Developing a Platinum Fractal Microneedle Biosensor for Uric Acid Monitoring

Altheibany, Meshary (School: Misk Schools)

Chronic kidney disease (CKD) is a major global health problem affecting over 850 million people, with direct costs exceeding 372 billion USD annually. Uric acid is an important renal biomarker used to monitor CKD progression and to help determine when dialysis is required. However, conventional methods used to monitor CKD progression, such as periodic blood testing, are time-consuming, invasive, painful, and not continuous, limiting their reliability and complicating treatment scheduling. In this study, a microneedle-based electrochemical biosensor was developed using interdigitated electrodes (IDEs) modified with electrodeposited platinum fractals for minimally invasive detection of uric acid in interstitial fluid. Polyimide microneedles were fabricated by micromolding, coated with titanium and gold by sputtering, and then electrodeposited with platinum using AC and DC deposition. The fabricated biosensor was characterized mechanically and electrochemically. Mechanical testing showed the microneedles withstood forces up to 2.4 N per needle, exceeding the estimated skin insertion requirement. Electrochemical characterization showed an improvement by over 9 times in the electrochemically active surface area compared to gold sputtered microneedles. Square wave voltammetry enabled detection of uric acid in the range of 10 - 150 µM with a limit of detection of 6.4 µM. Selectivity testing at frequencies above 30Hz showed that the uric acid peak oxidation signal was 87 times greater than that of ascorbic acid at equal concentrations, confirming strong interference suppression. These findings position this platform as a promising tool for continuous, minimally invasive monitoring of CKD. This approach could enable earlier detection and more timely clinical intervention.

Awards Won: