World Academy of Science, Engineering and Technology
International Journal of Biomedical and Biological Engineering
Vol:13, No:06, 2019

Integration of a Protective Film to Enhance the Longevity and Performance of Miniaturized Ion Sensors

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Abstract : The measurement of electrolytes has a high value in the clinical routine. Ions are present in all body fluids with variable concentrations and are involved in multiple pathologies such as heart failures and chronic kidney disease. In the case of dissolved potassium, although a high concentration in the blood (hyperkalemia) is relatively uncommon in the general population, it is one of the most frequent acute electrolyte abnormalities. In recent years, the integration of thin films technologies in this field has allowed the development of highly sensitive biosensors with ultra-low limits of detection for the assessment of metals in liquid samples. However, despite the current efforts in the miniaturization of sensitive devices and their integration into portable systems, only a limited number of successful examples used commercially can be found. This fact can be attributed to a high cost involved in their production and the sustained degradation of the electrodes over time, which causes a signal drift in the measurements. Thus, there is an unmet necessity for the development of low-cost and robust sensors for the real-time monitoring of analyte concentrations in patients to allow the early detection and diagnosis of diseases. This paper reports a thin film ion-selective sensor for the evaluation of potassium ions in aqueous samples. As an alternative for this fabrication method, aerosol assisted chemical vapor deposition (AACVD), was applied due to cost-effectivity and fine control over the film deposition. Such a technique does not require vacuum and is suitable for the coating of large surface areas and structures with complex geometries. This approach allowed the fabrication of highly homogeneous surfaces with well-defined microstructures onto 50 nm thin gold layers. The degradative processes of the ubiquitously employed poly (vinyl chloride) membranes in contact with an electrolyte solution were studied, including the polymer leaching process, mechanical desorption of nanoparticles and chemical degradation over time. Rational design of a protective coating based on an organosilicon material in combination with cellulose to improve the long-term stability of the sensors was then carried out, showing an improvement in the performance after 5 weeks. The antifouling properties of such coating were assessed using a cutting-edge quartz microbalance sensor, allowing the quantification of the adsorbed proteins in the nanogram range. A correlation between the microstructural properties of the films with the surface energy and biomolecules adhesion was then found and used to optimize the protective film.

Keywords : hyperkalemia, drift, AACVD, organosilicon
Conference Title : ICB 2019 : International Conference on Biosensors
Conference Location : San Francisco, United States
Conference Dates : June 06-07, 2019