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Emerging MEMS Technologies to Watch

Report from the Hilton Head Sensors, Actuators and Microsystems Workshop
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Every two years, top MEMS researchers from the Americas gather at Hilton Head Island, South Carolina to present their latest work on novel MEMS devices. The relaxed and collegial nature of the workshop belies the fact that it is one of the most competitive MEMS conferences in the world, with an acceptance rate of only 10% for oral presentations.

The workshop, through the years, has provided a glimpse of new MEMS technologies that are poised to make the leap from research to commercial products. Indeed, papers from past workshops, both in quantity and quality, foretold the emergence of MEMS gyroscopes and oscillators as viable commercial products.

In this brief report, I highlight several topics and papers presented at this year's Hilton Head workshop that caught my attention. My criteria for noteworthiness were commercial relevance, relative maturity and a path towards mass production. Nearly all of the papers mentioned here would need at least three more years of intensive development to bring them to market, but nevertheless, they each hold potential to create new waves of commercial activity in the MEMS industry.

The emerging MEMS technologies to watch are:

- Biodegradable sensors
- Surface texturing and manipulation
- Proximity sensors
- Resonant sensors

Biodegradable sensors

At this year's workshop, medical and biotechnology-focused papers were a dominant theme. One technology that stood out was biodegradable electrodes, formed from zinc, magnesium, or copper, which conveniently are also essential minerals to humans. Microelectrodes formed from these metals will degrade in the body at a rate that will provide a daily dose *lower* than that in a single multi-vitamin pill.

Researchers at Georgia Tech have developed a polymer and zinc-based biodegradable pressure sensor for implantable use, and Proteus Biomedical has developed a pill-mounted chip that can be used to authenticate pills (counterfeit meds being a growing problem) or to detect whether a patient has indeed taken their medication.[1,2] The Proteus

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chip is powered by what CTO Mark Zdeblick described as the "potato battery": magnesium and copper electrodes that form an electrolytic circuit when exposed to stomach acid. So go ahead, swallow that sensor, it's not just safe, it's good for you, too.

Surface texturing and manipulation

Manipulation of a surface's properties, to make it more or less hydrophobic, or to increase its area, may seem like a banal technology to the casual observer. Several papers demonstrated exciting and important possibilities for the humble surface using a variety of clever manufacturing technologies. Prof. George Whitesides of Harvard University set the pace in his keynote address, which described how mere newspaper can be transformed into a low-cost blood and urine diagnostics tool.[3] A group at Univ. of Maryland is using colonies of tobacco viruses, distributed on a surface, as a nanoscale electroplating template that drastically increases the surface area of battery electrodes and thereby improves battery performance.[4]

The MEMS engineer's favorite tool, the deep reactive ion etch (DRIE), is also useful for texturing surfaces. For some time, it has been known that creating controlled micro-scale roughness on a surface can make it super-hydrophobic (think about how water beads up on a carpet with dense pile). Researchers at UC Davis demonstrated how a silicon surface, etched with an ingenious pattern, can be used to first condense water droplets, and then to move them around on the surface, without any external power source.[5] Super-hydrophobic surfaces have diverse commercial opportunities: imagine smudge-free displays, fog-free windshields and slippery, fast hulls for boats.

Proximity sensors

Researchers at UC Berkeley and Davis have created a new type of MEMS ultrasound sensor for proximity detection.[6] Much of the prior research on MEMS ultrasound had been on sensors optimized for medical diagnostic imaging, i.e. in an aqueous medium. The Berkeley/Davis team has instead developed an aluminum nitride ultrasound sensor optimized for transmission in air, which can be used as a proximity sensor, just as a bat uses ultrasonic cries to find and catch its prey. This technology could make the leap to the commercial market as a sensor that enables gesture recognition in mobile phones, gaming systems and other user interfaces.

Resonant sensors

The MEMS resonator, as a design element, seems to have no end of uses – it can keep time, detect motion, and now, it can measure temperature, too. A collaboration between Stanford University and Bosch RTC, building on their MEMS oscillator research, has developed a MEMS thermometer with 10 mK resolution using an epi-seal process (also used in SiTime's products).[7] This highly accurate thermometer can be co-fabricated with a MEMS sensor, thereby enabling on-chip high-performance temperature compensation.

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Using their thermometer, the researchers were able to reduce the temperature-induced error of a pressure sensor by two orders of magnitude. Sensor applications requiring excellent long-term stability and accuracy would greatly benefit from this new thermometer.

SiTime, one of the few commercial companies presenting at the conference, provided some insight into their market dominance: superior stability (sub-picosecond phase jitter in the 12kHz-20MHz range) achieved through sophisticated temperature compensation of their silicon MEMS oscillator.[8] Their newest product, which incorporates this technology, will be the first MEMS oscillator capable of serving the high-end data communications markets.

For more in-depth analysis of the technologies discussed here, please contact Alissa Fitzgerald at amf@amfitzgerald.com or +1 650 347 6367 x101.

REFERENCES

1. M. Luo, C. Song, F. Herrault, M. Allen, "A Microfabricated Wireless RF Pressure Sensor Made Completely of Biodegradable Materials." Georgia Institute of Technology.
2. M. Zdeblick, "How Wireless Health Will Change Health Care Delivery," Proteus Biomedical, Inc. Keynote presentation.
3. G. Whitesides, "Simple Bioanalysis" Harvard University. Keynote presentation.
4. K. Gerasopoulos, E. Pomerantseva, A. Brown, C. Wang, et. al, "Three-Dimensional Hierarchical Microbattery Electrodes for Tunable High Energy and Power Density Batteries," Univ. of Maryland and Drexel University.
5. K. Zamuruyev, H. Bardaweel, J.P. Delplanque, N. Kenyon, et. al, "Microscale Surface Energy Properties for Enhanced Surface Condensation and Sampling of Exhaled Breath Metabolites," UC Davis and Georgia Institute of Technology.
6. R. Przybyla, S. Shelton, A. Guedes, R. Krigel, et. al., "In-Air Ultrasonic Rangefinding and Angle Estimation Using an Array of AlN Micromachined Transducers." Univ. of California, Berkeley and Davis.
7. C. Chiang, A. Graham, E. Ng, C. Ahn et. al, "A Novel, High-Resolution Resonant Thermometer Used for Temperature Compensation of a Cofabricated Pressure Sensor," Stanford University and Robert Bosch RTC.
8. R. Melamud, P. Hagelin, C. Arft, C. Grosjean, et. al., "MEMS Enables Oscillators with Sub-ppm Frequency Stability and Sub-ps Jitter," SiTime Corporation.