**Medical Microsystems from Moths to Man**

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Significant interest exists in creating integrated, autonomous medical microsystems combining electronics and microelectromechanical systems (MEMS) to monitor and/or control physiological parameters. Ideally, these systems should be small, low-weight, low-power, yet with a high degree functionality in terms of sensing, actuation, and processing. Here I will describe the development of integrated implanted microsystems. These were originally intended for interfacing with the nervous systems of moths and are now being translated for human applications. These two applications pose many of the same challenges, in that the systems must be low mass (<1 g), have small volume (~ cc), and consume low power (~1 mW), and yet must contain components necessary to be useful.

To meet these challenges, we have developed microsystems that include MEMS-based electrical stimulation of the nervous system, 10-100 meter radio telemetry, computation, and electromechanical energy harvesting and accompanying power electronics. One critical part of the system is electrical stimulation and recording of the nervous system. Many technologies have been developed over the past 40 years to record and/or stimulate neurons. One outstanding challenge has been in recording from small cylindrical nerve bundles. Penetrating MEMS electrodes can damage the axons and are typically large, while cuff electrodes can encircle cylindrical nerves but are large and hand-made. Instead, we have developed microfabricated flexible neural probes that contain a split-ring structure that incorporates the anatomical structure of the nerve to be encircled. To improve the electrode impedance properties, we electroplated a carbon nanotubes-Au nanocomposite film onto the neural probes to enhance the charge injection capability at the probe-neural interface and to reduce the stimulation voltage. This electrode can in turn be implanted, and we have demonstrated that it is possible to implant the neural probes during the pupal stage of moth development and have adult moths emerge normally and fly.

Alongside these neural probes, we developed an energy harvesting device that is capable of harvesting mechanical motion and converting into electrical energy. The device is an electromagnetic harvester that uses a phenomena very similar to a motor, but tuned to the motions of moth wingbeats, and by carefully matching mechanical impedance and frequency, we can recover ~1 mW of electrical energy from flying moths. These two systems are in turn coupled to a set of electronics including a radio receiver and microprocessor to provide for a remote-controlled instrument for biasing the flight of moths in order to understand how flapping insects fly.

We have more recently focused our efforts on translating these technologies to medical use. It turns out that many nerve fibers in humans are similarly sized to those in invertebrates, and thus present intriguing possibilities for adaptation of our flexible neural probes. As well, by changing the geometry we can interface with other parts of the central and peripheral nervous systems. The other components in the system also have applicability for wearable, minimally invasive, and implanted microsystems because of their small size and low power.