

MEMS'

Trends

ISSUE N°8

OCTOBER 2011

Magazine on MEMS Technologies & Markets

Printed on recycled paper

INDUSTRY REVIEW
From MEMS die
to multi sensor functions

COMPANY INSIGHT
TRONICS view on MEMS
integration

ANALYST CORNER
Combo sensors will
become the inertial
growth driver...

Teledyne DALSA Semiconductor

MEMS FOUNDRY LEADERSHIP

LEADING INDEPENDENT PURE-PLAY MEMS FOUNDRY
ON 150MM & 200MM WAFERS

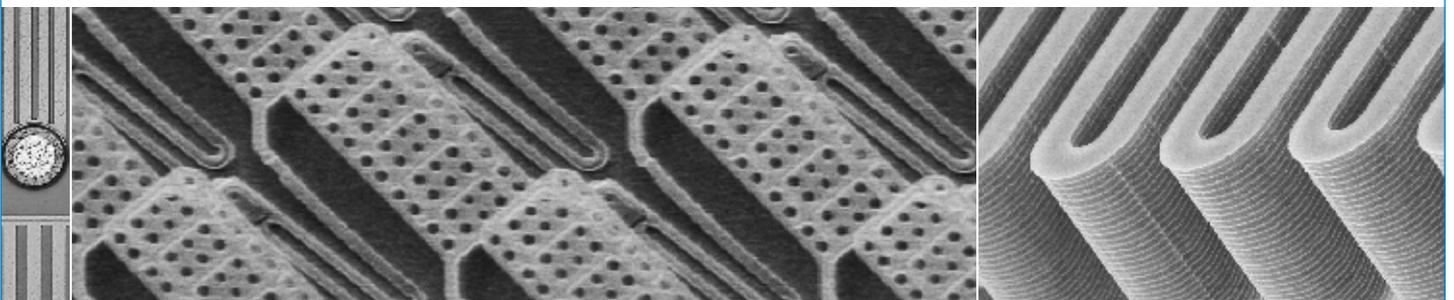
WAFER-LEVEL PACKAGING PROCESS TECHNOLOGIES EXCEEDING YOUR EXPECTATIONS

From design to completion, we can manage your custom project and bring your breakthrough concept to full volume production.

With years of experience in 3D and wafer level packaging technologies including through-silicon vias and a wide range of bonding techniques, Teledyne DALSA can help you transcend traditional design limitations.

www.teledynedalsa.com/semi

 **TELEDYNE DALSA**
A Teledyne Technologies Company





"An increasing complexity comes from the integration of multi-chips into a module."

**Dr. Eric Mounier, Project Manager,
Yole Développement**

Dr. Eric Mounier has a PhD in microelectronics from the INPG in Grenoble. Since 1998 he is a cofounder of Yole Développement, a market research company based in France. Dr. Eric Mounier is in charge of market analysis for MEMS, equipment and material. He is Chief Editor of Micronews and MEMS Trends magazines (MEMS Technologies & Markets).

MEMS modules, why it will be important in the future

For this last 2011 MEMS Trends issue, we have chosen to focus on MEMS Modules. We believe this will be a topic of growing importance both on the technical and business side. It is sometimes confusing to make the difference between MEMS sub-systems, MEMS sensors, MEMS modules ... At Yole Développement, we selected what we think to be the most rational definition: MEMS module is the integration of one (or many) packaged MEMS dies, the electronics, all assembled into a single housing (for e.g., it can be a combo sensor like a 9 DOF inertial module or an infrared core integrating the IR optics).

An increasing complexity comes from the integration of multi-chips into a module. It is already started with inertial modules, from 6DOF to 10DOF, creating significant integration, software and supply chain challenges. There are indeed challenges at very different levels. The first one is at the individual sensor level: how to decrease cost to achieve further price reduction? Then a challenge at the packaging level: which technical evolutions for back-end process? Which test and calibration procedures for combo sensors? Third type of challenges will be at the processing / software level: which level of signal processing / sensor fusion? Where to integrate this software part: ASIC, MCU, other external chipset, application processor...? And finally there are challenges at the system level: e.g. what kind of combo for which applications?

But challenges are not only technical and new business models are likely to emerge as well. Integrating different sensors require more complex software for the sensor fusion calculations, and those will likely need to be done on an MCU, not just the usual ASIC. This is driving changes in the supply chain, as makers of microcontrollers, software, and subsystems start to take over more of the sensor management.

All these factors are changing the MEMS Industry landscape. We hope you will enjoy reading this issue to learn all the new challenges with MEMS modules.

Dr Eric Mounier
Project Manager
Yole Développement
mounier@yole.fr

PLATINUM PARTNERS:



C O N T E N T S



Yole Développement,
SYSTEM PLUS Consulting
and JBBOX creation

FINANCIAL BUZZ

Maxim / SensorDynamics: A new MEMS solution provider is born 6

MEMS IN THE WORLD

MEMS in Taiwan 10

INDUSTRY REVIEW

From MEMS die to multi sensor functions 12

Case study: Hillcrest Labs 16

ANALYST CORNER

Combo sensors will become the inertial growth driver 18

COMPANY INSIGHT

Maradin samples lower cost scanning mirror chipset for laser pico projectors 21

And also: MicroGen Systems & Tronics Microsystems 25

ADVERTORIAL

Semefab, a "one-stop" shop for MEMS and ASICs 27

E V E N T S

• **MEMS Executive Congress**
November 2 to 3, 2011 - Monterey, CA

• **Be flexible**
November 23 to 24, 2011 - Munich, Germany

• **Semicon Japan**
December 7 to 9, Tokyo, Japan



FROM I-MICRONEWS.COM



Stay connected with your peers on i-Micronews.com

With 18,000 monthly visitors, i-Micronews.com provides for MEMS area: current news, market & technological analysis, key leader interviews, webcasts section, reverse engineering / costing, events calendar, latest reports...

Please visit our website to discover the last top stories in MEMS:

- VTI technologies acquired by Murata manufacturing
- Dytrans introduce a new family of Trixial MEMS DC accelerometers
- Acacia subsidiary enters into settlement agreement with Kionix



GOLD PARTNERS:





Working with you
**Multi-Nationals, SMEs,
Start-Ups and Academia**

Fair, Ethical & Dynamic
**Continuous improvement
environmental compliance**

Sensor & Silicon Solutions
**Over 200 million die shipped
per year**



For more information,
please visit our website:
www.semefab.com

Diverse Process Portfolio
**MEMS & CMOS/Bipolar
Volume Foundry**

Maxim / SensorDynamics: A new MEMS solution provider is born



Laurent Robin,
Market Analyst, MEMS,
Yole Développement

Maxim Integrated Products' acquisition of SensorDynamics on July 18, 2011, for \$130.0 million in cash plus the assumption of approximately \$34.0 million in debt - a \$164.0 million price for a pre-revenue company—appears to be the richest deal for the sensor industry in the last 20 years!

Clearly the purchase was for SensorDynamics' medium and long-term potential, not what it has the potential to earn in the next 1-3 years. The Austrian startup began series production of ESC inertial sensors only at the end of 2010, and sales of this and other products in 2010 we estimate were still in the single digit million dollar range, so the company is still essentially a "pre-revenue" company. With this MEMS acquisition, Maxim expands in the sensor and wireless communication market, which fits well with its expertise in analog components. The market is large, it is fast-growing and these interfaces with the real world are where Maxim is focused right now. Maxim had to pay a significant price to acquire one of the few remaining private MEMS inertial companies with great technology (such its double cavity structure which allows easy monolithic integration of accelerometers and gyroscopes), a good management team, a solid supply chain, and first supply agreements with customers. In addition to immediate access to the market and the IP portfolio, Maxim also gets customer credibility with wins in the automotive market and potential access to the sensor side of its target high-end consumer markets.

SensorDynamics, meanwhile, will benefit from Maxim's manufacturing, distribution and sales force. Maxim's volume capacity and resources will be a key asset when dealing with large automotive accounts and when competing with other large IDMs such as Bosch or Panasonic. And the same will apply for the consumer electronics area, where we have seen that one needs to be big in order to be successful (see the Yole Développement MEMS company ranking for CY 2010). More of a challenge may be the management of the high-performance inertial sensor business for aerospace applications, where SensorDynamics has also recently launched products and already has a few design-wins, as this produce line is quite different from Maxim's usual markets.

Another key benefit is linked to technology development. There is a high synergy between SensorDynamics' MEMS sensor technology and Maxim's analog expertise, and this synergy will play directly in to a major trend that we see developing in the inertial MEMS industry. Being able to supply a solution instead of a sensor will be a key asset for all consumer MEMS companies in the next 1-3 years. Maxim is a leading provider of MCU and power management units for mobile applications, so can develop the processing solutions based on sensor fusion algorithms to create high added value, integrating these solutions with analog functions and support for MEMS sensors as systems in a package or systems on a chip. We can thus expect many innovative products in this direction to be released by the combined Maxim / SensorDynamics company in the near future.

The acquisition may also impact some existing strategic agreements. In particular we note that SensorDynamics has close links with Kionix, since Kionix accelerometers are integrated in some SensorDynamics ESC accelero-gyro combo sensors, and Kionix is now part of Rohm, a competing analog mixed signal company.

Maxim, founded in 1985, reported revenue of approximately \$2.0 billion for fiscal 2010, from its business designing, manufacturing and selling analog and mixed-signal semiconductor products. SensorDynamics develops inertial microsystem sensors, sensor interface solutions for automotive,

Strategic Acquisitions

- "Tuck-in" acquisitions
 - Support integration strategy
 - Time to market
 - Unique engineering expertise
 - Support balanced business model
- Recent activity
 - Teridian: smart meters, energy measurement
 - Phyworks: optical infrastructure

MAXIM
INNOVATION DELIVERED

Extract from Maxim presentation, Analyst Day, March 2011. SensorDynamics acquisition is in line with Maxim's strategy: it provides support for more integration, provides MEMS expertise and significantly speeds time to market, and is in line with Maxim's balanced business model.

automotive keyless entry and ignition, and building automation. The company was founded in 2003, with initial links to Siemens VDO, whose VC arm was an early investor in the company. When Siemens sold its automotive unit to Continental in 2007 this relationship with SensorDynamics was terminated. At that time, SensorDynamics had to start customer development from scratch but had the advantage that the technology and product development were already at an advanced stage.

Interview with Demetre Kondylis

Yole Développement: the acquisition of SensorDynamics is Maxim Integrated Products' first major M&A transaction in almost two years in the MEMS industry. What is the progress on the integration of SensorDynamics into Maxim?

Maxim: Maxim is currently integrating SensorDynamics employees into its Sensing Solutions and RF Solutions business units. Activities are underway to assess, focus and critically resource targeted SensorDynamics' technology and IP, identifying the differentiated value propositions, target markets and customer needs.

YD: It seems that a major motivation behind this transaction was MEMS convergence with the analog and mixed-signal world, and the potential opportunities in the medium and long term. What can SensorDynamics bring to mobile applications to compete with the existing large suppliers which are already in mass production? What are SensorDynamics' plans for this consumer business?

M: Environmental, behavioral, or biological contextual data acquisition, coupled with state of the art analog and mixed signal capabilities and fused with innovative algorithmic content, can define and refine solutions to market needs and benefit the consumer and the supply chain.

YD: Besides the inertial consumer market, which is a new strong focus for Maxim, what is the outlook in automotive? In particular, how will you compete in the large and dynamic ESC gyroscope market, which is today dominated by Panasonic and Bosch?

M: The automotive market was the original target of Sensor Dynamics, showcasing significant innovation and customer interest. Therefore we already have differentiating features both in content and performance, which are already integrated into solutions serving the convergence of passive safety, stability control and suspension applications. Maxim technologies, architectures, solutions and roadmap competitiveness have already been evaluated and recognized by the automotive supply chain.

YD: You announced that SensorDynamics' MEMS processes will be transferred to Maxim's fab. Can you comment further on the motivation and timeframe for this change in the supply chain?

M: There is some benefit to maintaining existing production within current manufacturing facilities. However, over time, we will examine the trade-offs between using external foundries and bringing this technology in-house. Maxim and SensorDynamics are committed to continuing their work with the Fraunhofer Institute. Our expectation is that higher volume applications will be manufactured in Maxim facilities, which are more cost-effective as a result of their scale. We expect to maintain a very strong R&D relationship with Fraunhofer.

YD: To conclude, how do you see SensorDynamics in 2015, both in terms of core technologies that are used in your MEMS-based products and in terms of business situation?

M: By 2015, SensorDynamics will be fully integrated into Maxim. Contextual acquisition will continue to be improved and expanded. Embedded control and functionality will amplify the value proposition. We will earn the sourcing decisions of our expanding customer base by serving first and foremost their needs and ambitions.

"By 2015, SensorDynamics will be fully integrated into Maxim."
says Demetre Kondylis,
Maxim Integrated
Products.



Demetre Kondylis, Vice President Sensor Solutions at Maxim Integrated Products

Demetre Kondylis recently joined Maxim Integrated Products as Vice President of the Sensing Solutions BU, aiming to increase the sensory content in the company's leading-edge solutions. Demetre has an extensive experience in the sensor market, being a founding member of Motorola's and Freescale's sensor development and industrialization efforts in the early 90s. Demetre started the Inertial business and over 13 years, led the company's Sensors division to commercial success, attaining leading market share for automotive safety applications. Under his leadership an abundance of diverse technology and product developments were initiated and brought to commercial success. Demetre Kondylis holds a BSC he and a MSC he from the University of Pittsburgh.

www.yole.fr

Tables below are depicting July/August/September latest M&A & new investments in MEMS. With \$600M deal, the acquisition of Caliper Life Sciences by Perkin Elmer is the highest deal of the quarter.

M&A

Company	Type of product	Type of transaction	Price of the deal (US\$)	Acquirer	Yole Développement Comment
<i>July 2011</i>					
Sensor-NITE (BE)	High temperature exhaust gas sensors	Acquisition	\$325M	Sensata	Sensor NITE integrates remote infra-red temperature measurement technology for HVAC application. This technology corresponds to thermopile sensors, which are manufactured with MEMS micromachining technologies
Sensor-Dynamics (AT)	Inertial MEMS, RF keyless systems, Sensor interface	Acquisition	\$130M + \$34M in debt	Maxim Integrated Products	See analysis article
<i>Sept. 2011</i>					
Caliper Life Sciences (US)	Microfluidics, lab automation and liquid handling, optical imaging technologies	Acquisition	\$600M	Perkin Elmer	Amount of acquisition seems quite high (about 5 times higher than Caliper 2010 revenue). But although Caliper revenue has decreased over the past 3 years, the gross profit increased thanks to a focus on the most valuable product areas and the company is now supposed to be profitable. This transaction gives access to Perkin Elmer to complementary detection and imaging technologies. The major benefit for Perkin Elmer is the acquisition of a very broad patent portfolio in microfluidics. In addition, among other products Perkin Elmer gets access to the well-known " LabChip", a reference electrophoresis chip.
Micronics (US)	Point of care diagnostics	Acquisition	NA	Sony	This is the second major microfluidic acquisition in September, few weeks after Caliper acquisition. Micronics is a technology leader in point of care diagnostics and has a broad IP portfolio. This transaction is in line with Sony strategy to become a leading player in the medical and healthcare fields
NetCrystal (US)	MEMS based solar cell technology	Acquisition	NA	Solar Semiconductor	Founded in 2007, NetCrystal is working on developing a solar cell technology that aims to achieve high efficiency at low price. This is maybe the only PV venture that uses MEMS production technology (DRIE process upon a flexible polymer substrate)
Santur Corporation (US)	Tunable laser arrays based on Indium Phosphide (InP)	Acquisition	\$39.2M	NeoPhotonics	Few months after its IPO, this is a first significant acquisition for NeoPhotonics, enabling the company to provide more integrated and complete solutions

New investments (VC rounds, IPOs)

Company	Type of product	Type of investment	Level of new investment (USD)	Investors	Yole Développement Comment
<i>July 2011</i>					
poLight (NO)	MEMS Auto-Focus	2nd round	\$18.5M	Investinor (lead investor), Viking Venture III AS, Alliance Venture Polaris AS and SINTEF Venture III AS	poLight is developing a wafer level autofocus solution based on a piezo polymer. Such solution is of high interest for the next generation of handset cameramodules: wafer scale cameras and reflowable cameramodules
Qualtre (US)	MEMS Gyroscope	3rd round	\$10M	Matrix Partners, Pilot House Ventures	This new investment is likely to cover product launch of Qualtre disruptive gyroscope. Based on 3 tiny BAW resonator dies, the first generation of Qualtre 3-axis gyroscope is expected to compete in the gaming and navigation markets
Advanced Diamond Technologies (US)	Diamond films	Series D	\$5.2M	S-Group Capital Management (Lead Investor) + existing ADT investors	ADT commercialize diamond coatings that have been successfully demonstrated for AFM probe or RF MEMS switch applications. This new fund should support the transition to volume production
Wispry (US)	RF MEMS - Tunable capacitors	Bridge	\$3.6M	undisclosed	After a 6th round in 2010, Wispry now closes a bridge financing. In total the company has raised about \$60M since 2003. Wispry is going to ramp up production over the next months, with recent real first orders for antenna tuner application
Calient Technologies (US)	Photonic switching products based on internal MEMS mirror technology	13rd round	\$4.38M	Cayuga Venture Fund	The market for optical communication networks started a dynamic growth last year and is still dynamics. Neophotonics and Capella Photonics have also raised new funds this year: in February 2011
<i>Sept. 2011</i>					
GnuBIO (US)	DNA sequencing technology by using microfluidic and emulsion technologies	2nd round	\$5M	NA	DNA sequencing systems is one of the most growing segments of the microfluidics market at the moment. GnuBIO technology is developed to enable low cost point-of-care diagnostics
Alphabet Energy (US)	Waste-heat-to-electricity generators based on low-cost thermoelectric materials	1st round	\$12M	TPG Biotech (Lead Investor), California Clean Energy, Claremont Creek Ventures	Alphabet Energy plans to leverage existing MEMS and semiconductor manufacturing expertise and capacity, following a fabless model. This development is focused on thermal energy harvesting. This is quite different from Microgen Systems, a leading MEMS energy harvesting start-up, which focuses on piezo energy harvesting



MEMS in Taiwan

Despite lack of big MEMS design & manufacturing players, Taiwan still plays a very important role in the worldwide MEMS industry with its strong foundry and CMOS manufacturing background, and especially its capability to drive MEMS manufacturing costs down.



Wenbin Ding,
Market & Technology
Analyst,
Yole Développement

"Even though the recent growth of MEMS industry in Taiwan is prominent, local MEMS design companies still have a long way to go to compete with European and US companies."
says Wenbin Ding,
Yole Développement.

In the top 20 MEMS foundries ranking released in April 2011 by Yole Développement, we already saw that the sales at Asia Pacific Microsystems (APM) jump some 60%, moving the Taiwan company into fourth position. Other foundries, TSMC, tMt and UMC made big steps this year in the ranking list.

APM and tMt are pure MEMS foundries and have capabilities to manufacture inkjet heads for Taiwanese and Chinese inkjet cartridge and printer manufacturers, as well as RF devices, pressure sensors and optical devices. TSMC and UMC were CMOS foundries and stepped into MEMS business several years ago. They started to work on the CMOS-MEMS platform like other European and US MEMS foundries. TSMC sees the trend of Integration of CMOS and MEMS, whether by monolithic or hybrid solution and is providing CMOS-MEMS total integration with standard process for fast time to market. Maxchip is also starting CMOS-MEMS foundry service.

Yole Développement attended Semicon Taiwan in early September and verified a significant progress of Taiwanese MEMS players.

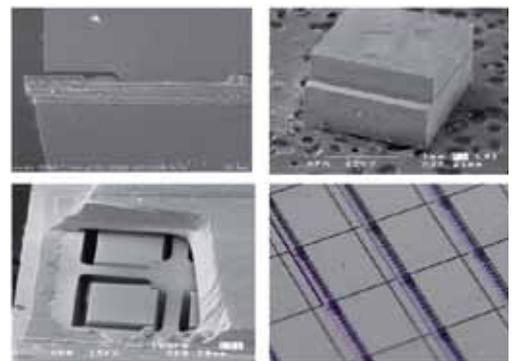
With the help of Taiwan's academic R&D at universities and national labs based in the Hsin-chu Science-based Industry Park, more and more local companies started to design and produce mature MEMS products, such as inkjet heads, micro-mirrors etc. ITRI is such an applied R&D center which started MEMS R&D more than 10 years ago and created today's MEMS industry in Taiwan.

Yole Développement identified several companies in Taiwan that target specific sectors: Agnitio develops a microfluidics platform for point-of-care immune analysis and on-site molecular profiling, Metrodyne Microsystems produces pressure sensors for industrial, medical and consumer applications, Merry Electronics and Solid State System are developing silicon based microphones, Domintech works on inertial sensors design and produced its first accelerometer in 2011, Micro Base Technologies specializes in nozzles, microfluidics and inkjet head, MicroJet focuses on inkjet head and inkjet cartridge manufacturing, Phalanx Biotech develops microarrays, UniSense is working with UMC on pressure sensor design and manufacturing, Opus develops micro-mirror

based light engines, scanning mirror and pico-projectors, Sitronix announced to produce MEMS accelerometer and so on. For these companies ITRI, the major semiconductor R&D lab, has done a great job in terms of technical development and provides support to several industry associations for the development of silicon-based microphones, MEMS packaging...

