Next-generation Consumer, Medical Products Drive Sensor Advances

MEMS facing competition from printed, flexible sensor technologies

By Spencer Chin, Managing Editor

The growth of the Internet of Things (IoT), wearable electronics, advanced medical products, and other applications has triggered a demand for sensors with advanced sensing capabilities that can fit into tight spaces, have extremely high resolution and accuracy, and consume low power. At the same time, the need for higher integration and value-added electronics assemblies is increasing the need for sensors able to perform multiple sensing functions. These requirements have prompted sensor maker to inject new and improved technologies in their parts.

For many years, sensors that incorporate MEMS (Micro-Electro-Mechanical Systems) technology were considered among the state-of-the-art. Although MEMS continues to benefit from process and production improvements, the technology faces increasing competition from printed and flexible technologies, according to industry analyst Roger Grace of Roger Grace & Associates.

Grace believes printed/flexible sensors will find their way into a number of wearable and disposable sensor applications in the health and medical field, due to their small size, low profile, ability to conform to attaching surfaces, and low manufacturing cost on existing batch mode processing.

The key, according to Grace, is reducing manufacturing costs. Grace and other industry followers assert that printed/flexible sensors will become a more attractive proposition once high volume, roll-to-roll manufacturing can be scaled up to lower production costs. Roll-to-roll manufacturing is expected to lower capital expenditures and eliminate costly clean room equipment requirements that are needed for MEMS.

One company that has already established roll-to-roll manufacturing of flexible sensors is Si-Cal Technologies Inc. (Westborough, MA), a business unit of Japan's Nissha Printing. According to Jaye Tyler, president and CEO OF Si-Cal, the company has been doing roll-to-roll manufacturing of wearable medical sensors for several years, with volume capabilities of 10,000 to 100,000 parts per production run. To date, parts produced by Si-Cal a sensor to detect oxygen flow, a diabetes sensor, a two-way sensor to stimulate nerves, and an esophageal sensor tube to alert surgeons.

Recently, Nissha USA Inc. acquired the printed electronics business of GSI Technologies Inc. Tyler expects the acquisition to bolster the company's capabilities in printed electronics, to meet growth demands for wearable medical sensors.

Challenges to roll-to-roll manufacturing remain, according to Tyler. Asides from the fact the part production volumes need to ramp up to realize cost benefits, Tyler notes relatively few inks have been formulated for high-speed printing, and that the inks available to date often require high deposit thicknesses and are relatively slow to dry. "However, ink suppliers are actively tackling this issues," he adds.

Grace is bullish on the technology. "The key to success in the commercialization of printed/flexible sensors are not the sensors themselves but rather will be in their expected low cost and their ability to solve application problems which leverage their inherent benefits and the ability for a solution to include more than just a sensor in the total deliverable solution," says Grace in a recent research report.

The key driver in sensor technologies, Grace adds, is the end market applications.

"Silicon MEMS sensors were driven by the mobile phone market," he says. Grace estimates there are now 1.3 billion smart phones alone in the world, all of which use MEMS sensors. "(But) now the market is leveling off; there's not that much more opportunity in smart phones."

Market research firm ID TechEx has projected that the market for fully printable sensors will be more than $6 billion of the $340 billion flexible global electronics market by 2030. As with Grace, the firm expects significant applications to be sensors used in sports/health activity/fitness applications.

So far, flexible sensors are in relatively limited production. TEKSCAN has developed a force sensor fabricated between two polyester film substrate layers. A high-temperature version of the sensor (Figure 1) is constructed with two polyamide layers, a conductive silver layer followed by a layer of pressure-sensitive ink. Adhesive is used to laminate both substrate layers together to form the force sensor. The active sensing area is defined by the silver circle atop the pressure-sensitive ink. Silver traces from the sensor area to the connectors on the other end of the sensor forms the conductive leads.

The barriers to roll-to-roll manufacturing, according to Tyler, stem partially from the fact that relatively few inks have been formulated for high-speed printing, and that the inks available to date often require high deposit thicknesses and

Figure 1. A high-temperature version of TEKSCAN's flexible sensor is constructed with two polyamide layers, a conductive silver layer followed by a layer of pressure-sensitive ink.

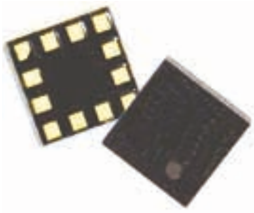

Figure 2. The MC3451 accelerometer from mCube uses the company's 3D monolithic single-chip MEMS platform and contains a precision pedometer algorithm for walking and running.

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A number of companies are developing flexible sensors. Grace noted that INESC Microsystems and Nanotechnologies of Lisbon, Portugal, has developed a technology to enable the integration of magnetic field sensors and other devices fabricated on flexible substrates that are able to bend and conform to non-planar geometries. The fabrication process is based on polyamide substrates, due to their flexibility, thermal stability, chemical resistance, and biocompatibility.

Bioling is developing a flexible epidermal bio sensor system that can be used to determine a wearer's dehydration level. The sensor comprises a printed/flexible electromechanical sweat sensing device on 7 x 40-mm substrate, with several other printed/flexible sensors. The system will assist users in determining the quantity, intensity, and chemical composition of the fluids the user will need to ingest to overcome dehydration problems.

