Functional polymers for energy, sensing and biomedical applications

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Polymer-based functional materials are advancing applications in energy, soft robotics and biomedical sensing across length scales, enabling adaptive systems for energy harvesting, precise actuation and continuous health monitoring. Our research involves understanding structure-property and functionality relationships in novel functional polymers, with a focus on the role of phase, crystallinity and morphology on their functionality. The ability to engineer material properties at the nanoscale gives rise to a wide range of applications, for example, in the case of nanostructured piezoelectric polymers [1]. These nanomaterials can also be integrated into sensors and energy harvesters using advanced additive manufacturing techniques to create a range of functional devices, including those aimed at biomedical or clinical applications. For example, a combination of aerosol-jet printing and 3d printing can be used to fabricate "soft" functional interfaces based on piezoelectric polymer nanostructures [2] for sensing and stimulation of cells, and also to enhance and control piezoelectricity in printed structures based on collagen [3] for possible applications in tissue engineering. The same techniques can be used to create "soft" micro-patterned ultrathin electrochemical actuators [4] with controllable multimodal actuation, macroscale printed shape-memory polymer (SMP) structures for soft robotic applications [5], self-powered and self-healable triboelectric tactile sensors [6], and printed microfluidic biosensors for real-time physiological analysis [7]. By bridging microscale actuators, macroscale shape-memory transformations, and biosensing applications, our work highlights the versatility of polymer-based devices in automation, healthcare, and robotics, paving the way for multifunctional, adaptive technologies.

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