Regarding MEMS packaging, ASE remains the worldwide leader, as the largest MEMS packaging and assembly services provider, working with every large MEMS company on inertial sensors, pressure sensors and MOEMS packaging. Tong Hsing is another fast-growing player, focusing mainly on R&D and small quantity, high-end products. SPIL and Xintec are also promising MEMS packaging players. Xintec's main activities are focusing on inertial sensors (accelerometer and gyroscope), inkjet print head and CMOS image sensors packaging. They are now working with TSMC and InvenSense on the development of a MEMS platform, Apollo.

Even though the recent growth of MEMS industry in Taiwan is prominent, local MEMS design companies still have a long way to go to compete with European and US companies. MEMS foundry's business is on the right track and players need to put more effort on MEMS platform development to follow the steps of other big MEMS foundries. The collaboration of Taiwanese MEMS foundries, design houses, packaging and assembly service players can paint a beautiful future of MEMS industry in Taiwan.



Wafer-scale encapsulation of MEMS manufacturing.
(Courtesy of APM)

SEMICON Europa 2011

Post Show Report - MEMS-Experts at SEMICON Europa

MEMS are an increasingly pervasive technology in our daily lives. Smartphones and tablets feature an array of MEMS, from motion sensors and gyroscopes, to microphones and speakers; while automotive MEMS are present from airbag systems and brakes, to emissions control and navigation. Still more opportunities exist for MEMS in other applications, including biomedical sensors and drug delivery systems. According to Yole Développement, the MEMS market is positioned to grow 16% per year (CAGR) through 2014, rising to a \$14 billion market.

The unique manufacturing challenges and technologies for MEMS had been featured at SEMICON Europe from October 11 – 13, 2011.

Steve Nasiri, CEO of InvenSense, is one of the pioneers and market leaders in intelligent motion processing solutions. He pointed out, that motion interface is rapidly becoming ubiquitous in many leading consumer electronic devices, such as, smartphones, tablets, smart TVs, gaming and many others, and it is expected to exceed an annual shipment of 2 billion units by 2016. Today, motion interface is offered only in high-end and more costly devices due to their overall complexity, cost, size and lack of available complete plug and play solutions. He presented the key principals technologies used for Motion Tracking technology; how it can improve the user experience through a variety of intuitive motion interface applications; key design considerations and vision for future technology and market trends.

But, the MEMS high growth rate is driven by mobile phones and by adding more sensor technologies within the same device: Si microphone, accelerometer, magnetometer, pressure sensor. Stephane Gervais-Ducouret, Director at Freescale emphasises this also at SEMICON Europa. Such breath of technologies featured with low-power, small size and low-cost constraints, can only grow robustly if they are combined efficiently and effectively. The depth of MEMS and sensors is therefore the next key enabler for further growth and adoption. It can be achieved through merging sensors or in more generic way through intelligent sensor hubs.

Once again, the MEMS Conference showed a lot of chances and tasks of the MEMS Market. The topics showed the current state of the discussion and the speakers proved their high quality. As one attendant said afterwards: "You will definitely fall behind if you miss this conference."

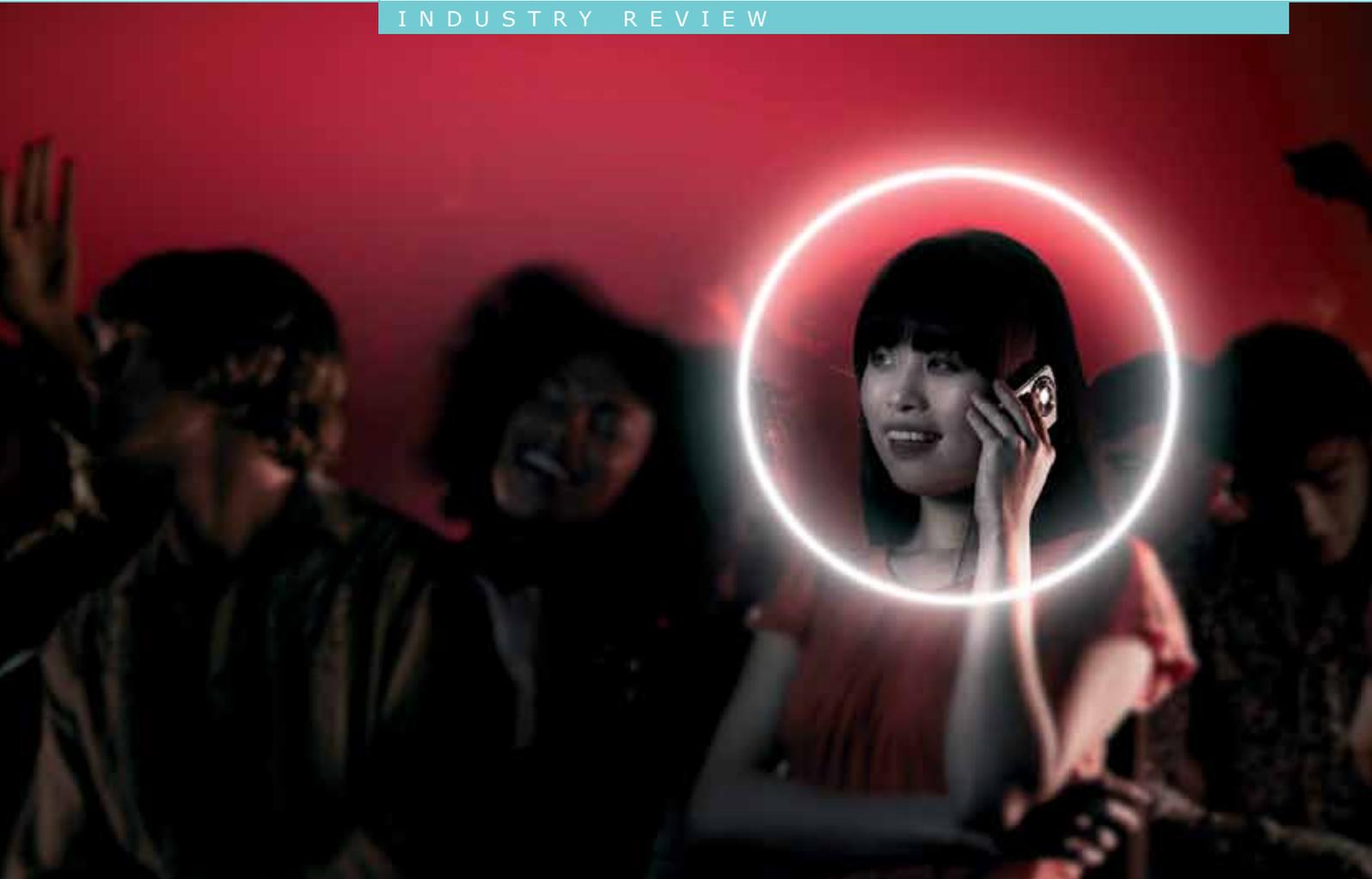
In this spirit is the next chance the SEMICON Europa 2012 which will be held from October 9 – 11, 2012 in Dresden.

For more information about the conferences, speakers and issues visit www.semiconeuropa.org

Discover
the technology
inside the new
SensorDynamics
IMU

SensorDynamics
SD746 - 6 DoF IMU

Discover the NEW
report on
i-Micronews.com/reports



(Courtesy of Wolfson Microelectronics)

"We expect 4-5 mics on a smartphone to become the norm in the next couple of years,"
says Nick Roche, Wolfson Microelectronics.

From MEMS die to multi sensor functions

Integration is the next key step to increasing the performance and lowering the cost of MEMS sensor solutions, to grow the market to new applications and greater penetration of existing applications. And companies from MEMS makers to mixed signal IC and software companies are introducing solutions.

Multi-sensor MEMS modules, integrated with the software and processors to convert their output into useful functions, have great potential to improve performance and reduce costs—and to extend usage to a wider range of applications. Not only MEMS makers but also semiconductor, software, and subsystems specialists aiming to capture more of this value-add are introducing integrated modules and subsystems for easier design-in into end systems, ranging from audio processing with multiple MEMS mics to inertial measurement units from consumer to tactical grade.

MCU maker Wolfson Microelectronics introduces hub processor for easy integration of MEMS mics for better audio processing

Wolfson Microelectronics aims to speed adoption of more sophisticated audio processing with

MEMS microphones for better quality sound in portable consumer applications by integrating all the processing functions into a single audio hub system-on-a-chip.

"The main driver is to speed time to market," says Nick Roche, Wolfson director of global applications, arguing that concentrating all the distributed audio and voice processing into one center makes it easy and affordable to add new sound quality features to a product, as the processing capability is already available and often only additional sensor processing software modules need be dialed up. "Our proposition is if you use the hub, you can add better solutions like transmit and ambient noise cancellation or digital signal processing for voice, without increasing the BOM for the [processor] silicon," says Roche. "It makes it easy to add MEMS mics --the only decision becomes how many mics can I afford to add to the product." Though the hub and its software work

with any type of mic, and are likely to be most widely used with the market leading MEMS mics, Wolfson does of course also make a MEMS mic of its own. Roche argues that although the SoC hub is sensor agnostic, using Wolfson's own CMOS-process MEMS mics has some advantages because their closely matched sensitivity simplifies beam forming, and the digital modulation and demodulation can be matched with their characteristics.

One key new feature is more sophisticated noise cancellation for better voice quality in ambient noise, and ways to do so using fewer mics. Adding this ambient noise cancellation requires one or two additional mics, besides the two already typically used for transmit noise cancellation, and perhaps one more for correction. The hub supports up to eight mics, that might be needed for some complex situations. "We expect 4-5 mics on a smartphone to become the norm in the next couple of years," says Roche.

Also already included in the hub is support for ultrasonics, where very similar MEMS mics can be used as ultrasonic receivers to sense distance for gesture recognition. "Customers all talk about the problem of homogenization –how all smart phone and tablet hardware seems the same, and is hard to differentiate. Ultrasonics could be a low cost way to add at-distance interaction," suggests Roche. With all the processor capability available on the SoC, the cost of including additional features is minimal. Another interesting option: slowing down speech to make it easier for the elderly to understand, something some Japanese phone makers are exploring. "We're pushing the envelope for the widest possible solution set to provide differentiation for our customers," he says.

"Companies using tactical IMUs are very curious about MEMS," says Michael Donfrancesco, Intersense.

