Micro- and Nanofabricated Platforms: From Hydrogel Sensors to Therapeutic Devices

In the last few decades, nanotechnology has had a profound influence on everything from the design of new biomaterials to our understanding of systems biology. In particular, successful fabrication techniques from the semi-conductor industry have influenced researchers to engineer synthetic biological devices at the micro- and nanoscale for diagnostic and therapeutic applications. My research is directed towards combining the versatility of polymers with nanotechnology to develop advanced biomedical platforms for faster and better diagnosis and point-of-care targeted therapy. In this work, the development of surfaces with responsive hydrogel nanopatterns for rapid sensing is first introduced. In particular, the viability of achieving precise spatial XY control of patterns on planar gold using microcontact printing and tunable thickness (Z control) of hydrogel structures using atom transfer radical polymerization (ATRP) is demonstrated. The effect of crosslinking parameters on equilibrium response kinetics of hydrogel patterns at the nanoscale is also characterized. Then, the transition of controlled hydrogel growth into gold nanoparticle (GNP) systems is highlighted. Herein, a novel strategy of using degradable polymers to isolate nanoparticles, functionalize their surface via ATRP, and releasing them is discussed to produce stable hydrogel functionalized nanoparticles. This strategy is further extended to enhance the functional loading of proteins over nanoparticle surfaces for therapeutic applications. Finally, a novel planar bioadhesive microdevice platform for oral drug delivery is detailed to overcome issues of micro- and nanoparticle agglomeration, luminal drug loss, and limited therapeutic residential time. The microdevices are designed to target gastrointestinal epithelia and release multiple drugs independently from multiple reservoirs in a unidirectional way, thereby enhancing the overall therapeutic efficacy of oral drugs. The versatility of using polymers with various micro- and nanofabrication techniques can prove to be a simple yet powerful method to greatly enhance the development of innovative biomedical devices for diagnostic and therapeutic applications.