Engineering Novel Cost-Effective Polymer-Coated Dry Electrodes for Extended-Period ECG Monitoring

Alabdullateef, Faisal (School: Riyadh School for Boys and Girls)

Electrocardiography (ECG) is the primary diagnostic method for cardiovascular disease, the leading cause of mortality. Conventional wet ECG electrodes (Ag/AgCl) are metal-based and rely on conductive hydrogels, which cause discomfort and skin irritation. Critically, their signal-to-noise ratio (SNR) drops by up to 40% after a few hours of usage, limiting extended-period cardiac monitoring. Therefore, effective dry ECG electrode engineering necessitates a flexible, gel-free, biocompatible conductive interface with low impedance and stability under prolonged physiological conditions. This study engineers PEDOT:PSS (Poly(3,4-ethylenedioxythiophene) polystyrene sulfonate) films on gold-Kapton substrates to produce dry ECG electrodes compatible with extended-period cardiac monitoring. Films were deposited at varying spin-coating speeds and characterized using cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) to evaluate electrochemical properties. In addition, an ECG simulator with open-circuit potential (OCP) measurements was connected to electrode pairs to assess performance under simulated physiological signals. The best performance was achieved at a spin-coating speed of 1500 rpm, yielding a 3,484% increase in capacitance compared to bare gold (155 ± 46.16 μF vs. 4.32 ± 0.44 μF, $p < 0.01$) and an SNR of 41.37 ± 0.19. Compared to benchmarked Ag/AgCl electrodes, the optimized PEDOT:PSS-coated electrode demonstrated 518% greater operational stability over a typical 72-hour ICU monitoring period, while costing 95% less per electrode set. This work introduces a novel dry ECG electrode with strong potential for next-generation ECG monitoring, demonstrating that conductive polymers such as PEDOT:PSS hold promise for clinical and wearable applications.

Awards Won: