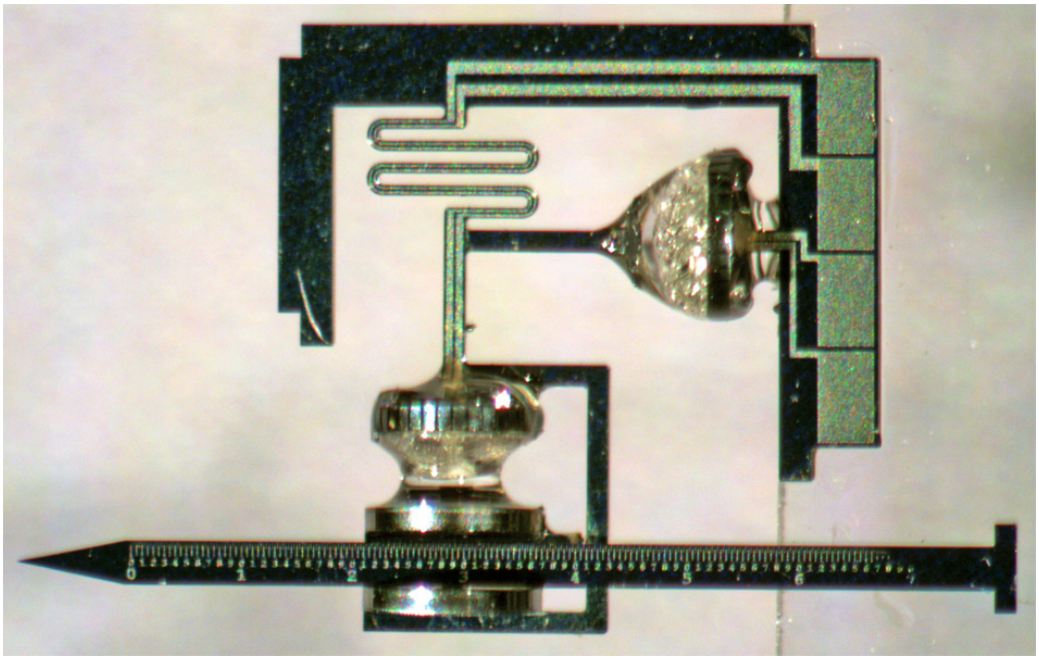
MEMS Robotic Inchworm for Cortical Neural Prosthesis

Yu-Chong Tai, PhD
Division of Engineering and Applied Science
California Institute of Technology
Pasadena, CA 91125
yctai@caltech.edu

Summary

Over decades of cortical neural prosthesis, it was recently concluded that "movable" neural probes that can follow or track a neuron are important for long-term, reliable prostheses. This is challenging because practical movable probes require low voltage, small power, bidirectional/latchable movement, and large total traveling distance. The device should also be small enough to entirely fit under the skull after implantation. Many different devices have been demonstrated to move neural probes, but none of them satisfies all the actuation and size requirements. This talk presents our work on actuators for movable neural probes that combine MEMS technology with an electrolysis-based actuation mechanism. Each inchworm is based on two electrolytic balloon actuators. The actuators rely on gas generation by electrolysis inside a sealed balloon, which causes its expansion. When electrolysis is stopped, gas recombination and permeation across the balloon membrane cause the balloon to relax. Electrolytic actuation, although slow, has several advantages: low power, low voltage, and ability to provide large force and displacement. The balloons have been characterized and their behavior mathematically modeled. Innovative salt-shell-based processes have been developed to fabricate the balloons and to allow their replenishment by osmosis. Minimally two balloons are needed to make a bidirectional inchworm mechanism. Large traveling distance can be obtained in multiple cycles, the only constraint being the probe length. Displacements of a silicon probe and a commercial metal probe have been demonstrated in both directions, with a displacement per cycle between 0.5 and 75 μm. The voltage required to drive electrolysis is typically around 3.5 V, with a peak power per balloon around 100 μW. The devices were tested both in air and in water. The demonstrated inchworm is promising for neural probe applications.



Short Bio:

Yu-Chong Tai is a Professor of Electrical Engineering, Mechanical Engineering and Bioengineering at the California Institute of Technology (Caltech). His main research interest has been MEMS technology, sensors and actuators. While in graduate school at UC Berkeley, he developed the first electrically-spun polysilicon micromotor. At Caltech, he built the Caltech Micromachining (or MEMS) Laboratory, which is an 8,000 sq. ft. facility completely designed for MEMS research. This facility includes a clean-room MEMS fabrication lab (~3,000 sq. ft), a CAD lab, a measurement/metrology lab and a bio lab. It is currently supporting more than 20 researchers (mainly graduates and postdocs) with various MEMS research projects (http://mems.caltech.edu). Research examples include neural chips, neural probes, micro actuators, lab-on-a-chip, cortical/retinal/spinal implants, biomedical electronics, etc. His recent new research also include MEMS for cancer and stem cell applications. He has published more than 400 technical articles in the field of MEMS. He is the recipient of the IBM Fellowship, Ross Tucker Award, Best Thesis Award (at Berkeley), Presidential Young Investigator (PYI) Award, Packard Award, ALA Achievement Award, and the 2010 Discover Magazine Breakthrough Award. He is a fellow of IEEE and IOP.