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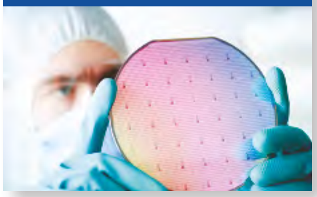
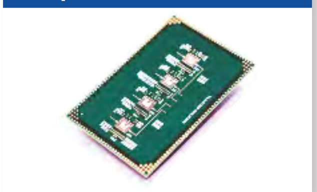
MES applications



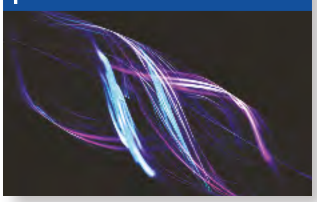
Quantum computing

Futuristic radar chip



Conductivity measurements

Spiralling laser pulses



Linde Electronics:
Addressing challenges in gas supply to fabs

inside SiS SILICON SEMICONDUCTOR

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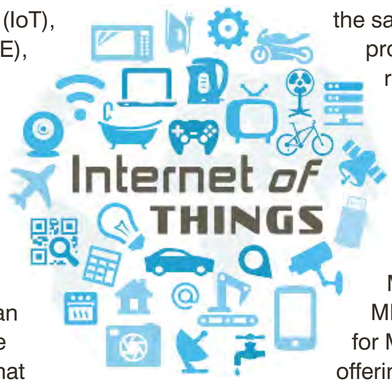
AN ANGEL BUSINESS COMMUNICATIONS PUBLICATION

executiveview

by Tony McKie, CEO, memsstar

Accelerating the development of MEMS for the Internet of Things



THE PROMISE OF THE INTERNET OF THINGS (IoT), or as Cisco calls it, the Internet of Everything (IoE), has lit an unquenchable fire under the entire microelectronics industry. Cisco predicts that the IoE will have a $17 trillion economic impact worldwide by 2025. This impact is said to be greater than that of the entire U.S. economy.

Despite concerns about security, most believe the benefits the IoT will bring to our daily lives—from everything to global food supplies and clean water to clean energy and affordable health care for all—far outweigh any risks. Experts predict that achieving this world of "abundance" requires 45 trillion existing and new sensor types. The goal is to reach this number by 2050. However, historically it has taken 20-30 years to take new sensors from concept through production. What can we do to accelerate growth and innovation to accomplish this monumental goal?

Broken down to its simplest form, the IoT three-legged stool includes sensing, processing and communications. We can maximize the IoT by mobilizing MEMS sensors and the adjacent ecosystems. One piece in this puzzle lies in optimal process control throughout the MEMS development and manufacturing process.

In addition to developing a large variety of MEMS and sensor types, MEMS device cost is also critical to this effort, particularly for consumer-sensitive areas such as wearable devices, automobiles and smart homes. The main driver of cost in manufacturing is yield, so MEMS fabs are looking to achieve the same levels of yield as IC fabs. Consequently, process details like etch-rate, uniformity, repeatability and end-point control all must be considered from the start.

For many years, the MEMS industry has been served by modified IC fab tools, which don't achieve the optimum performance for MEMS processing. Dedicated tools and MEMS foundries will also help in accelerating MEMS development. There is already a market for MEMS foundries, with different companies offering assistance with MEMS design, process development or high-volume manufacturing cost reduction. Ultimately, MEMS-specific process innovations will be required to achieve the performance and manufacturability requirements of the IoT.

As an original equipment manufacturing (OEM) company, memsstar specializes in tools for isotropic etch to release movable MEMS structures, and tools to deposit anti-stiction coatings. The company was founded to provide the best possible performance and control in material selectivities when etching and depositing thin-film materials for MEMS manufacturing.

Our founders came from the CMOS IC manufacturing industry with strong OEM backgrounds, with a vision to design MEMS process tools that provide the same level of performance as CMOS tools. We look forward to a bright future for MEMS as an integral part of realizing the IoT, and look forward to contributing to achieving the goal of 45 trillion sensors.

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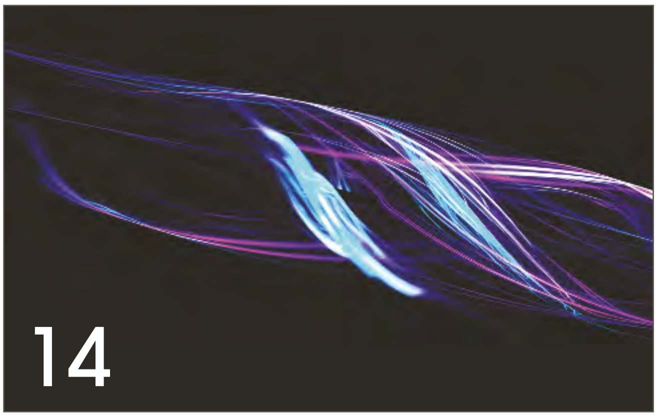

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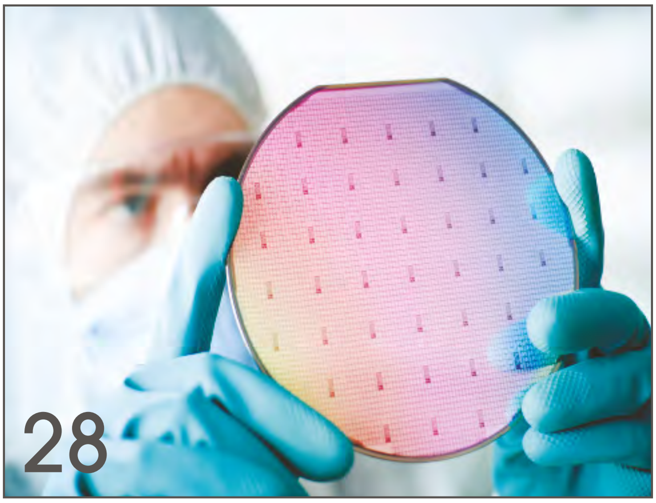

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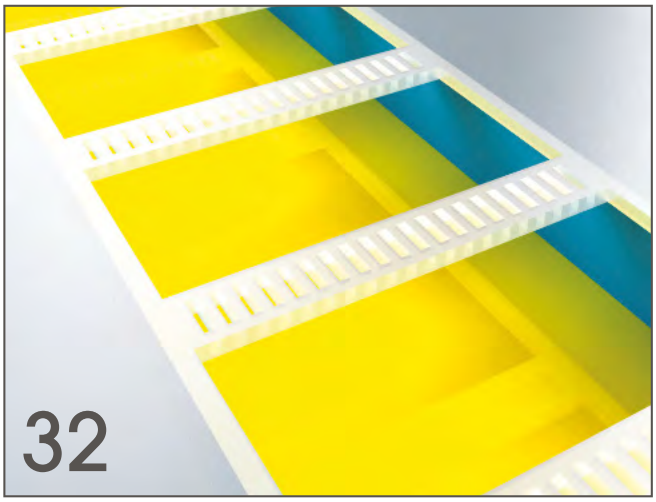

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While creating practical quantum computing remains a stretch goal, recent achievements at MIT and UC Santa Barbara show that beating Moore's Law may be on the cards after all.

Fab equipment growth continues into 2015

SEMI has announced the update of its World Fab Forecast report for 2015 and 2016. The report projects that semiconductor fab equipment spending (new, used, for Front End facilities) is expected to increase 11 percent (US$38.7 billion) in 2015 and another 5 percent ($40.7 billion) in 2016.

Since February 2015, SEMI has made 282 updates to its detailed World Fab Forecast report, which tracks fab spending for construction and equipment, as well as capacity changes, and technology nodes transitions and product type changes by fab. Capital expenditure (capex without fabless and backend) by device manufacturers is forecast to increase almost 6 percent in 2015 and over 2 percent in 2016.

Fab equipment spending is forecast to depart from the typical historic trend over the past 15 years of two years of spending growth followed by one of decline. For the first time, equipment spending could grow every year for three years in a row: 2014, 2015, and 2016

According to the SEMI report, fab equipment spending in 2015 will be driven by Memory and Foundry - with Taiwan and Korea projected to become the largest markets for fab equipment at $10.6 billion and $9.3 billion, respectively.

The market in the Americas is forecast to reach $6.1 billion, with Japan and China following at $4.5 and $4.4 billion, respectively. Europe/Mideast is predicted to invest $2.6 billion. The fab equipment market in South East Asia is expected to total $1.2 billion in 2015.

