Nanofluidic redox cycling for localized detection of chemical gradients

Bernhard Wolfrum[1,2], Enno Kätelhön[1,2], Marcel A.G. Zevenbergen[3], Edgar D. Goluch[3], Serge G. Lemay[3], and Andreas Offenhäusser[1,2]

1) Institute of Bio- and Nanosystems (IBN-2), Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

2) JARA-Fundamentals of Future Information Technology

3) Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, 2628CJ Delft, the Netherlands

We have developed arrays of electrochemical redox cycling amplifiers for the localized detection of chemical gradients in real-time. At every single detector site, the redox-active molecules undergo reversible oxidation and reduction at two independently biased electrodes (see schematics in Figure 1). The electrodes of each detector are separated by a nanosized gap. Fast diffusion between the electrodes increases the electrochemical signal in redox-cycling mode by orders of magnitude. The amplification factor depends on the device layout, in particular the electrode distance, and allows monitoring a low number of molecules in a confined geometry. Using a nanofluidic channel with integrated electrodes we have demonstrated the detection of less than 50 redox-active molecules in the active zone between the electrodes.

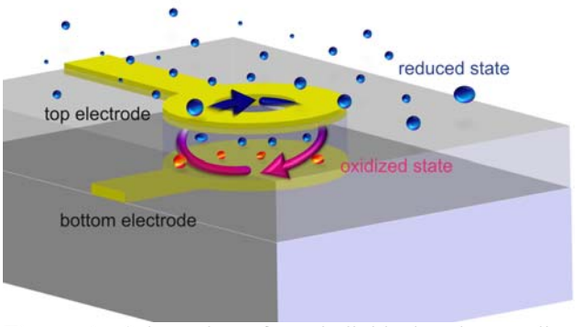

Figure 1: Schematics of an individual redox cycling sensor. Molecules enter the active zone of the detector through an aperture in the top layer. Inside the nanofluidic gap, molecules are reversibly oxidized at the bottom and reduced at the top electrode.

We employ the chip-based detector arrays to identify time-dependent chemical gradients of redox-active compounds with high spatial resolution. The principle is demonstrated by detecting laminar flow gradients of redox-active molecules in a microfluidic environment.

The presented method is particularly sensitive for the detection of catecholamine-based molecules, which comprise an important group of hormones and neurotransmitters such as dopamine. Unwanted background interference, for example by ascorbic acid, can be efficiently suppressed by choosing appropriate sensor designs (1).

Our goal is to construct an on-chip biohybrid system, in which dopaminergic cells are coupled to the nanofluidic redox cycling detector arrays. Such a system will be a powerful tool for the investigation of information processing phenomena in reconstructed cellular networks and will also be useful for the development of cell-based biosensors.

(1) B. Wolfrum, M. Zevenbergen, and S. Lemay, *Anal. Chem.*, **2008**, 80