Design and development of paper-based microchip for healthcare applications

The prevention and treatment of disease depends on accurate disease diagnosis that reliant on the use of sensors. The development of a sensor for use in healthcare is an urgent requirement for disease detection. However, the materials required to produce majority of sensors for rapid healthcare applications are expensive and require lengthy operations. The detection can be performed on a paper substrate to reduce operational complexity and cost of the test. The present dissertation aims to develop paper based microdevice following a unique approach by establishing a hydrophobic barrier for confinement of liquid samples as well as reliable electrodes on paper for electrical analysis. To avoid the double layer capacitance that occurs at the electrode-electrolyte interface, electrodes are placed on the bottom surface of the paper. Non-invasive biological fluids such as saliva, breath, and sweat are examined using paper microdevices. Initially, a paper chip was utilised to analyse various concentrations of an artificial sweat sample using impedimetric method, followed by electrical equivalent circuit analysis to better understand the detecting phenomena. For the obtained impedance data of sweat samples, the sensitivity values for the lower and higher regions are 74.06/mM and 678.03/mM, respectively. The study was extended to analyse evaporation of an aqueous solution using a paper chip by electrical impedance technique. The evaporation process is predicted by analysing impedance variation with change of liquid volume in a paper chip. The weight loss process was compared to weight balancing and impedance method, further equivalent circuit was developed from impedance data to comprehend the evaporation process. Subsequently the normal evaporation process was utilised to modify the paper substrate to develop resistance-based sensor. The modified paper was used to analyse the human breath in three different modes: slow, normal, and fast. The comparison of the original paper and the paper that was previously treated under evaporation process is performed for the analysis of the breath. Time variation of resistance between two electrodes imprinted on paper chip was recorded during breathing process and rise and fall time is analysed for each individual peak. Results reveal that difference of resistance between inhalation and exhalation is much higher (17 MΩ) in sensor chip using paper modified by evaporation process as compared to original paper. Finally, the biomolecules on the artificially prepared saliva sample were detected using a paper microdevice. The paper microchip was further utilized to detect urease molecules of artificially prepared saliva samples by enzymatic process using colorimetry approach. The RGB values were calculated using Image J software after the photographs were shot with a smartphone camera in macro mode. The paper microdevice has a sensitivity of 38.61 blue value/mg and a detection limit of 0.28 mg/ml, according to analytical investigations. Furthermore, by using the incineration procedure, these paper devices can be effortlessly disposed. The non-invasive biological fluids have been effectively analysed using paper-based sensors. It can be used as a low-cost, easily produced device to analyse samples in places with limited resources.

Key words: Paper based sensors, Impedance sensor, Sweat analysis, Human breath, Colorimetric sensor, Urease detection