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Polymer-based Mixed Conductors For Applications In Bioelectronics

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Direct measurement and stimulation of ionic, biomolecular, cellular, and tissue-scale activity is a staple of bioelectronic diagnosis and/or therapy. Such bi-directional interfacing can be enhanced by a unique set of properties imparted by organic electronic materials. These materials, based on conjugated polymers, can be adapted for use in biological settings and show significant molecular-level interaction with their local environment, readily swell, and provide soft, seamless mechanical matching with tissue. At the same time, their swelling and mixed conduction allows for enhanced ionic-electronic coupling for transduction of biosignals. Through synthetic design and processing we are able to establish design rules towards high performance and stable polymer bioelectronic materials. Such materials open new opportunities for unique form factors and novel device concepts. To this end, I will demonstrate how relaxed design constraints allow for flexible amplification systems for electrophysiological recordings and biochemical detection. These co-localized devices, forming a complementary inverter, highlight new advances in ambipolar polymer mixed conductors, enable up to 30x amplification in a footprint the size of a typical passive electrode (tens of micrometers). Finally, while such devices present important advances for on-site signal amplification and processing, degradation and stability continue to be critical bottlenecks for devices in direct contact with biological environments. I will highlight recent work probing mixed conductor degradation under operation. In this work, we go beyond a discussion of energy levels, and find that device implementation/biasing and contact electrodes play a critical role. These case studies show that fundamental materials research and device engineering continues to fill critical need gaps for challenging problems in bio-electronic interfacing.