Mainstreaming MEMS

Microfluidic Drug Delivery Systems are Now a Market Reality

A Market and Patent Review by Deborah Munro, D.Eng., 2009

While “nanotechnology” has been a popular buzz word among investors and researchers, “microtechnology” has graduated from university research labs into commercialized realities. MEMS (Micro-Electro Mechanical System) technology has been around since the late 1970s, and had a huge surge in popularity in the 1990s with the telecommunications industry because it could be used to make fiber optic switches at the microscopic scale.

Nowadays, MEMS devices are used commonly for digital projectors, accelerometers, automotive sensors, and medical applications. Based on silicon wafer integrated circuit (IC) etching technology, MEMS devices are actually mechanical actuators fabricated at the microscopic level.

The Industry Sees Benefits

Recently, the pharmaceutical medical device industry has recognized the benefits of MEMS, leading to the development of a whole new industry of miniaturized, microfluidic drug delivery systems. Although many drugs are being used in microfluidic systems, the one that has held the most appeal for consumers and industry alike is insulin for diabetics. With insulin-dependent diabetes on the rise, there is a huge market for implantable, painless, automatic insulin devices that give precise dosages based on automatically sensed needs of the patient. As always, these devices need to be cheap, which means the MEMS fabrication process needs to be able to produce large volumes, something that has been a challenge until recently.

According to the Center for Disease Control, from 1997 to 2004, the incidence of diabetes among 45- to 79-year-old patients rose 43 percent. Now, about 12 of every 1000 people over 45 will become diabetic. This means about 3.6 million people in the United States in 2004 were diabetic. Looking at hospital discharges in 2005, over 6.4 million people were hospitalized for diabetes, and a conservative cost for these hospitalizations was $22 billion. Obviously, societal costs due to lost wages, lost earning years, and other medical conditions complicated by the presence of diabetes, would increase this figure dramatically.

Diabetic patients often complain of how difficult it is for them to properly regulate their insulin dosage. Not only does it require them to collect a blood sample for analysis, but then they must administer that dose intravenously. In an elderly or obese patient, this is complicated by poor vision, lack of coordination, and fat, all of which make injecting a proper dose more difficult. Hospitals also make mistakes when administering drug doses, some reports putting these mistakes as high as 200,000 serious injuries and 7,000 deaths in the U.S. each year. Microfluidic drug delivery systems address all these problems and have additional advantages as well.

Configuring Microfluidic Systems

Microfluidic drug delivery systems have three main components; a needle array, a pump and valve system, and chemical sensors. The needle array is usually hundreds of microscopic silicon wafer etched needles with orifices for the drug to pass through. Because these needles are so small, they are painless, and yet their vast quantity delivers the drug instantly.

The pumps and valves are also microfabricated, and can be integrated with the needle array and implanted under the skin. The pumps come in two varieties, either passive with some type of electrode or other stimulating means for fluid flow, or active with valves that can control the precise dose being administered at the micro-volume scale.

The third and most important feature of MEMS insulin delivery systems is the chemical sensor which can detect the level of blood glucose in the patient and automatically administer a precise dose of insulin to correct their glucose levels. Thus, the patient and the hospital are removed from the maintenance process. The patient has a discreet, refillable insulin pouch, and all of the glucose control is maintained 24 hours a day with no pain, measuring, or administration required.

Integrated Solutions Hold Promise

Leaders in the market for microfluidic insulin pumps, such as ISSYS, Eksigent, Debiotech, and Biophan, are all focusing on integrated solutions that can be produced in volume. They realize that the key to success will be to provide a low cost, complete system that can be implanted in an out-patient procedure, monitored by sensors within the sensor system, and refilled with insulin by the patient. The market for microfluidic insulin pumps is expected to reach $2 billion by 2010, with substantial continued growth over the following ten years.

Biomedical applications are already the second largest application area for MEMS technologies after automotive; however, to date commercial success has been limited to sensors that measure physical (heart rate) rather than biochemical parameters (glucose). Other than glucose, there are no in vivo sensors in widespread clinical use for monitoring metabolites, such as cancer cells.

Implantable drug infusion pumps were first used with terminally ill cancer patients in the 1980s, but these worked on a predetermined drug release schedule into the blood stream with no sensor feedback from the patient and no targeting of the drug to the cancerous cells. Now, researchers are beginning to use MEMS to improve the delivery of drugs to cancer cells.

Breast Cancer, Blood Cells & Pacemakers

The biochemical signals that guide breast cancer tumor cell migration are poorly understood, but new microfluidic devices designed specifically to track how breast cancer cells move in response to chemical signals are under development. This will allow doctors to decrease the amount of cell-killing drugs administered to the patient and allow the those drugs to target only the cancer cells, rather than any cells they contact. For women with breast cancer, this could mean an end to hair loss, debilitating fatigue, and other detrimental side effects associated with chemotherapy.

Sandia National Labs has created a mechanized microfluidic device that can ingest red blood cells and alter them in a positive fashion. Eventually, they hope to expand their device to work with any cells in the body. The ultimate goal of the Sandia device is to puncture cells and inject them with DNA, proteins, or pharmaceuticals to counter biological or chemical attacks, gene imbalances, and natural bacterial or viral invasions.

Electrical stimulation devices, such as the pacemaker and defibrillator, have been the most successful products of microelectronic implants. But now, pressure and flow sensors are being added to pacemakers to make them rate-responsive. This will enable patients to be more active, as the pacemaker will respond to increased or decreased demands according to the needs of the moment.

In another electrical application, Transneuronix, Inc. has made an implantable gastric stimulator that applies electrical stimulation to the stomach wall. The company is currently conducting clinical trials for the treatment of severe obesity. Rather than a risky, expensive surgical procedure such as gastric bypass, the stomach will continue to digest food, but the stretch and chemical receptors in the wall of the stomach will provide neural feedback to the patient that they are full.

And, Medtronics' "Activa" system delivers a mild electrical stimulation to block brain signals that cause tremors, such as Parkinson's disease.

Opportunities Seem Endless

For the medical device industry, this is a wake-up call to seek out MEMS and microfluidic solutions to large-scale problems we face in the United States. With the growing epidemics of obesity, diabetes, heart disease, and cancer, there are countless opportunities for large and small companies alike to develop sensor-based diagnostic and therapeutic devices that will help patients live longer, healthier lives with less invasive procedures.