Utilizing Spectroelectrochemical Detection to Improve Sensitivity in the Shear Enhanced Lab on a Chip Device

Burgula, Shweta[1,2]

1. Department of Chemical and Biological Engineering Rensselaer Polytechnic Institute, Troy, New York
2. Department of Chemical and Materials Engineering, New Jersey Institute of Technology , Newark, New Jersey

Abstract

Pathogen detection is currently limited by a lack of widespread access to equipment that is portable and accurate. Point of care detection techniques strive to make detection more accessible for healthcare applications. One example is a lab-on-a-chip device which detects changes in properties of the chip, including electrical resistance and optical absorbance, after running a sample through the channel. Substrates in the chip would bind to biomarkers of interest from the sample, and thus change the overall properties of the chip. These devices are often effective in either detecting molecules in a sample (called sensitivity) or differentiating similar molecules (called selectivity). However, they may fail to achieve high sensitivity and selectivity simultaneously, thus reducing accuracy by either creating false negatives or false positives, respectively. In order to achieve higher sensitivity a new technique is being developed, in which carbon nanotubes (CNT) or other materials are packed into the channel, creating a web through which the sample has to navigate. This creates turbulent flow to enhance mixing and creates more active locations for the biomarkers to bind. Additionally it enhances the shear force of the device, thus improving selectivity by washing away different molecules with similar structures.

Until now, the device only utilizes one type of detection, which limits the sensitivity. This paper addresses the potential of optical detection to be used as a secondary measure to further enhance sensitivity. In order to add an optical component, it is necessary to replace CNT with another optically reactive nanotube. This involves testing for an appropriate electrochemical response, ensuring an ability to functionalize the nanotube, and gathering data for optical reactivity. Due to its versatile properties such as being a dielectric and highly optically reactive, rhenium disulfide (ReS_2) was chosen as a potential replacement.

By replacing the CNT with the optically reactive nanotubes ReS_2, it was found that the change in current through the chip caused by an induced AC voltage varied based on the concentration of the sample. This variation in the chip's properties was consistent with the data gathered for chips packed with CNT. The similarities remained regardless of different electrode configurations and sample concentrations, indicating that ReS_2 is electrochemically similar to CNT. Therefore, these substances can be used for spectroelectrochemical detection in place of CNT, as the electrochemical detection will act similarly to CNT. Spectroelectrochemical analysis can greatly improve sensitivity and with further testing, the shear enhanced lab on a chip design can incorporate multiple detection methods. Future works include testing for changes in optical properties caused by biomarker build up and functionalizing ReS_2 to improve selectivity.

Overall, the use of ReS_2, a dielectric material with excellent optical properties, in place of CNT can allow for a secondary detection technique of optical detection. Utilizing spectroelectrochemical detection can greatly enhance sensitivity of the chip and allow for more accurate results. The work in this paper proves that ReS_2 is a suitable candidate for electrical and optical detection.

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