The chip maker has also taken downstream integration a step further still, combining the processor, software and microphones into a noise cancelling headset design. Though it started out as a marketing exercise, to have something to demonstrate to customers, ODMs or phone makers turned out to want to use it as a reference design for an accessory they could easily brand and offer as their own.

Software maker Hillcrest integrates sensor modules for easy design of low cost motion controls

Hillcrest Laboratories has moved beyond its motion processing software to now also assemble and sell inertial sensor modules to work with the software. The company buys components from leading MEMS makers, assembles and calibrates the modules at the assembly house it uses, then calibrates them dynamically, does the sensor fusion, and maps the motion to specific output for cursor positioning, 3D motion or gesture recognition.

Hillcrest argues that integrating the sensor calculations not in the sensor module but on to the processors already in the system cuts costs. "Sensor management requires a bunch of power that already exists elsewhere," says CEO Dan Simpkins. "Other silicon can already do the processing." The company has so far ported the sensor module management to 6 to 8 different processors, providing the binary code and leaving the system maker only to integrate it with the API, says marketing VP Chad Lucien. That's helped bring costs of motion sensing remote controls down to the point where one can be included in the \$99 cost of the new Roku 2 set top box.

The company is also going a step further in integration and offering basic reference designs for a remote control for TVs and an air mouse with laser pointer for presentations, each customizable by the customer with different looks and features. "We take the design risk out of the equation," says Lucien of these complete system designs around the key motion processing functions.

Hillcrest Labs executives argue that the development of easy-to-use and low-cost sensor modules for motion sensing controls will also enable new applications on the industrial side as well, noting increasing interest in applications like head tracking for goggles for simulation for training as well as gaming. Enabling these more complex applications is of course the progress in inertial MEMS sensor technology, but also

crucial is the greatly improved speed and cost of general purpose processors, now capable of doing or approximating floating point math to do the signal processing without requiring an expensive custom signal processing chip "Cost is coming down and performance improving so motion sensing is becoming practical for more applications, both consumer and non consumer," says Simpkins.

Subsystem integrator InterSense introduces low cost IMU sensor module to expand range of high performance MEMS applications

Similarly introducing its own MEMS sensor module to improve subsystem performance and reduce costs is software and subsystems specialist InterSense. The company has long put together inertial sensor modules from others' MEMS devices with its own its sensor fusion algorithms and combined them with ultrasonic and optical technology to counter



NavChip Top with Penny (Courtesy of Intersense)

drift, to make high performance subsystems for flight and weapons training simulators. But it found it needed smaller IMU sensor modules with higher accuracy to move beyond simulation into real life applications such as head tracking for pilots and personnel tracking for first responders. So it set out to develop its own, presumably with serious help from its MEMS manufacturing partners.

First production runs for InterSense's NavChip integrated IMU on a chip started in September. The company says in-run stability is 10°/hr, with random walk noise of 0.18°/hr, in a package slightly smaller than 3cm³.

The beta program for developers last year found interest in the smaller, cheaper high performance module for applications including low end flight recorders, accurate personnel location, GPS/INS for robots and unmanned vehicles, and stabilization for gimbals for cameras and video. "Companies using tactical IMUs are very curious about MEMS now that they're reaching this level of performance," says VP of sales Mike Donfrancesco, noting that the smaller, less expensive MEMS sensors allow better motion and location sensing capability to be extended to more applications.



HG1930 MEMS IMU
(Courtesy of Honeywell)

Even among the company's sophisticated customer base of defense and avionics systems makers, Donfrancesco notes that users remain divided between those who want a full turnkey solution, with, say, integration with GPS for the inertial navigation system, and those who do their own integration into systems. But some functions, like wireless, are going to off the shelf solutions.

Donfrancesco expects the NavChip IMU module will shift the company's sales significantly towards sensor modules instead of subsystems, as it will take two to three years for the company or its partners to integrate and qualify the modules in products. InterSense itself plans to integrate the module with dead reckoning algorithms and processors on board for full INS with GPS solutions for small personnel tracking units like its NavShoe, and with algorithms for cockpit head tracking.

Honeywell pushes high performance MEMS IMU systems to compete with traditional gyros in business and regional jets

In the high end inertial sensor world, systems integration is of course an old story, as optimizing performance with the tiny MEMS proof mass for demanding avionics applications necessitates optimizing the whole system, from the single-axis device design to the high vacuum packaging to the processors and software for sophisticated calibration, compensation and integration with compass data and calculations for roll, pitch and attitude. So the Honeywell Aerospace sensors group works closely with its commercial avionics group, which integrates

the sensors into functional rate sensors or attitude heading reference systems, or with INS/GPS for full inertial navigation systems. Honeywell's MEMS gyros and MEMS accelerometers have bias repeatability of ~5°/hr, and 3-5mg bias stability respectively, for consistency each time the IMU is turned on, key for AHRS applications, bringing performance of the small and relatively low cost MEMS systems to the level needed for business and regional jets and air transport.

While most military buyers do their own integration of the IMU into their specialty navigation systems, commercial aviation buyers don't want to do this themselves, but prefer to buy the complete navigation system.

In these high end markets, the question is if MEMS technology is approaching the practical limit of performance of the small devices. Can MEMS inertial sensors be improved without running up against the cost limit ceiling imposed by the competing ring laser gyro and quartz accelerometer products? "There's a lot of desire to push performance to less than 1°/hr," says David Arch, director of inertial sensors. "We think we can get performance down another order of magnitude, but is the cost worth it?" he wonders, noting that as the proof masses get smaller, the electronics to distinguish the smaller signals, and the packaging to better isolate the sensitive systems will continue to become more expensive, perhaps approaching the cost of the competing ring laser gyros and quartz accelerometers. "I don't want to say MEMS inertial may be reaching its limits of scaling," says Arch. "But MEMS may be reaching its limits of scaling."

Paula Doe for Yole Développement



Daniel S. Simpkins
Founder, Chairman and CEO,
Hillcrest Labs

Dan Simpkins founded Hillcrest Labs in 2001 with a team of experienced technical and business professionals. Prior to founding Hillcrest, Dan was vice president and general manager of the SALIX Switching Division of Tellabs, Inc., which was established in 2000 when Dan sold Voice over IP leader SALIX Technologies to Tellabs for \$300 million. Dan founded SALIX in 1990 and continued as president and CEO through the sale.



Chad Lucien
Senior Vice President – Sales and
Marketing, Hillcrest Labs

Chad Lucien is responsible for Hillcrest Labs' worldwide sales, marketing and business development activities. Since joining Hillcrest in 2004, Chad has been a member of the company's executive management team where he has held positions encompassing corporate strategy, business development, and general management of the Freespace® motion computing product line. During his tenure, he has licensed Freespace solutions to global consumer electronics companies, developed a wide variety of strategic partnerships, and led numerous product launches in the Freespace product line.

David K. Arch
Director of Inertial Sensors, Navigation Sensors
and Subsystems Marketing and Product
Management Honeywell Aerospace

David Arch joined Honeywell in 1980 as a Research Scientist working in advanced sensor technologies and subsequently has held numerous positions in sensor development and sensor products. Currently he oversees marketing and product management for Honeywell Aerospace's inertial sensors. Arch holds a BS in Physics and a PhD in Solid State Physics.



Michael Donfrancesco
Vice President of Sales, Intersense

Michael Donfrancesco draws on more than 10 years experience in the motion tracking industry when managing the sales organization at InterSense. Mike joined InterSense in 1999 and has consistently grown sales by introducing the technology into the Military, Industrial, Commercial, Entertainment and R&D markets. Prior to InterSense, Mike was the General Sales Manager at Qualisys, a Swedish company that specializes in motion capture in the Industrial, Entertainment and Medical markets. Mike graduated from Boston University with a BS in Engineering.



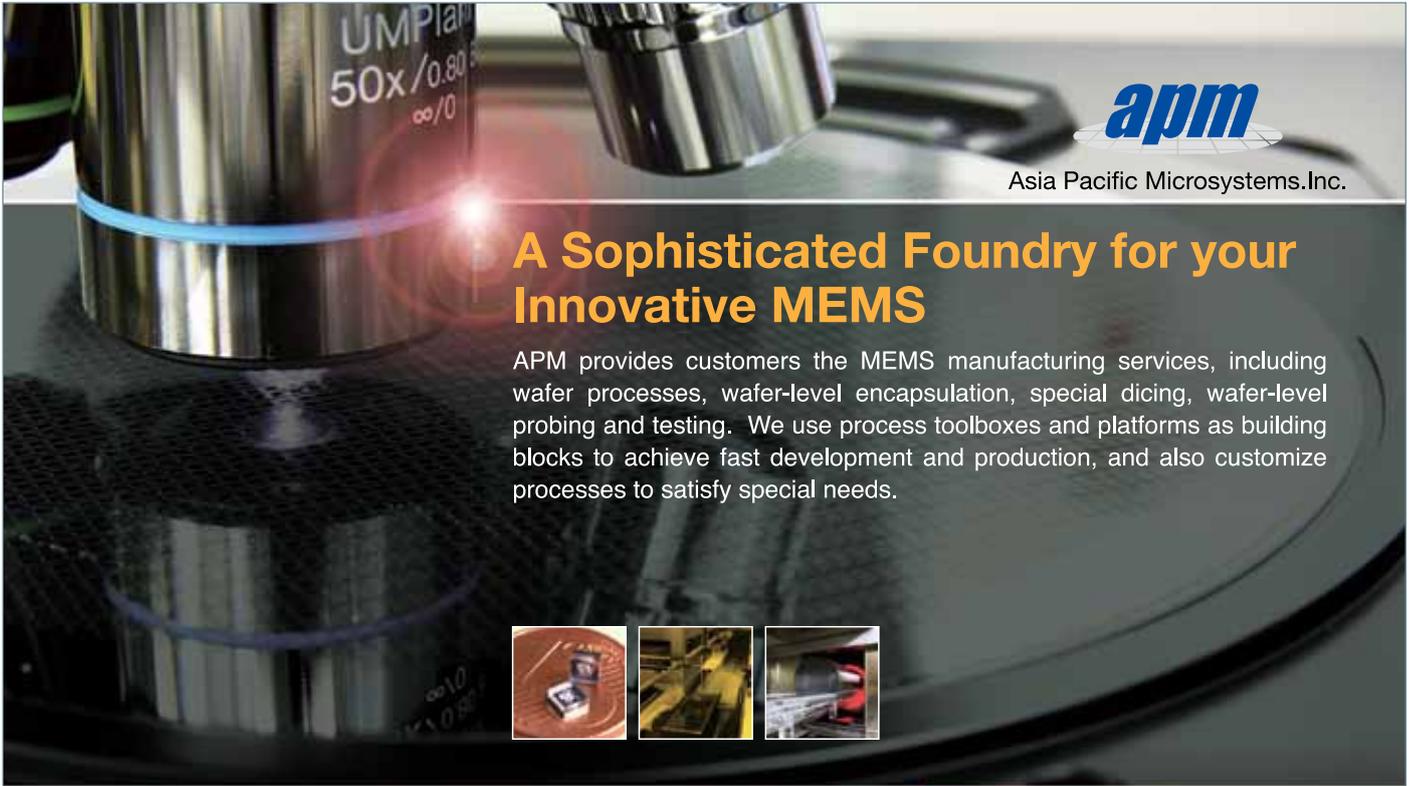
Nick Roche
Global Applications Engineering
Director, Wolfson Microelectronics

Nick Roche joined Wolfson Microelectronics in 2004 and is the Global Applications Engineering Director, with overall responsibility for application support.

