Abstract

Implantable bioelectronic devices promise precise diagnosis and therapy, yet their durability is often decided at the interface where metal meets living tissue. Mechanical mismatch, and nonspecific biofouling trigger glial activation and fibrotic encapsulation that compromise device's performance. Coating the surface of the metals with organic layers can serve as a promising strategy to improve the biocompatibility of bioelectronic devices. Nevertheless, even when device performance is improved in the short term, many coatings struggle with poor long-term adhesion and limited chemical control of cell interactions, all of which constrain reliable, chronic operation.

This thesis responds to the current needs in biomedical sector by introducing ultrathin, covalently anchored organic layers that are molecularly programmed to couple electrical stability with biological selectivity. Pro-adhesive ligands have been used to develop neuron-preferring surfaces that enhance neural adhesion and differentiation while tempering astrocytic responses. Adhesion-promoting interlayers have been used to stabilize conducting polymer films without compromising their conductive and capacitive behavior. Composition-tuned mixed monolayers have been introduced as a way to provide fine control of wettability and interfacial charge, supporting neurite outgrowth while limiting astrocytic branching. Together, these outcomes yield clear structure-function design rules and a modular, scalable strategy for building reliable, long-lived, and multifunctional bioelectronic interfaces advancing the practical engineering of next-generation neural electrodes and implantable biosensors.