"Development of a Flexible Dual-Conductive Hydrogel sEMG Sensor for Hand Motion Monitoring"

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Abstract:

A flexible dual-conductive poly(vinyl alcohol)-based hydrogel electrode was fabricated for surface electromyography (sEMG) to monitor hand motion. This electrode features a composite structure consisting of a copolymer of aniline and pyrrole infused with silver nanoparticles (AgNPs), embedded within a sodium chloride (NaCl) solution matrix. The synergistic integration of the copolymer and AgNPs facilitates highly efficient electrical pathways, markedly improving the sensitivity and performance of sEMG signal acquisition. The synthesized dual-conductive hydrogel achieves a notable electrical conductivity of 4.17 S/cm, exhibiting its effectiveness for precise and high-resolution electrophysiological signal acquisition. The material displayed good ductility and resilience, withstanding a mechanical stress of 42 kPa and enduring substantial deformation, achieving an ultimate tensile strain of 305% prior to failure. It retains structural integrity under repeated mechanical loading, exhibiting minimal permanent deformation or degradation over 15 cyclic tests. The inclusion of sodium chloride (NaCl) imparts ionic conductivity, enabling efficient charge transport and enhancing signal fidelity. Concurrently, silver nanoparticles contribute not only to improved sensor performance but also impart valuable antibacterial functionality. The skin-contact impedance measured using OpenBCI software for the hydrogel was found to be 81 kΩ. The developed desktop application functions as a vital interface for real-time visualization and analysis of high-resolution electromyography (EMG) signals, leveraging the ADS1299 sensor in conjunction with the nRF52840 microcontroller. This dynamic visualization capability enables users to identify muscle fatigue, track rehabilitation outcomes, and evaluate overall neuromuscular health. Overall, the dual-conductive nature, mechanical robustness,

biocompatibility, and inherent antibacterial properties of this PVA-based hydrogel establish it as a compelling contender for next-generation flexible sEMG electrodes designed for advanced human–machine interface systems.

Keywords:

Dual-conductive hydrogel, surface electromyography, poly(vinyl alcohol), flexible electrode, hand motion.