MEI announces integrated dryer

MEI WET PROCESSING SYSTEMS and Services LLC (MEI) has announced an integrated Marangoni dryer with HF and HCl injection for its automated wet processing systems, enabling cost effective wafer drying with lower particle counts.

Marangoni dryers enable high purity drying of semiconductor wafers during the computer chip manufacturing process. Modern chips for devices such as smartphones require ever smaller geometries with very low particle contamination. Their use has been limited because of the challenges of integration, and the high cost of N2 (Nitrogen gas) needed for production.

MEI's Genesis Xi dryer enables multistep oxide or ionic cleaning with integrated wafer drying; this eliminates the air interface, producing superior surface conditioning for semiconductor processing. MEI's Genesis series of integrated Marangoni dryers use significantly less N2 and provide high drying performance in 7-20 minutes.

"Our Genesis Marangoni dryers enable chemical oxide cleans before drying with no air interface and no damage to photoresist," says Product Marketing Manager Scott Tice. "We've achieved exceptional particle control, which is really meeting customer needs for improved yield."

Avago to buy Broadcom for $37 billion

AVAGO TECHNOLOGIES, a developer of analogue semiconductor devices with a focus on III-V based products and mixed signal chips, is acquiring the communication chip company Broadcom. The cash and stock transaction values the combined company at $77 billion. On completion of the acquisition, the combined annual revenues will be of approximately $15 billion.

Under the terms of the agreement, Avago will acquire Broadcom for $17 billion in cash consideration and the economic equivalent of approximately 140 million Avago ordinary shares, valued at $20 billion as of May 27, 2015, resulting in Broadcom shareholders owning approximately 32 percent of the combined company. Based on Avago's closing share price as of May 27, 2015, the implied value of the total transaction consideration for Broadcom is $37 billion. Avago intends to fund the $17 billion of cash consideration with cash on hand from the combined companies and $9 billion in new, fully-committed debt financing from a consortium of banks.

"Today's announcement marks the combination of the unparalleled engineering prowess of Broadcom with Avago's heritage of technology from HP, AT&T, and LSI Logic, in a landmark transaction for the semiconductor industry," said Hock Tan, president and COE of Avago.

"The combination of Avago and Broadcom creates a global diversified leader in wired and wireless communication semiconductors. Avago has established a strong track record of successfully integrating companies onto its platform. Together with Broadcom, we intend to bring the combined company to a level of profitability consistent with Avago's long-term target model."

"This transaction benefits all of Broadcom's key stakeholders," remarked Scott McGregor, president and CEO of Broadcom. "Our customers will gain access to a greater breadth of technology and product capability. For our shareholders, the transaction provides both compelling up-front value as well as the opportunity to participate in the future upside of the combined business."

"When Henry Nicholas and I founded Broadcom, we had a vision of creating the world leader in communications semiconductors. Today's announcement is a continuation of that vision and we could not think of a better partner for the future than Avago," stated Henry Samueli, co-founder, CTO and chairman.

Entegris reaches milestone

ENTEGRIS, INC has announced the first shipments of production quantities of UPE (ultra-high molecular weight polyethylene) membrane from its i2M Centre for Advanced Materials Science in Bedford, Massachusetts.

UPE membrane is a core material used in high-purity filtration solutions for semiconductor and life sciences applications.

"In the first half of 2015, we reached multiple milestones in our expansion plan to provide new membrane technologies to solve the yield challenges our customers face to manufacture semiconductor devices," said Entegris Vice President of the Liquid Microcontamination Control business unit, Clint Haris. "Several key customers have completed their qualification process and are now receiving i2M-based products for use in current applications, as well as for their developmental programs. We're excited to take this step forward as we continue to commercialize other UPE-based technologies in 2015."

The 80,000 sq. ft. facility opened in June 2014 as a $60 million investment intended to create one of the most advanced facilities of its kind. The investment included an expansion of membrane manufacturing capacity, implementation of advanced process controls and upgraded quality monitoring systems.

Brewer Science unveils ultrafast printed sensor technology

BREWER SCIENCE, a pioneer in electronics-grade carbon nanotube technology, invites the readers of Silicon Semiconductor to join them at COMPUTEX TAIPEI for a preview of the future of sensor technology with the world's first CNT sensor network for clean room application.