Nick leads a global team of applications engineers focused on providing unrivalled support, understanding and solving customer design problems and enabling customers to get their products to market faster with a richer feature set.

He previously worked at Analog Devices as a senior applications engineer.

Nick holds a first class Master of Engineering degree from Glasgow University.



Asia Pacific Microsystems, Inc.

A Sophisticated Foundry for your Innovative MEMS

APM provides customers the MEMS manufacturing services, including wafer processes, wafer-level encapsulation, special dicing, wafer-level probing and testing. We use process toolboxes and platforms as building blocks to achieve fast development and production, and also customize processes to satisfy special needs.



A MEMS wafer foundry partner for your MEMS devices from prototype to high volume production.

\\ No. 2, R&D Road 6, Science-Based Industrial Park, Hsinchu, Taiwan

\\ Tel: +886-3-666-1188 \\ Website: www.apmsinc.com



How MEMS market growth changes the supply chain & companies adapt

Status of the MEMS Industry Report

Discover the NEW report on i-Micronews.com/reports



Case study: How Hillcrest Labs helps in the integration of motion sensing modules

An early focus on natural user interface technologies

Hillcrest started in 2001 and was focused on providing applications for digital TVs. Expertise in motion sensors was quickly developed as the company wanted to provide pointing function to the user through a "point & click" interface. As the company's sensor expertise grew, the expansion of applications also grew especially with the developments within the gaming solutions.



Hillcrest Labs' Freespace MotionEngine used in motion-sensing remote for Roku 2 streaming players (Courtesy of Hillcrest)

Hillcrest rapidly adopted the combination of MEMS sensors in their solutions. For instance 2-axis gyro and 3-axis accelerometers were integrated in the Logitech MX Air mouse (launched in 2007), using Hillcrest's motion software for in-air pointing and gestures. Today sensor fusion is even much more sophisticated and additional sets of specific motion functions have been developed. Indeed most pointing products now have 3-axis gyros and 3-axis accelerometers and other products even feature 3-axis magnetometer when it comes to adding gaming functions.

Current solutions for simplification of integration in modules

The 40-people company is now providing a wide range of solutions for motion sensing. In addition to the broad motion analysis platform available as patented software, algorithms and an API, Hillcrest has developed hardware to target a broader market, from virtual reality applications to medical and industrial markets.

Sensor modules are offered to integrators who might not have the expertise who do not have the engineering resources to develop their own motion solutions. These modules are comprised of a selection of sensors from various vendors among the leading MEMS manufacturers (ST, InvenSense, Bosch, Kionix, Freescale, ADI) and sold as a very small fully calibrated board with the processing to provide the appropriate function. This algorithm (plus drivers and firmware to make the system function) is typically sold as a software license for use in a 32-bit MCU.

Higher level of integration is also offered such as the "Scoop pointer remote" which is sold both as an off-the shelf reference design and as a complete product.

Structural changes in the MEMS industry

The story of Hillcrest is a nice illustration of solutions that ease integration of MEMS-based modules and that provide time and cost savings to integrators. Hillcrest provides an enormous amount of support to the OEMs at every stage of the design cycle by guiding customers on what is the best solution to achieve motion-based functions . OEMs can benefit from optimization of latency, onscreen cursor performance, gesture implementation, mechanical and ID design, and UI design tuned for use with a motion device.

We note MEMS makers also start to help OEMs for multi-sensor integration, such as ST with its iNEMO software. However this overlap in sensor fusion is limited. MEMS companies generally focus on the software for using their sensors and on algorithms for the most popular motion functions. But software is everywhere from sensor fusion to the application: this is why in many cases a more specific processing solution will be required. Sensor agnostic software providers are able to answer those requests by providing OEMs with the option of designing in sensors from a variety of suppliers.

Finally despite the current proliferation of combo sensors, future remains bright for sensor modules. And when current inertial combos are commoditized within a few years, then people will ask for integration of additional type of sensors (pressure, temperature...).

Editorial Webcast available today

Upcoming webcasts:

- Oct. 26:
PV inverter
Technical innovations
and market trends

- Nov. 8:
Glass emergence
into the semiconductor
wafer-processing world

- Nov. 29:
High Concentration
Photovoltaics
Technology on the way
to the utility market

Thin Wafer Handling and Processing

View our Editorial webcast to learn:

- Motivations to go thin, then ultra-thin
- Thin wafer applications/roadmap
- Challenges to thin wafer manipulation
- Overview of temporary bonding approaches
- Forecast for thin wafers and temporary bonding equipment

To watch the webcast, please go to
www.i-micronews.com/webcasts.asp or click here.

Hosted by



Powered by



Sponsored by



Can you trust your MEMS foundry?

You can with Tronics.

We'll smooth the path to production and handle your volume, no matter where you are.



MUCH MORE THAN A MEMS FOUNDRY. Whether you need wafer processing, manufacturing and assembly of your MEMS, or a turn-key product design and development, we have the experience to help you succeed. Tronics provides one of the broadest technology portfolios in the industry—and across the globe—with wafer fabs in France, the United States, and representation in Asia. If you are looking for a truly collaborative partner to guide you through your next MEMS project, Tronics can provide all the peace of mind you need.

Discover the Tronics difference at www.tronicsgroup.com



Laurent Robin,
Market Analyst, MEMS,
Yole Développement

Combo sensors will become the inertial growth driver

Lower cost units combining multiple MEMS sensors are poised for healthy growth, starting with ESCs, bringing opportunity for new players and demands for sensor management solutions.

The inertial sensors market for consumer and automotive will see healthy 15% growth this year to surpass a \$2.6 billion business, thanks to the increasing penetration of more motion sensing into more mobile devices, and more automotive safety systems in more cars across the globe. Though unit growth will continue at double digit rates, maturing markets and continued price erosion means sales revenues from discrete inertial sensors will level off and start to decline over the next several years. Growth will then come from largely from combination sensors, which Yole Développement projects will come to jump from very tiny volumes currently to penetrate some 40% of the \$2.7 billion consumer inertial market and more than 12% of the \$1.1 billion automotive inertial market by 2016.

This trend is showing up first in the more mature automotive MEMS sector, where the price of the sensor unit for the electronic stability control system (ESC) can now be reduced by about \$4, or a significant 25%, by combining the accelerometer and the gyroscope in one package with one

ASIC. Adoption is a little slower on the consumer side, where the fast changing technology means discrete device prices are still falling rapidly, so combination sensors of products from even six months before have less of a cost advantage. But the consumer market's fast model turnover and short replacement cycles means that once the economics become compelling and adoption starts in 2012 - 2013, market penetration will be faster and deeper than on the automotive side, driving the consumer combination sensors to become more than 900 million units by 2016.

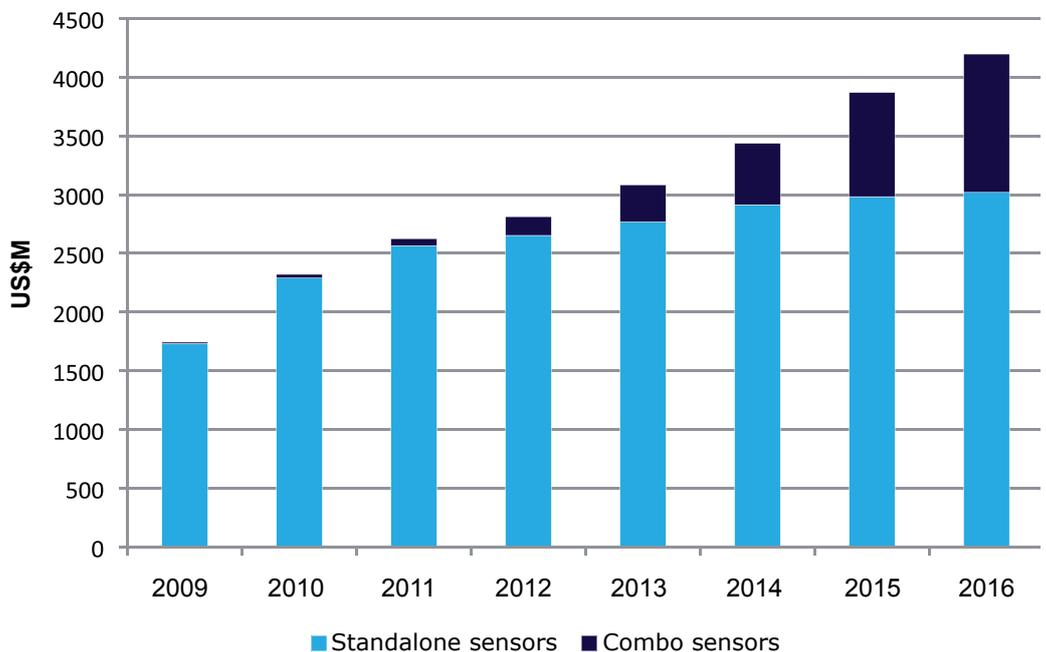
ESC and rollover sensors drive the combo market

The big and growing ESC market is the first prime driver for combination sensors. Demand for these safety systems in emerging markets as well as developed ones now means they're on 52% of all vehicles produced already. With the US, Europe and Australia now requiring the units on all cars in 2011 and Japan, S. Korea and Canada poised to require them by 2013, ESC units should reach 77%

"The ESC combo market will take off in the next few years, so companies who get in fast before the market starts to level off will likely do the best, even if that may mean gyro"
says Laurent Robin,
Yole Développement.

2009-2016 Consumer and automotive inertial sensor market (US\$M)

(Inertial Combo Sensors for Consumers & Automotive report, Yole Développement, Oct. 2011)



penetration of new vehicles by 2016. We expect the lower cost combination sensors to take over as much as 41% of the ESC market within five years.