One challenge with flexible sensors will be where the processing and communications handling circuits will reside, according to Jason Marsh, Director of Technologies at Next Flex, an industry association involved in advanced technology development. "At the device level, we need to think about power management and communications." Marsh adds that requirements for on-board signal processing must be weighed against the need to keep the sensor thin and flexible.

Another issue with flexible sensors is that the technology may not easily lend itself to inertia-type sensors, which have moving parts, because the sensors cannot be bent, noted Ben Lee, CEO of mCube, which manufacturer MEMS sensors for motion applications. "The sensor would have to be made very small – under 1 mm x 1 mm—to be immune to the effects of bending", Lee says.

MEMS Market Maturing

While printed and flexible sensors are grabbing more attention, MEMS sensor manufacturers are not standing still. Perhaps in a sign that the sector is maturing, recent industry consolidation indicates suppliers are trying to leverage each others' expertise and team up to produce future solutions.

In early November, mCube acquired 3D motion tracking products and technology company Xsens from ON Semiconductor. mCube has patented technology to fabricate a MEMS accelerometer together with a CMOS signal-processing ASIC on a single chip, and volume production

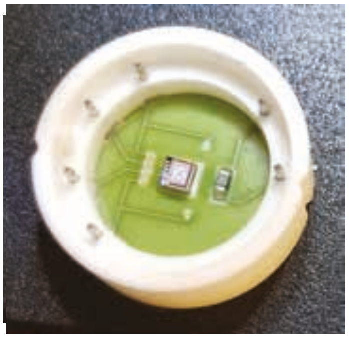

Figure 3. DunAn's TP Series sensor comprises a ceramic substrate on which a MEMS piezoresistive pressure sensor and the thermistor are mounted.

capability. Xsens has a suite of technologies to convert motion sensor measurements into application data, deploying expertise in sensor fusion and motion-tracking applications, drawing on patented algorithms.

Lee of mCube expects the merged company is expected to bring new motion sensing and tracking solutions to the Internet of Moving Things (IoMT) market. This includes motion sensor tracking technology that can monitor a human body's motions and warm of impending injury, or in a rehabilitating patient, if certain body parts are now ready for use again. "Hospitals will use technology to help a patient monitor his or her own rehabilitation," Lee says. "These devices will able to tell you how and when to exercise a body part."

Recently, mCube started sampling its latest accelerometer, the MC3451, which is built on the company's 3D monolithic single-chip MEMS platform. The MC3451 (Figure 2) contains a precision pedometer algorithm for walking and running that attains up to 95% efficiency. The pedometer maintains high accuracy during a phone call or in different motion environments. The sensor also provides gesture recognition functions such as display brightness control in multiple applications.

In another move, Japan-based TDK acquired InvenSense, a supplier of six-axis and nine-axis motion sensors. The move enables TDK to expand its portfolio of sensor and software platforms with its portfolio of magnetic, pressure, temperature, and microphone sensors. TDK will also be able to combine multiple sensor and software solutions to expand its reach into various markets, including IoT, automotive, and information and communications technology (ICT).

Grace believes that with the smart phone market leveling off in growth, future opportunities for MEMS sensors will proliferate in IoT and autonomous vehicle applications. "Many enlightened engineers are selecting MEMS for what they bring to the party….and not because of their technology," Grace writes. "MEMS will continue to play a major role in satisfying the measurement of a wide range of physical, chemical, and optical sensing applications."

MEMS sensor suppliers continue to refine production processes, according to John Chong, president of MEMS sensor supplier Kionix (Ithaca, NY). "MEMS product suppliers are continuing to focus on improving manufacturing yields, reliability, test efficiency, and coverage, which in turn are helping to achieve further cost reductions. There is also more outsourcing of manufacturing as the supply chain gets better at MEMS-related processes."

Figure 4. STMicro's LPS33HW ruggedized MEMS sensor withstands submersion at up to 90 meters and maintains drift within +/-1 mbar a year. It is aimed at smart watches and wearable fitness trackers.

Sensor manufacturers are also integrating MEMS technology with other devices to create solutions that perform multiple sensing functions. DunAn Sensing (San Jose, CA) recently announced its TP Series integrated pressure and temperature sensors comprising a ceramic substrate on which a MEMS piezoresistive pressure sensor and the thermistor are mounted (Figure 3). The sensor's package does not expose its bond wires or electrical signals to the media, thereby improving reliability and enabling it to operate in conductive media.

The TP Series (Figure 3) is available in pressure range from 0 to 15 through 0 to 750 psi in both absolute and sealed gauge versions. Device accuracy at 25°C is +/-0.5 percent of span, and +/-1.5 percent of span from -20 to +125°C. Extended temperature range is -40 to +125°C, suiting the device for HVAC, heat pumps, compressors, hydraulics, off-road vehicles, and industrial equipment.

Ruggedization of MEMS sensors also continues. STMicroelectronics (Geneva, Switzerland) has introduced a water-resistant pressure sensor, the LPS33HW (Figure 4), aimed at smart watches and wearable fitness trackers. The sensor is designed for Samsung's Gear Fit 2 Pro fitness device. The 10bar pressure sensor can withstand being submerged up to 90 meters, and exhibits low pressure noise of 0.008 mbar to allow apps such as an altimeters, depth gauge, or weather monitor to deliver consistent and stable results. Sensor accuracy drift is less than +/-1 mbar a year. PDD