"Innovation at Brewer Science leads to the invention of new products, technologies, and outcomes," said Dr. Terry Brewer, President and founder of Brewer Science. "By bringing decades of expertise and creativity to the industry, we invent products that position companies to succeed. Our newest sensor technology utilizes hardware- and software-system integration capabilities that enable clean rooms to become smart rooms, and transform today's manufacturing environments into smart factories of the future."

More than 30 years of design and materials expertise make Brewer Science unique as a printed electronics service house, providing rapid-scale prototyping and small-scale manufacturing capabilities that give customers a competitive edge.

Brewer Science provides a full array of printed, carbon-based sensors, configured wirelessly to deliver real-time information.

EV Group sees strong demand for emerging photonic applications

EV GROUP (EVG), a supplier of wafer bonding and lithography equipment for the MEMS, nanotechnology and semiconductor markets announced that its NILPhotonics Competence Center—established to assist customers in enabling new and enhanced products and applications in the field of photonics—has generated strong interest from customers and resulted in multiple system orders since its launch in December 2014. New system orders have included the company's EVG700/7000 Series UV-NIL (UV nanoimprint lithography) systems with SmartNIL technology to support high-volume manufacturing applications, including displays, light emitting diodes (LEDs) and wafer-level optics.

Since its initial launch, the NILPhotonics Competence Center has also expanded the products and applications it is supporting. These include photonic and microfluidic devices for bio-medical applications that pave the way for faster and more accurate diagnosis of diseases, as well as plasmonic structures that simultaneously carry optical and electrical signals and can be scaled to the smallest dimensions to enable new chip designs as well as better-performing devices, such as waveguides and sensors.

"The prevailing perception has been that despite the potential benefits of NIL technology, the barrier to entry for integrating it into high-volume manufacturing (HVM) is high. That simply isn't the case. EV Group has invested significant resources over many years in developing NIL technology as an HVM-capable solution for a number of applications," stated Markus Wimplinger, corporate technology development and IP director at EV Group. "Today, we have the world's largest installed base ofmore than 200 systems at customer facilities around the globe supporting volume-manufacturing of LEDs, MEMS, optics, photovoltaics and other devices. Our NILPhotonics Competence Center allows us to more easily bring all of our process and product capabilities

and expertise to bear in helping our customers enable new photonic products and applications."

EVG's NILPhotonics Competence Center leverages EVG's field-proven process and equipment know-how in NIL and other process areas such as wafer bonding to support emerging photonic applications and significantly shorten time to market through fast process implementation and optimization, as well as through customized equipment design. In addition, EVG has a global partner network to draw from to support its customers' process integration and optimization efforts across the NIL infrastructure, including template manufacturing, resist materials and supporting equipment. As a result, EVG is able to provide consultation and support across all phases of the product lifecycle—from design for manufacturing and prototyping through process development, qualification runs, pilot manufacturing and process transfer.

"More than a decade ago, EV Group launched the NILCom Consortium with support from companies representing key aspects of the NIL supply chain in order to speed commercialization of NIL technology. Through the dedicated efforts of all of our members, we are pleased to announce that the NILCom Consortium has successfully completed its charter and will end formal operations.

That said, we will continue to collaborate with companies across the NIL supply chain including our former members as needed to ensure that NIL technology continues to address future customer roadmap requirements," added Wimplinger.

Dow Corning collaborate with IBM

DOW CORNING has unveiled new Dow Corning TC-3040 Thermally Conductive Gel, a next-generation thermal interface material (TIM 1). Developed through the help of IBM, this cutting-edge new material offers more effective and reliable thermal management, reduced stress and excellent under-die coverage for demanding flip chip applications the company says. Dow Corning unveiled the new product technology here at the IEEE Electronic Components and Technology Conference (ECTC 2015).

TIM-1 solutions are a class of high-purity, thermal interface materials that are applied between the chip surface and a heat spreader to help dissipate damaging heat to the exterior of a semiconductor package. However, as applications from data centers to consumer devices to automotive electronics all demand higher functioning integrated semiconductor devices with increasing processing power, the temperatures within chip packages are rapidly increasing and testing the limits of conventional TIM-1 solutions.

"A long-time member of IBM's ecosystem, Dow Corning brought decades of expertise in advanced silicone technology to help formulate this break-through TIM-1 material for high-end chip packaging," said Andrew Ho, global market segment leader, Semiconductor Packaging Materials at Dow Corning. "It is only the latest innovation on the ambitious roadmap of thermal management solutions that Dow Corning has planned for this rapidly evolving global market."