Combo sensors also have potential to reduce the cost of rollover sensors. Though little used in most of the world, rollover sensors with an accelerometer and a gyroscope already are in 40% of new vehicles in North American markets, where vans, SUVs and pickup trucks are common. Further demand is assured as the US government is likely to mandate their use on new cars from 2018. Integrating this sensing function into a combo sensor, or into the ESC unit, will reduce the additional processor silicon cost and bring price down to gain wide adoption for the combo solution here as well.

There's no near term play for combination sensors in the airbag sensor market, though eventually integrating the main ECU crash sensor with the ESC or rollover sensor will likely make sense. Front crash sensors are already installed in almost all new cars, but demand continues to grow for adding additional, peripheral crash sensors as well, both to deploy the side curtain airbags and to provide more time and information to decide whether to deploy the front airbag or not. Developed markets already average two to three peripheral sensors per car, with high end cars averaging as many as eight. And autos in developing markets are quickly adding peripheral sensors as well. China already averages two high-g sensors per car.

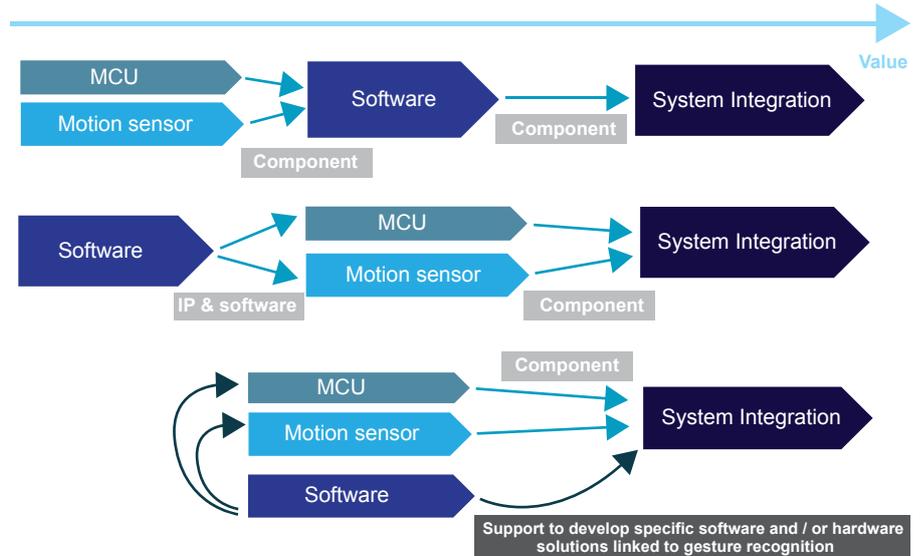
Tire pressure monitoring systems will of course have to remain in each wheel, so won't be integrated with other inertial sensors, but there too the trend is to integrate the very basic cantilever accelerometer with the pressure sensor in the same package, or even on the same chip, as Infineon does. Integration of other functions, such as an MCU processing, RF capability, or even energy harvesting will likely follow.

Longer term, combination inertial sensor units for the ESC or other central sensor and sensor management on a central processor already on the car could allow low cost solutions to use this sensor information for other functions, such as for navigation systems, electronic parking brakes or hill-start assistance, platform stability, lane keeping, car alarms, vibration noise cancellation, or head light positioning. But

Description of the motion sensor value chain

New business models linked to software and MCU

(Motion Sensors for Consumer & Mobile Applications report, Yole Développement, 2011)



this would require much major change to automotive design, and not many players have all the skills to offer these integrated features, so adoption will likely take a while, but could start by 2014-2015.

Opportunity for new competitors to challenge established suppliers

The ESC combo market will take off in the next few years, so companies who get in fast before the market starts to level off will likely do the best, even if that may mean gyro makers without their own accelerometer technology may need to purchase or license that component. though all internal components. Though companies that can make both components themselves at good yields will have an advantage in qualifying their sensors and in profit margins.

Automotive accelerometer market leader Robert Bosch reduced die size by 70% in its 2-axis accelerometer, gyroscope and combined ASIC in one package introduced last year. Finland's VTI is selling its combo sensor unit to Continental. And SensorDynamics' combo sensor combines that supplier's gyro with an accelerometer from consumer supplier Kionix—and now has a major boost of processor design sophistication from its new parent Maxim. These companies are likely to gain share, unless the other major automotive inertial suppliers come up with competitive combo products. Automotive gyro market leader Panasonic is still working

on developing its accelerometer and combo unit. Automotive accelerometer powerhouse Denso introduced a gyroscope last year, but has yet to develop a combo unit. Big consumer inertial players are also likely to continue to expand to the automotive market.

Consumer combo sensors jump to \$900 million market by 2016

In the consumer market as well, sales of discrete inertial sensors will begin to level off in the next couple of years, as growth also will start to come from modules combining accelerometers with magnetometers, then accelerometers with gyroscopes, and finally all three sensors together for gaming, smart phones, and tablets. Accelerometer-magnetometer combos have of course been on the market for some time, but the better performance from the two sensors' cross correction should spur strong growth starting next year, as applications require more accurate positioning and location functions. Continuing demand for better performance for indoor location-based services and more precise gesture and position recognition to distinguish mobile consumer devices will then drive the integration of gyros with accelerometers as well. Yole Développement projects sales of 9 DOF combo sensor packages with gyros, accelerometers and magnetometers will start to see serious growth within two to three years, helping drive the total consumer combo sensor market to nearly \$900 million by 2016.

New technical demands for combo sensors

Combo sensors require more complex software for the sensor fusion calculations, and those will likely need to be done on an MCU, not just the usual ASIC. This is driving changes in the supply chain, as makers of microcontrollers, software, and subsystems start to take over more of the sensor management.

Though the accelerometer and gyroscope can be made by the same MEMS process and could potentially be efficiently integrated on the same die to reduce costs, the magnetometer requires different technology and will remain a separate die. Low cost Hall sensors currently dominate the magnetometer market, though other CMOS based technologies used by some suppliers have similar performance. MEMS magnetometer solutions that would allow integration with the other MEMS sensors are under development at a number of companies, but still remain a ways out. However, new approaches such as Baolab's integration of the MEMS magnetometer into the metal layers of the CMOS chip could offer cost effective alternatives, though performance still needs to be improved.

The separate magnetometer technology, as well as the increasing use of MCUs, means most integration will remain by wire bonding in a package. Tighter integration, with TSVs or wafer-level bonding, will likely remain too expensive for mainstream applications. Wire bonding remains good enough for consumer and automotive uses, and highly cost effective.

Combo sensors will however require new test solutions. Beyond the usual wafer-level electrical test and package-level electrical and mechanical or functional testing, these sensor combos will need module level testing and calibration of the combined sensors. If they include an MCU in the package, the communication between the sensors and the MCU will also need to be tested. And they'll need cost effective, high throughput solutions to test multiple axes of multiple devices, either in parallel or in separate modules, rather like separate chambers in IC equipment. Much high volume product testing is currently done with 32 parallel sites, and this will likely increase to 64 sites going forward. Another challenge is to generate a localized and accurate magnetic field to test the magnetometers and to integrate it into the same tool as that for mechanical testing of the accelerometers.

Conveniently, the world of MEMS testing has moved in the last several years from internal development at MEMS makers to co-development with test suppliers to commercial off-the-shelf equipment, from companies like SPEA and Multitest. So combo solutions that can test all axes of the module in a single tool for higher throughput will also likely be co-developed with the test equipment suppliers and available commercially. Assembly and test houses may also start to offer these test services on an outsource basis for fabless or fab-light MEMS makers.

www.yole.fr

Laurent Robin is in charge of the MEMS & Sensors market research. He previously worked at image sensor company e2v Technologies (Grenoble, France). He holds a Physics Engineering degree from the National Institute of Applied Sciences in Toulouse, plus a Master Degree in Technology & Innovation Management from EM Lyon Business School, France.

Which combo?
When will it be
adopted?
And why?

Inertial Combo
Sensors
for Consumer
& Automotive

Discover the NEW
report on
i-Micronews.com/reports

Maradin samples lower cost scanning mirror chipset for laser pico projectors

Maradin Ltd is sampling a high performance and low cost MEMS scanning mirror unit, aiming at a ~\$20 target price for embedded laser pico projector light engine subsystems once the new direct green lasers ramp to volume production.

The Israeli startup reports it has shipped engineering samples of its single, gimbaled mirror that oscillates in two dimensions to some ten companies across different markets and geographies, targeting projection applications from pico projectors to gesture recognition and head mounted displays. Maradin's VP of marketing Itamar Berchman says the company's two dimensional movement on its single gimbaled mirror will provide a better quality picture at lower cost, as its strong separate actuation methods for the horizontal and the vertical directions allow lower resonant frequency, enabling faster scanning for higher resolution imaging--and allow the use of low cost non-hermetic packaging.

The use of plastic parts can reportedly save a significant amount towards the ~\$20 estimated target light engine cost needed to drive cell phone adoption of embedded projectors. That's the price target a few years out for a light engine with MEMS scanning mirror, RGB lasers and related driver and video processor electronics, assuming direct green lasers will ramp to volume production and get costs down. Currently green laser output is obtained by a relatively costly system of doubling the frequency of an infrared laser.

The scanning mirror is assembled with a relatively complex controller ASIC, developed with Singapore's Institute of Microelectronics (IME), and an electromagnetic actuator in an optical chamber, for a <0.5cm³ chip set. An electromagnetic actuator, with rotating magnets around the mirror, drives a step and scan vertical scanning system, allowing the more conventional comb-drive electrostatic resonating actuator to drive straight, parallel-line bi-directional interlaced scanning, instead of the more typical scissors pattern with retrace. Maradin says this allows the resonant frequency to be cut in half, making it much easier to get mirror rotation up to the speeds needed for higher resolution images. Closed loop controls for each of the two axes compensate for changes in temperature, and for the variations in MEMS performance from variability in manufacturing. The initial scanner is designed to project a WVGA/SVGA image at a 30-Hz refresh rate with 85% optical efficiency. It does

mean, however, that the system needs to integrate mechanical components of magnetic coils and rotating magnets.

Berchman says at least three major green laser makers are now sampling products and targeting production in the second half of 2012, and say they expect to meet cost targets of a few dollars for the \$20 target module --but that depends of course on ramping volume production. With low cost green lasers likely actually on the horizon this time, lots of pico projector players are considering the technology. "We're seeing lots of interest now from first row DLP and LCOS players who're starting to explore laser solutions," says Berchman. "Once the green lasers are available we expect the pico projection solution to become MEMS and lasers." Maradin has agreements with foundries in place, is finishing up its ASIC design and expects to have first reference designs out early next year, ready for production by the end of 2Q, once the green lasers are available and demand develops.

