MECHANICAL ENGINEERING

The Department of Mechanical Engineering presents:

The Ph.D. Dissertation Defense of

Omid Khandan

Tuesday, December 2, 2014, 10:00AM
in Bourns Hall A265

Titanium MEMS Technology Development for Drug Delivery and Microfluidic Applications

Doctor of Philosophy, Graduate Program in Mechanical Engineering
University of California, Riverside
Dr. Masaru P. Rao, Chairperson

The use of microelectromechanical systems (MEMS) technology in medical and biological applications has Increased dramatically in the past decade due to the potential for enhanced sensitivity, functionality, and performance associated with the miniaturization of devices, as well as the market potential for low-cost, personalized medicine. However, the utility of such devices in clinical medicine is ultimately limited due to factors associated with prevailing micromachined materials such as silicon, which poses concerns of safety and reliability due to its intrinsically brittle properties, making it prone to catastrophic failure. Recent advances in titanium (Ti) micromachining provides opportunity to create devices with enhanced safety due to its proven biocompatibility and high fracture toughness, which causes it to fail by means of graceful, plasticity-based deformation.

Motivated by this opportunity, we discuss our efforts to advance Ti MEMS technology through the development of titanium-based microneedles (MNs) that seek to provide a safer, simpler, and more efficacious means of ocular drug delivery. We show that devices with in-plane geometry and through-thickness fenestrations that serve as drug reservoirs for passive delivery via diffusive transport from fast-dissolving coatings can be fabricated utilizing Ti DRIE. Our mechanical testing and finite element analysis results suggest that these devices possess sufficient stiffness reliable corneal insertion. MN coating studies show that fenestrated devices can increase drug carrying capacity by 5-fold, relative to solid MNs of identical shank geometry. Furthermore, using an *ex vivo* porcine cornea model, we demonstration that through-etched fenestrations can provide a protective cavity for increasing delivering efficiency. Collectively, these results demonstrate the potential embodied in developing Ti MNs for effective, minimally invasive, and low-cost ocular drug delivery.

Additionally, we report the development of an anodic bonding process that allows, for the first time, high-strength joining of bulk Ti and glass substrates at the wafer-scale, without need for interlayers or adhesives. We demonstrate that uniform, full-wafer bonding can be achieved at temperatures as low as 250°C and that failure during burst pressure testing occurs via crack propagation through the glass, rather than the Ti/glass interface, thus demonstrating the robustness of the bonding. Moreover, using optimized bonding conditions, we demonstrate the fabrication of rudimentary Ti/glass-based microfluidic devices at the wafer-scale, and their leak-free operation under pressure-driven flow. Finally, we also demonstrate the monolithic integration of nanoporous titanium dioxide within such devices, thus illustrating the promise embodied in Ti anodic bonding for future realization of robust microfluidic devices for photocatalysis applications. Together, these results demonstrate the potential embodied in utilizing Ti MEMS technology for the fabrication of novel drug delivery and microfluidic systems with enhanced robustness, safety, and performance.