The successful efforts of IBM and Dow Corning scientists have raised the bar for TIM-1 performance. Dow Corning TC-3040 Thermally Conductive Gel delivers nearly two times the thermal performance of other industry standard TIMs, as well as high thermal conductivity targeting 4W/mK. reliability.

Why Intel is considering acquiring Altera

ACCORDING to media reports, Intel has agreed to buy Altera Corporation for $54 a share, which is roughly $16.7 billion.

;Intel's largest purchase comes on the heels of a long series of semiconductor mergers and acquisitions – including last week's announcement that Avago had agreed to purchase Broadcom Corporation for $37 billion.

Prior competitor mergers also include NXP and Freescale, Cypress Semiconductor and Spansion, Lattice Semiconductor and Silicon Image, Qualcomm and CSR, Infineon and International Rectifier, and several more. While none of these companies directly competes with Intel for its largest market -- PC central processing units (CPUs) -- each of these mergers has had an influence on various embedded markets where Intel has a stake.

Intel is the largest supplier of microprocessors (MPUs) in the world, with overall semiconductor revenues nearing $50 billion in 2014 and MPUs comprising 80 percent of that revenue. While not as large as Intel, with $2 billion in 2014 revenues, Altera is the second-largest supplier of programmable logic devices (PLDs) and system-on-chip (SoC) field programmable gate arrays (FPGAs).

The largest markets for Intel's MPU solutions are CPUs for portable PCs and tablets, desktop PCs, notebooks, servers and high-performance computing (HPC) platforms. In the last several years, demand has stagnated for desktop PCs and the forecast for portable PCs has begun to slow. Much of this market sluggishness has been related to the introduction of more portable computing platforms, such as smartphones and tablets.

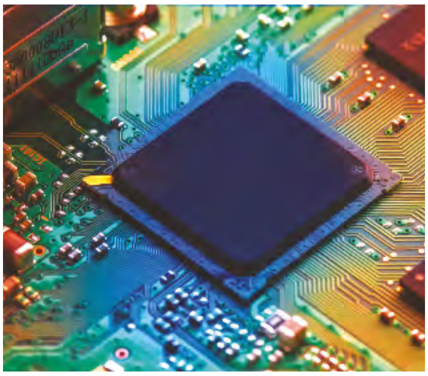
IHS predicts that the tablet market is entering a saturation phase, with larger sizes also entering a slowing growth. More relevant to the Altera purchase, Intel supplies a host of integrated chip solutions to many markets beyond computers, and it is in many of these markets that Intel has the most potential for continued growth.

Communications infrastructure and data center equipment comprise some of the largest synergetic markets for Intel and Altera. Intel is already the leading supplier of high-performance wired and wireless telecommunications infrastructure processor solutions and -- with an increasing market for internet-of-things (IoT) connected devices -- these markets provide even greater opportunity for the right solutions. Altera's position as a strong supplier of broadband, networking and telecommunications solutions was likely a crucial consideration for Intel, when the company decided to purchase Altera.

On the whole, Intel's x86 microprocessors and applications processors would be very complementary to Altera's broad base of programmable logic, especially for networking solutions. Intel microprocessors are optimized for high-performance control, and Altera PLDs and FPGAs are flexible and can be easily configured to process huge parallel streams of packet data as a coprocessor to the MPU, which could be a key strength of the acquisition.

There are a few small overlaps to consider, such as the Altera system-on-chip (SoC) FPGA with embedded ARM Cortex A processors. Whether Intel will continue to develop ARM core-based solutions, a strategy they tried and abandoned with the XScale technologies, will be the type of strategic choices IHS will continue to follow after the acquisition.There are many applications and markets where a high-performance MPU and configurable logic are designed to work side by side: Industrial applications for military and aerospace, manufacturing and process control, automotive applications, security and surveillance, broadcast, and many more. Even in HPC, FPGAs will perform co-processing functions. Whether it is offering complementary solutions, or combining intellectual property, in order to create new unique SoCs, the combined potential of Intel and Altera should be well poised to target a growing telecommunications market and IoT applications. *Tom Hackenberg, principal analyst, embedded processing for IHS.*

Semiconductors play a key role in PV inverters



THE MARKET for semiconductors used in photovoltaic (PV) inverters, which convert direct current (DC) to alternating current (AC) from the PV modules, will continue to expand in the long term. According to IHS, amid increased awareness and demand for energy-efficient products, revenue from semiconductors used in PV inverters amounted to $387.1 million last year, a year-over-year increase of 9 percent. The PV inverter semiconductor market is on track for strong long-term growth of 12 percent in 2015, 20 percent in 2016, 14 percent in 2017 and 16 percent in 2018.