Target customers are ODMs and OEMs who will develop their own light engines. Most likely to be involved are the integrators already in the projector subsystem market, who will likely continue to integrate the MEMS devices with the laser components, optics, drivers and power management.

Initial market for the projector may be sensing or gesture recognition applications for gaming, using IR instead of visible lasers. "It's a hot market willing



Maradin Chip (Courtesy of Maradin)



"Once the green lasers are available we expect the pico projection solution to become MEMS and lasers," says Itamar Berchman, Maradin.

Itamar Berchman, VP for Sales and Marketing , Maradin

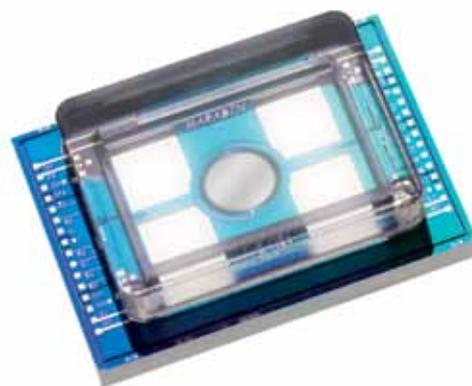
Itamar Berchman has been Maradin VP for Sales and Marketing since January 2010. He is responsible for finding and acquiring Maradin's initial customers. Prior to working at Maradin, Itamar worked for seven years at eglue, a leading software provider for call center enhancements that was acquired by Nice Systems, where he held served as VP for Strategic Accounts & Strategic Partners and VP for Business Development. Previously he served for eight years in an elite Israeli Air-force unit. He has a B.A. in Business Administration from IDC and an MBA from the Technion – Israel Institute of Technology.

to pay a premium," notes Maradin. There's also interest in combining IR sensing with projection, to extend gesture control beyond the touch screen to add a third dimension of depth for more complex natural gesture control for things like Autocad software. Projector suppliers also report seeing growing interest from emerging markets in China and India for this next generation of lower cost pico projectors, for projectors in rural classrooms, or an a television alternative, and where VGA resolution is good enough.

For Western markets, however, pico projectors may need to offer higher resolution to meet consumers' rising expectations of display quality. Berchman argues that users are getting so accustomed to high resolution displays, that VGA does not seem good enough anymore. Size and power consumption will likely make it difficult for embedded units to get brightness much higher than about the 20-25 lumen range.

Maradin was founded by MEMS manufacturing veterans Matan Naftali and Adi Baram who worked previously at Israeli avionics inertial sensor supplier SCD. The initial \$1 million seed capital came from

the Israel innovation promoting organization the Startup Factory. Swiss MEMS maker Physical Logic, whose own high end inertial development division is in Israel, later put in an additional \$3 million. The Singapore-Israel Industrial R&D Foundation to promote joint R&D initiatives funded joint development of the packaging technology with the Singapore company Lynxemi.



Maradin 2D scanning mirror (Courtesy of Maradin)

www.maradin.co.il

Review the cost breakdown of VTI latest gyroscope

VTI CMR3000 3-Axis MEMS Gyroscope

Discover the NEW teardown on i-Micronews.com/reports



MicroGen Systems to ship MEMS energy harvester samples in wireless sensor node subsystems



Harvesting useful amounts of energy from vibrating MEMS parts is one challenge, but it takes a whole power subsystem to make that energy easy to use.

Companies aiming to develop entirely new MEMS applications likely can't rely on systems makers to figure out how to integrate their new devices into finished products. MEMS energy harvester developer MicroGen Systems, of Ithaca, New York, aims to integrate their technology with existing energy generation subsystems from the beginning, assembling its small and low cost MEMS energy harvester with a rechargeable battery, a power management chip and an ultra low power RF unit—all the core components needed for a subsystem to power and connect a wireless sensor node in a network.

The energy harvester supplier aims to integrate its product with existing wireless sensor node subsystems available from thin film rechargeable battery and ultra capacitor suppliers like Infinite Power Solutions, Cymbet Corporation and Advanced Linear Devices.

MicroGen is currently shipping engineering samples to several wireless sensor node companies, essentially a commercial version of a demo board developed by IPS with that company's trickle-charged thin film battery, a power management chip from Maxim Integrated Products, and a low-power RF device from Texas Instruments, ready for a sensor node supplier to integrate with its choice of sensors. "Power consumption issues have been holding the wireless sensor network industry back," argues Robert Andosca, MicroGen founder and president/CTO, noting that many of these issues have now been solved. The IPS postage stamp-sized battery can be continually recharged with small amounts of harvested energy with very low losses, and the new generation of lower-power RF chips has reduced the once power-hungry radio consumption down to the 50µW range.

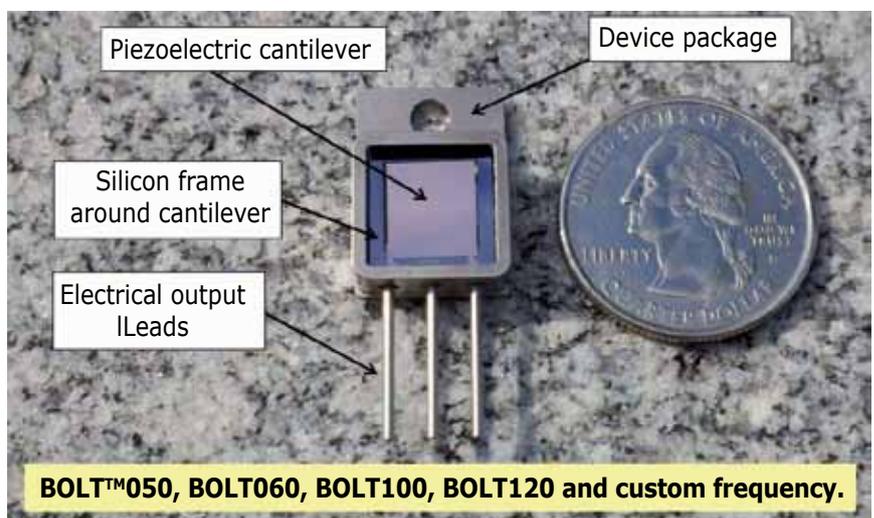
One large market, says Andosca, may turn out to be tire pressure monitoring systems, as suppliers have been approaching the company for a longer lasting solution now that they are starting to see the first failures of batteries on these systems after only 3-5 years in the field, requiring expensive replacement of the entire TPMS unit. When the European Union starts to mandate the devices in 2012, it will require

the TPMS OEMs to also manage the depleted batteries, sparking increased motivation to get the battery issue under control. "TPMS suppliers want energy harvesting now," he says. "They haven't found another viable solution that competes with the battery. They know how MEMS works and can see that it can come down in cost to be competitive."

Getting usable amounts of power out of a tiny MEMS device has been an issue, but MicroGen claims 200µW from its 1cm² device, at the relatively

"TPMS suppliers want energy harvesting now. They haven't found another viable solution that competes with the battery,"
says Robert Andosca, MicroGen Systems.

low ~0.5g vibrations and 60Hz frequencies typical of the electrical industrial equipment usefully monitored for preventive maintenance by wireless sensor nodes. The device consists of one chip-sized cantilever with a mass at the end, whose vibration stresses a piezoelectric AlN layer underneath to convert the movement to electricity.



BOLT Single Can (Courtesy of MicroGen Systems)



Robert Andosca,
Founder,
President and
CTO, MicroGen
Systems LLC

Prior to co-founding MicroGen, Mr. Robert

Andosca has more than 20 years developing and introducing a variety of new MEMS and integrated circuit devices. He held senior level positions at the Infotonics Technology Center, Lilliputian Systems, Umicore, Corning IntelliSense/IntelliSense and Clare Corporation, where he managed technical development and product introduction of MEMS-based products ranging from micro fuel cells, optical and RF switches, microfluidics and micro relays. Two micro-manufactured products developed and introduced in 1999, a high-voltage BiCDMOS line-card-access switch (LCAS), and a photo-voltaic optically-isolated switch/energy harvester have been manufactured at roughly 5000 wafers per month with very high yield.

Andosca says the piezo effect of the AlN is 10-12x higher than that of the usual solgel PZT, and the simple design allows resonant frequency to be controlled within +/-2Hz of the 50-250Hz central frequency in the Cornell University development fab, with potential for tighter control still in a high volume MEMS production fab. This is reportedly partly a function of the particular structure of the thin layers within the cantilever, with some minimal trimming after final test, but the relatively large cantilever (7x7mm² or less) is also relatively insensitive to minor deviations in printing resolution, and thickness can be largely controlled by consistent thickness in the incoming wafer. Versions of different sensitivities from 0.1g to 1.0g can be made on the same wafer.

Andosca figures the device has the usual MEMS roadmap to bring down costs by reducing die size and ramping volumes. Currently the sample devices are packaged in a metal can, but the company is working on moving to wafer level packaging, probably a fairly standard process except that the high degree of deflection of the vibrating cantilever will require a higher space between the bonded wafers. Recent developments reducing the energy consumption of RF transmission to <50µW from 100µW may mean the energy harvester can also get by with producing half as much energy, so can

be reduced to half the current die size to reduce production costs.

MicroGen is starting to move towards manufacturing with a \$1.2 million commercialization contract from the state of New York, and is starting to identify a foundry for its harvester manufacturing. It recently brought on MEMS veteran fundraiser Didier LaCroix as a strategic advisor to start a Silicon Valley corporate office to be close to the venture capital world, though will also maintain its manufacturing in New York with its more appealing cost of living.

"High volume production will bring our costs down less than \$1, but you need deep pockets to get to those volumes," says Andosca. "Though it will take some time and money, we believe we're the enabling technology to bring costs down for the wireless sensor network industry."

www.microgensystems.com



Solid State Equipment Corporation

FABRICATION EQUIPMENT FOR THE INTEGRATED CIRCUIT INDUSTRY



SINGLE WAFER WET PROCESSORS & CLEANERS

SINGLE WAFER WET PROCESSORS & CLEANERS

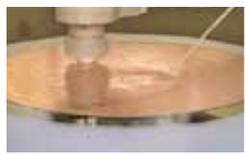
Configure your wet fabrication process to increase yields and lower costs with SSEC's 3300 Series of Single Wafer Wet Processors. SSEC provides complete process development services to enable system configuration according to your process and manufacturing requirements.

CLEAN

99% Particle Removal Efficiency at the 88 nm, 65 nm, and 45 nm Nodes



High Velocity Spray



Rotary PVA Brush

STRIP & LIFT-OFF

Immersion and Single Wafer Processing



Heated Solvent Immersion



Heated High Pressure Scrub

WET ETCH

Uniform, Selective Etching on Multiple Process Levels



Wafer Thinning



Stream Etch for Films & Metals

COAT / DEVELOP

Photolithography Clusters



Spin Coating



Low Impact Developing

TRONICS view on MEMS integration

The leading inertial MEMS foundry won several big customers during the last 12 months, thanks to its know-how in sensors integration.

