) and singular value decomposition (SVD) for data evaluation. Both electrochemical biosensors provided the lowest limit of detection, LOD (at picomolar level) compared to earlier reports.

The electrografting of 4-CBD on glassy carbon electrode (GCE) using CV and the parameters that influence the number of monolayers that can be grafted on the surface are demonstrated (paper III). The CVs obtained during grafting showed one or two reduction peaks, and this was found to be related to the number of monolayers deposited on the electrode. One can increase the number of monolayers by increasing the concentration of 4-CBD or decreasing the scan rate. The GCE, grafted using 4-CBD, was incorporated with Bi by an in situ electrodeposition of Bi³⁺ and used as an electrochemical sensor for detection of Pb²⁺ and Cd²⁺ using square wave anodic stripping voltammetry, SWASV (paper IV). The sensor resulted in LOD of 10 μg L⁻¹ for Pb²⁺ and 25 μg L⁻¹ for Cd²⁺. The applicability of the sensor was tested for detection of Pb²⁺ and Cd²⁺ in tap water and compared with ICP-OES. The results were comparable, demonstrating the potential of the sensor as an alternative to ICP-OES for the detection of metal ions in water samples.

Keywords
Sensors, electrode surface modification, electrochemical immittance spectroscopy, square wave anodic stripping voltammetry, singular value decomposition, therapeutic drugs, heavy metals.