"One of the most important trends in the semiconductor industry today is the development of solutions that improve energy efficiency," said Robbie Galoso, associate director, semiconductor market shares and industrial electronics for IHS. "In particular, semiconductors play a key role in PV Inverters, where major power savings can be accomplished."

According to the latest IHS research on industrial semiconductors, there are three major types of PV inverters, as follows: microinverters, single-phase inverters and three-phase inverters. The small-scale inverter market is mainly composed of microinverters and single phase inverters, which are expected to capture more market share from three-phase inverters over the next five years.

"Microinverters convert direct current electricity into alternating current, from a single solar module," Galoso said. "Although they are more costly, in some cases microinverters can harvest up to 25 percent more electricity than conventional string- or central-inverter devices, which convert power from multiple solar panels."

The demand for high-quality energy conversion by PV inverters has increased the penetration of discrete and analog semiconductors. In fact more than three quarters of PV-inverter semiconductor revenue is made up of analog and discrete components.

Small-scale PV inverters – such as microinverters and single-phase inverters – generally include metal-oxide-semiconductor field-effect transistors (MOSFETs) and other components, given their low power rating of less than 500 watts (W). Large three-phase inverters with power ratings above 500W generally drive the demand for high-power discrete semiconductors, such as insulated-gate bipolar transistors (IGBTs), because of their better performance at high temperatures.

Microinverters and single-phase PV inverters generally use microcontrollers (MCUs) as a control unit, while three-phase inverters typically use digital signal processors (DSPs), especially those that require faster signal processing. "Due to increasing sales of microinverters, overall semiconductor unit sales and revenues in PV inverters will continue to show healthy growth," Galoso said. "In general, the discrete unit counts are highly correlated to the PV inverter's power rating." Ongoing component price erosion continues to be exacerbated by the rise of Chinese PV inverter suppliers; however, average selling prices (ASPs) for discrete power transistors, thyristors and power diodes may rise in the short term, due to the influx of gallium-nitride (GaN) and silicon-carbide (SiC) semiconductors and as other innovative next-generation technologies go into effect.

Road to low cost advanced industrial sensors now open

MICRALYNE INC.'S says their new MicraSilQ fabrication design kit cuts costs and speeds product introduction for industrial customers supplying and developing advanced inertial sensors. MicraSilQ offers an established fabrication process built for reliable operation and value, and eliminates costly discrete packaging.

MicraSilQ is designed for the development and supply of complex micro-electro-mechanical systems (MEMS) focused on vibration, motion, rotation and shock detection. It enables MEMS design professionals to create functionally robust and reliable devices utilizing a well-established process flow with design rules. MicraSilQ supports the production of high volume accelerometer and gyro fabrication in an all-in-one solution integrating wafer level fabrication, hermetic packaging and through-silicon-via (TSV) architecture.

"For a MEMS architect, designing into a mature process platform with established design rules is the fastest path to a functional device with desired performance," commented Alex Edwards, vice president of CMC Microsystems. "The MicraSilQ inertial MEMS platform provides a component that is ready for flip-chip integration, by providing through-silicon-vias, hermetic wafer level packaging, and ball grid array attachment."

For high attachment reliability, the microchip package is completed with lead-free solder with specially-designed under-bump metallization. The standard 60 micron device layer allows for the large capacitive comb finger overlap area widely used in inertial sensor designs. Custom device layer thicknesses greater or less than 60 microns are also available.

MicraSilQ moves new sensors from prototype to market with optimum performance, device reliability and speed. "MicraSilQ dramatically lowers costs by eliminating the need for external ceramic housing, wirebonds and hermetic sealing on a discrete basis," explained Collin Twanow, Micralyne's Vice President of Engineering. "Deposited getter material in the capping wafer provides exceptional Q-factor and long term stability."