Tronics Microsystems (Tronics) is an international, full service MEMS manufacturer with wafer fabs in Europe and the USA. It offers manufacturing services for a broad range of MEMS devices, from small to large volumes, and delivers qualified and tested dice or wafers, packaged chips, or even complete sensors, depending on the customers' capabilities and requirements. Tronics is currently the leading worldwide Inertial MEMS foundry. According to Yole Développement, Tronics' market share of the Inertial MEMS foundry business will reach 20% in 2011.

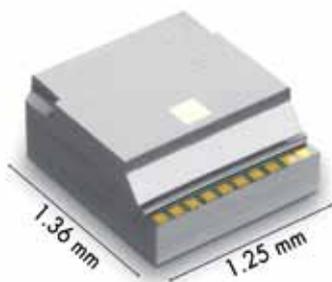
After 15 years in industry, we know that each application carries its own unique set of challenges that must be overcome. Because of this, we do not believe there will be a universal solution for sensors integration. Nevertheless, we currently see three major fields with their own set of requirements.

Consumer (cell phones, laptops, tablets...) and automotive applications are driven by cost

We think that there are still ways to drastically improve existing solutions.

For example, if we look at latest accelerometer MEMS dice (smaller than 2mm²), the active part is usually less than 20% of the MEMS die area. 80% of the die area is dedicated to sealing, interconnections and pads area. We have, therefore, been focused on reducing all these "un-used" areas through two main process improvement paths.

The first path is focused on reducing seal area. Instead of glass-frit technology, we are using metal-bonding technology, thereby reducing seal width from 250um down to 50um. This technology



3-axis accelerometer platform for consumer applications. (Courtesy of Tronics Microsystems)

is also compatible with out-of-plane detection and its benefits are direct. For example, we have applied this technology to our 3-axis accelerometer platform and the die area is reduced by 55% compared to a standard glass-frit seal.

The second evolutionary path is to remove the additional pad area by moving the pads to the top of the MEMS die. We offer a Through Silicon Via (TSV) technology with low-parasitic capacitance and perfect hermeticity compatible with the wafer-level vacuum. TSV technology is especially critical for ultra-small fusion sensors combining multiple functions such as 3-axis accelerometers and 3-axis gyrometers. For these devices, implementing a TSV process leads to die area reduction of up to 30%, also due to the improved interconnections routing. However, TSV is still more expensive than traditional interconnections and this added cost has to be balanced with the gain in die area. We nevertheless believe that TSV may become mandatory for the next generation of 1x1mm inertial devices, as well as for integrated 6 or 9DOF devices.

Industrial and aeronautics applications are driven by performance



High performance 1-axis gyrometer platform. (Courtesy of Tronics Microsystems)

In this field, the customer usually prefers to have an excellent single-axis inertial device (accelerometer or gyrometer) and do the 3D integration at board level. Indeed, whatever the MEMS technology, design concepts for in-plane and out-of-plane detection are still providing very different performance levels. High performance inertial devices require single-crystal Si proof mass, well-controlled advanced DRIE and vacuum-packaging, which are recognized in the industry as Tronics' expertise. We deliver ceramic vacuum-

tronics 

packaged MEMS which ensures perfect hermeticity and long-term reliability. Based on this technology platform, we have already shipped more than 750,000 high performance MEMS devices used in harsh environments. We also see an emerging trend toward the 3D integration of single-axis elements directly at the package level. This may be a smart way to deliver 3D components without compromising the performance.

Implantable medical applications are driven by biocompatibility

There is a clear trend toward the integration of pressure and flow sensors within implantable medical devices in order to improve control and monitoring. The complexity in this field comes mainly from biocompatibility requirements. It is, therefore, mandatory to reuse existing and proven

building blocks in order to minimize developments risks. For example, we have leveraged our absolute pressure sensor platform to develop a wireless Ti-packaged pressure sensor for a medical device manufacturer.

Why is Tronics well-positioned to address these integration challenges?

We believe that there are several reasons: First, in terms of industry leadership, we pioneered the development of SOI-based capacitive MEMS devices. Second, we are one of the few MEMS foundries with two fabs. This is clearly an advantage in terms of market coverage and sourcing reliability.

Last but not least, we design and fabricate MEMS sensing elements, as well as conduct 100% testing, thereby tightly controlling our process flow. We know what it takes not only to manufacture MEMS, but also to package, test and calibrate them.

Tronics has managed numerous MEMS sensors integration developments over the last five years. We have heavily invested in developing the technologies that are best suited to address these challenges. Thanks to this effort, a growing number of customers rely on us for their integration projects.



Dr. Antoine FILIPE, Manager of the MEMS Platforms Business Unit, Tronics.

Antoine Filipe has over 15 years of experience in the MEMS and IC industry. He held several management positions with Thales and STMicroelectronics prior to joining Tronics in 2007. Dr. FILIPE holds a M.Sc. from Ecole Polytechnique (France) and a Ph.D. in Solid State Physics from University Paris XI.



Absolute pressure sensor platform for implantable medical device. (Courtesy of Tronics Microsystems)

www.tronicsgroup.com

WEBCAST AVAILABLE TODAY on I-Micronews.com, webcast section

Learn more about **Ion Beam Etch Solutions to Drive Next Generation MEMS and Sensor Performance**

To watch the webcast, please go to www.i-micronews.com/webcasts.asp or click here.

Sponsored by



Hosted by



Semefab, a "one-stop" shop for MEMS and ASICs

Semefab manufactures microelectronics and MEMS in its wafer fabrication operation in Scotland supplying wafers, die and packaged devices to the market.



Pressure Sensor. (Courtesy of Microvisk)

Operating 3 wafer fabs, Semefab prides itself on its impressive track record of process development, process induction and volume foundry, all of which support Silicon based MEMS, CMOS, Bipolar, ASIC & Discrete technologies.

Founded in 1986, Fab 1 supports a diverse process portfolio of 4" CMOS, Bipolar, ASIC & Discrete technologies. At a component level, Fab1 fabricates precision analogue components, JFET transistors, Bipolar transistors, Photo Diodes, Mixed Signal ASIC and supports the 'front-end processing' for multiple MEMS technologies.

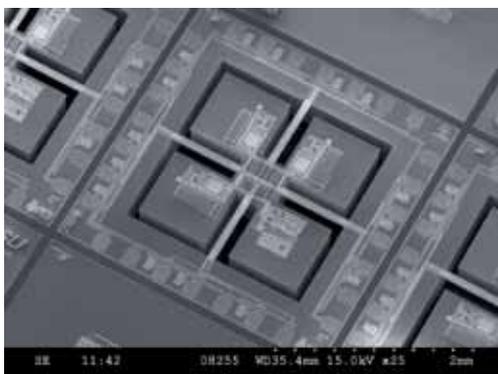
Semefab's MEMS fab2 became operational in 2002, fabricating MEMS gas sensors and pressure sensors. With a \$22.4m investment, part-funded by Scottish Enterprise and the Technology Strategy Board, Semefab's expanded 6" Fab2 became operational during June 2009 ; and a new Fab 3 became operational in August 2011 supporting 6" front-end processing for MEMS and 6" CMOS.

Semefab's volume foundry MEMS sensor portfolio currently consists of pressure sensors, gas sensors, thermopiles, viscosity sensors and accelerometers. Semefab also supports a development business model and has a range of development projects progressing through the technology cycle towards volume foundry.

In addition to its fabrication capability, Semefab operates its own test floor supporting wafer test and package test.

As a global foundry partner, Semefab exports >74% of its fabricated output to 20 different countries.

Using its development business model, Semefab's Fab2 commercialises research and development outcomes in a cost-effective manner, whilst its volume model supports a customer's volume demand. Development projects transfer seamlessly from development to volume with an internal knowledge transfer between the process development team and the process engineering team.



Pressure Sensor. (Courtesy of Semefab)

Semefab is a founding industrial member of the Scottish Sensor Systems Centre (S3C).

S3C has been established with Scottish Funding Council (SFC) assistance with the aim of progressing research in intelligent sensor systems towards the path of commercialisation. S3C comprises 8 of Scotland's leading universities with the collaboration of 23 industrial member companies.

Contact info@semefab.com to discuss your foundry requirements.

www.semefab.com

A total volume over 1 million units in 2016

Uncooled Infrared Imaging Market: Commercial & Military Applications



Discover the NEW report on
i-micronews.com/reports

About Yole Développement

Beginning in 1998 with Yole Développement, we have grown to become a group of companies providing market research, technology analysis, strategy consulting, media in addition to finance services. With a solid focus on emerging applications using silicon and/or micro manufacturing Yole Développement group has expanded to include more than 40 associates worldwide covering MEMS, Microfluidics & Medical, Advanced Packaging, Compound Semiconductors, Power Electronics, LED, and Photovoltaic. The group supports companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to develop their business.

CUSTOM STUDIES

- Market data, market research and marketing analysis
- Technology analysis
- Reverse engineering and reverse costing
- Strategy consulting
- Corporate Finance Advisory (M&A and fund raising)

MEDIA

- Critical news, Bi-weekly: Micronews, the magazine
- In-depth analysis & Quarterly Technology Magazines: MEMS Trends- 3D Packaging - PV Manufacturing - iLED - Power Dev'
- Online disruptive technologies website: www.i-micronews.com
- Exclusive Webcasts
- Live event with Market Briefings

CONTACTS

For more information about :

- Services : Jean-Christophe Eloy (eloy@yole.fr)
- Reports: David Jourdan (jourdan@yole.fr)
- Media : Sandrine Leroy (leroy@yole.fr)

TECHNOLOGY & MARKET REPORTS

- Collection of reports
 - Players & market databases
 - Manufacturing cost simulation tools
 - Component reverse engineering & costing analysis
- More information on www.yole.fr



Editorial Staff

Board Members: Jean-Christophe Eloy & Jeff Perkins – Media Activity, Editor in chief: Dr Eric Mounier – Editor in chief: Dr Eric Mounier – Editors: Frédéric Breussin, Wenbin Ding, Jean-Christophe Eloy, Patrick Keating, Jean-Philippe Leclercq, Jérôme Mouly, Dr Eric Mounier, Laurent Robin, Paula Doe – Media & PR Manager: Sandrine Leroy – VP New Media Development: Bill Stinson – Assistants : Clotilde fabre, Camille Favre - Production: atelier JBBOX

THE DISRUPTIVE SEMICONDUCTOR TECHNOLOGIES MAGAZINE
Micronews