Flexible Neurohybrid Synapses for Neurochemical Sensing

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Neural interfaces that combine electrical recordings with biochemical sensing are critical for understanding and interacting with complex neural circuits. Traditional microelectrode arrays (MEAs) provide high-resolution electrical mapping but often fail to capture the full range of neurochemical dynamics. Organic electrochemical transistors (OECTs), as a class of neuromorphic devices, offer a promising complementary approach by mimicking short- and long-term synaptic plasticity while enabling direct ionic-to-electronic transduction [1, 2]. Achieving a seamless interface with neural tissue requires combining these capabilities in a single platform, particularly for the detection of both active and non-active neurotransmitters [3].

In this work, we present a flexible neurohybrid platform combining PEDOT:PSS-based OECTs with MEAs, designed as an array to provide simultaneous neuromorphic processing and electrical recordings. Downscaled device dimensions and optimized channel-to-gate ratios aim to ensure physiologically relevant sensitivity and compatibility with soft neural tissue, offering a pathway toward future in vivo applications. The devices exhibit tunable short- and long-term plasticity, allowing synaptic-like signal processing while detecting electroactive neurotransmitters such as dopamine. To extend sensing to non-electroactive species, the gate electrode is functionalized with platinum nanoparticles (Pt NPs) and L-glutamate oxidase, facilitating interaction with glutamate as a target model [4]. Device performance is characterized by using electrical transfer and transient response measurements, electrochemical impedance spectroscopy (EIS), and SEM imaging to assess functionalization and surface morphology. Optimization of device geometry further explores the trade-off between amplification, neuromorphic behavior, and chemical sensitivity, providing design guidance for future neurohybrid systems.

Overall, this work establishes a flexible, biocompatible platform capable of bridging electrical and chemical neural signals. By combining arrayed OECTs and MEAs with Pt NP and enzyme-functionalized gates, the approach represents a step toward seamless multimodal neurohybrid interfaces, providing a versatile strategy for studying complex neurotransmitter dynamics, synaptic processing, and adaptive in vivo neuromorphic bioelectronics.

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