Imec reports 9 percent growth in 2014

NANOELECTRONICS research centre imec, has reported the financial results for fiscal year ended December 31, 2014. Revenue for 2014 totalled 363 million euros, a 9 percent growth from the previous year.

The fiscal year end total includes the revenue generated through R&D contracts from international partners, collaborations with universities worldwide and funds from European research initiatives. The annual revenue figure also covers a yearly grant from the Flemish government totalling 48.8 million euro in 2014, and a 4.1 million euro grant from the Dutch government to support the Holst Centre, a research centre setup by imec and TNO.

"I am extremely proud that 2014, our 30th anniversary year, concludes as one of our strongest years ever," said Luc Van den hove, president and CEO at imec. "We reported strong financial growth, announced new collaborations and inspiring innovations. We filed a record number of patents, achieved notable industry awards and published prominent scientific papers—all a testament to our commitment to innovate. Moreover, we also added significant talent to our already impressive roster of researchers, growing to a total of 2,188 employees by the end of 2014."

"Looking to the future, together with our partners, we are committed to overcome the next challenges. First, we work to enable the fabrication of sub-10nm technology.

With further scaling, new lithography techniques
and new materials, and based on CMOS technology, we'll be busy doing that for another number of years. But we have also started looking for materials and techniques for the post-CMOS era.

There are many alternatives, and it is our task to see which of these can be scaled to a technology that can be mass-produced. Next to that, we help our partners with technologies for the sustainable and smart applications of the Internet-of-Things, Internet-of-Energy, and Internet-of-Health. It is expected that 2015 will be an important year for the breakthrough of these systems.

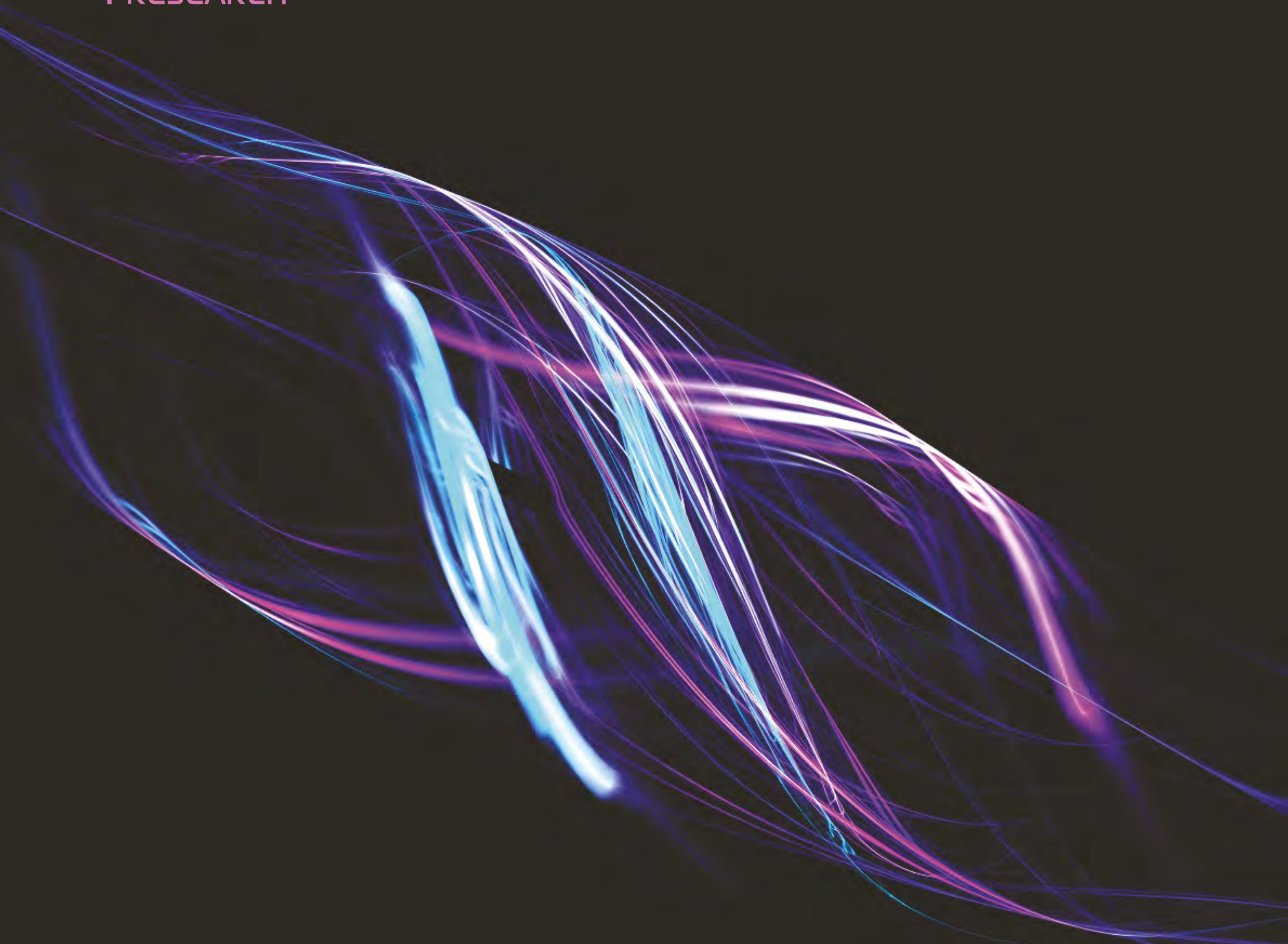
A breakthrough that will be positive for the whole semiconductor industry;" continued Luc Van den hove. "This ground breaking research requires ever more talent. That's why today we have over 100 vacancies for a variety of profiles. Vacancies for people who have the ambition to contribute to the technologies for a sustainable future."

