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*Abstract*

# Lab-In-A-Tube: From Molecule to Cell Detection †

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The intriguing properties of self-assembled microtubular architectures open new possibilities to develop three-dimensional functional devices for molecule and cell analysis. Here, we present an overview of novel applications ranging from highly sensitive protein detection towards cell analysis by either in-flow detection or impedimetric microtomography. The concept "lab in a tube", introduced previously by E. Smith in our institute in 2012 was presented as the integration of different components into a single microtube. It not only constitutes an interesting three-dimensional platform for cell analysis, but also serves as a building block for the incorporation of sensing and actuation components. This concept is based on rolled-up nanotechnology, which consists in deposition of strained nanomembranes on a sacrificial layer that is later selectively etched, transforming a 2D architecture into a tube-like device. In our group, we have developed high-performance electrochemical sensors by integrating electrical transducers in such microtubes. The axial configuration enhances the sensing capabilities in microfluidic devices as the sensing surface per fluid volume and total capacitance increase, favoring in this way the signal coupling with the detection volume of the sample. Our reported DNA biosensor showed superior sensitivity of four orders of magnitude compared to the equivalent planar counterparts, achieving attomolar detection levels of Avian Influenza Virus H1N1 DNA, without amplification or labeling. As a follow-up application, we proposed a direct and ultrasensitive detection system of VP40 matrix protein from Ebola virus, a virus of high relevance due to its high fatality rate. In this approach, we immobilized the capture antibody in the inner part of the tube and by incubating the analyte in-flow, attomolar levels of detection were achieved with high reproducibility and repeatability. The different functionalization steps were confirmed by XPS and AFM measurements. Further electrode nanopatterning within the tubular cavity will be developed in order to increase the sensitivity of the sensor. Our second device is a rolled-up high-throughput cell detection platform, which differs from existing ones because of its particular geometry and electrode configuration that allow highly sensitive detection with a simple readout system. In this approach, multiple rolled-up electrodes within a single tube, precisely integrated in a microfluidic channel, are implemented. Finally, as a complementary technique, a tubular electrical impedance microtomography (EIT) device was fabricated. This approach gives access to EIT devices with tunable sizes in the sub-100 μm range. EIT images of silicon dioxide microparticles were obtained as proof of principle. These devices could enable the impedimetric analysis of biological samples, such as single cells or small cell clusters. In the future, measurements will be carried out to study the behavior of single cells towards external stimuli, e.g., drugs or implant materials.

**Conflicts of Interest:** The authors declare no conflict of interest.