Capacitive based sensor for trace detection of amphetamine type stimulants in water

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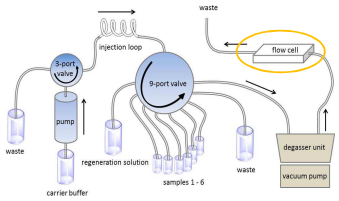
Introduction

Amphetamine-type stimulants (ATS) are the second most widely used drugs right after cannabis. Therefore, a robust and sensitive system, capable of detecting ATS, their metabolites, and their precursors in environmental water, is highly demanded. In this research, a selective detection system for *N*-formylamphetamine (*N*-FA) was developed. Over the last years, (label-free) capacitive sensors have established their own niche for analysis of low- and high molecular weight compounds due to their high sensitivity, high selectivity, fast response time, and their possibility to miniaturize.

Capacitive sensor



An automated flow-injection system was used to simulate continuously flowing systems.

Fig. 1.1: Schematic overview of capacitive sensor.

The working electrode consists of several layers that contribute to the system's total capacitance.

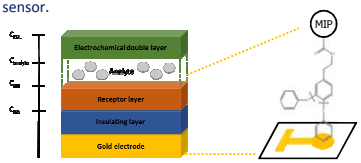


Fig. 1.2: Different layers on working electrode.

When analyte binds, the electrochemical double layer (EDL) is displaced further away from the gold surface. Assuming a good insulation, the insulating and receptor layers will contribute the least to the total capacitance. Hence, the partial capacitances of the analyte and the electrochemical double layer is most pronounced.[1]

$$\frac{1}{C_{tot}} = \frac{1}{C_{iso}} + \frac{1}{C_{rec}} + \frac{1}{C_{analyte}} + \frac{1}{C_{EDL}}$$

Molecularly imprinted polymers (MIPs)

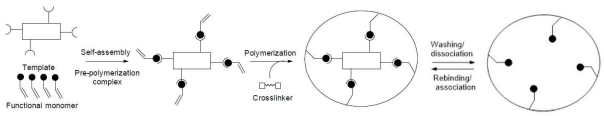


Fig. 2.1: Schematic overview of MIP-production process.

MIPs against *N*-FA were synthesized as follows: 50 µmol *N*-FA, 9 mmol ethylene glycol dimethacrylate, 3 mmol hydroxyethyl methacrylate, 3 mmol itaconic acid, and 0,3 mmol AIBN were dissolved in 2,5 mL DMF.[2]

The polymerization was kept under UV light for 20 minutes and subsequently heated at 80°C for 3h in an oil bath. The monolith (right, SEM) was grienden and sieved wetly.

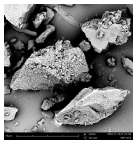


Fig. 2.2: SEM of MIP monolith.

Immobilization on gold surface

MIPs were immobilized using tyramine as a linker. Reaction was performed through electro-polymerization in a galvanic cell for 15 cycles from 0-1.5V. Dodecathiol was used to block active pinholes.

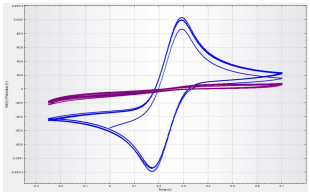


Fig. 3.1: Cyclic voltammogram of bare electrode (blue) and after MIP-immobilization (purple).

Fig. 3.2: Optical microscopy to visually check the presence of MIPs on the surface.

Affinity and selectivity

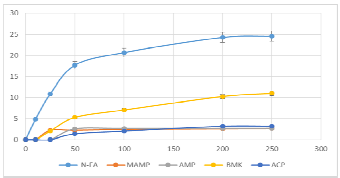


Fig. 4.1: Net capacitance changes (nF), due to binding of the analyte, in function of concentration (µM) Measurements were performed in triplicate.

This figure shows the affinity and cross-reactivity of immobilized MIPs against N-FA. As can be seen, these particles show a higher affinity towards N-FA than to any other tested ATS. The limit of detection was determined to be 5 µM. If higher concentrations of 500-1000 µM were tested, saturation of the MIPs occurs and the capacitive difference stays unchanged.

Conclusion

In this research, selective MIPs against N-FA were succesfully synthesized and immobilized on gold electrodes. Capacitive analyses show that these MIPs have a limit of detection of 5 µM, and low cross-reactivity towards other ATS.

Acknowledgement

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References:

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2. **Graniczkowaka** *et al.* Biosensors and Bioelectronics, **2017,** Volume 92, pages 741-747