AMFITZGERALD
& ASSOCIATES

700 Airport Blvd. Suite 210
Burlingame, CA 94010 USA
Phone: +1 650.347.MEMS
Fax: +1 650.347.6366
www.amfitzgerald.com

Emerging MEMS Technologies to Watch

Report from the Hilton Head Sensors, Actuators and Microsystems Workshop
June 9-12, 2014

By Alissa M. Fitzgerald, Ph.D., A.M. Fitzgerald & Associates, Burlingame, CA

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 several 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:

- Navigation-grade gyroscopes
- Magnetic sensors and materials
- GaN resonators

Navigation-grade gyroscopes

Several MEMS research groups presented papers with pioneering methods to shrink navigation-grade gyros down to chip scale. As typical for MEMS, multiple creative manufacturing approaches are being pursued: hemispherical shells made of quartz [1, 2] or diamond [3, 4], and a more familiar electrostatic silicon resonator which has been carefully designed for high-performance [5]. The latter features a Q factor of 2.7 million and a process flow that is viable for near-term commercial production.

These gyros, once commercialized, will not be used in mobile phones and toys – they are too large (~ 1 cm^3) and will be too expensive (tens to hundreds of US dollars). Their main application will be autonomous navigation. They would enable small vehicles to navigate without GPS assistance for minutes to hours, which currently only military and aerospace vehicles can do. Exciting commercial uses of this gyro technology would be navigating robots of all kinds, including self-driving cars; military use would be ever smaller and more deadly drones. As always, the technology knife cuts both ways.

Magnetic sensors and materials

Several research groups are working on advanced magnetic transducers with capabilities far beyond today's more familiar e-compass. A collaboration between Stanford and UC Davis has resulted in a Lorenz-force magnetometer that can be fabricated by the proven Bosch/Stanford "Epi-Seal" process (also the baseline process for the SiTime oscillator) [6]. This magnetometer has a very low temperature sensitivity, ten times smaller than commercially available AMR magnetometers, while also achieving a larger bandwidth and dynamic range.

Penn State has developed a high sensitivity, room-temperature magnetic sensor based on magnetostriction, or the ability of some ferromagnetic materials to mechanically strain in the presence of a magnetic field [7]. Penn State's sensor combines a mechanically compliant, high frequency quartz cantilever resonator with a highly magnetostrictive material, Metglas®. Magnetic fields induce a mechanical strain in the Metglas, which in turn induces a frequency shift in the piezoelectric quartz. The Penn State sensor is able to detect microTesla fields and could possibly stretch to nanoTesla levels, useful to magnetic resonant imaging (MRI) and magnetoencephalography.

Addressing a need for a scalable process to deposit permanent magnets while still retaining significant magnetic flux, a group at Georgia Tech/Univ. of Pennsylvania has developed a new CMOS-compatible electroplating/lamination method to build up thin layers of CoNiP, alternated with layers of copper [8]. Potential uses for this process are wafer-level formation of micromagnets for biasing magnetic sensors in a portable compass, high force MEMS magnetic actuators, and energy harvesting.

GaN resonators

After silicon MEMS, came quartz, silicon carbide and diamond MEMS. Now gallium nitride MEMS are coming, too. The material's wide band gap, high piezoelectric coefficients and ability to handle high temperature enables the wafer-level integration of high performance RF MEMS resonators with high power and high frequency electronics. Two groups, at MIT and Univ. of Michigan, presented different approaches for achieving GaN resonators integrated with High Electron Mobility Transistors (HEMT). MIT used phononic crystal patterning in GaN to optimize their resonator [9], whereas Michigan implemented a tethered resonator body [10]. These devices, once developed, could be used as high GHz resonators for channel-select filtering in RF receiver front ends.

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

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