Microsemi completes acquisition of Vitesse

MICROSEMI CORPORATION and Vitesse Semiconductor Corporation has jointly announced that Microsemi's wholly-owned subsidiary LLIU100 Acquisition Corp. successfully merged into Vitesse, completing Microsemi's acquisition of Vitesse under Section 251(h) of the General Corporation Law of the State of Delaware, with no vote of Vitesse's stockholders required to consummate the merger.

At the effective time of the merger, each outstanding share of Vitesse (other than shares directly owned by Vitesse and its subsidiaries, Microsemi or LLIU100 Acquisition Corp. and shares held by stockholders that are entitled to and properly demand appraisal of such shares under Delaware law) was converted into the right to receive $5.28 per share in cash, without interest and less any applicable withholding taxes, the same price that was paid in the tender offer. Following the merger, Vitesse shares will cease to be traded on Nasdaq.

Headquartered in California, Vitesse designs high-performance semiconductors, application software, and integrated turnkey systems solutions for carrier, enterprise and IoT networks.



Spiralling laser pulses

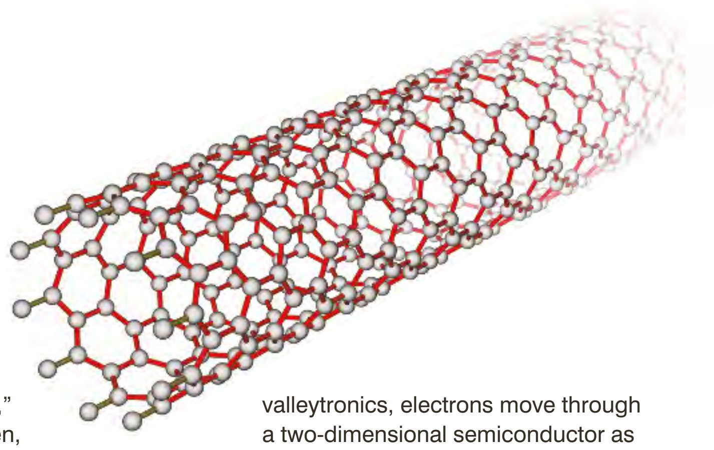
could change the nature of graphene

A new study predicts that researchers could use spiralling pulses of laser light to change the nature of graphene, turning it from a metal into an insulator and giving it other peculiar properties that might be used to encode information.

A NEW STUDY predicts that researchers could use spiralling pulses of laser light to change the nature of graphene, turning it from a metal into an insulator and giving it other peculiar properties that might be used to encode information. The results, published in May in Nature Communications, pave the way for experiments that create and control new states of matter with this specialized form of light, with potential applications in computing and other areas.

"It's as if we're taking a piece of clay and turning it into gold, and when the laser pulse goes away the gold goes back to clay," said Thomas Devereaux, a professor at the Department of Energy's SLAC National Accelerator Laboratory and director of the Stanford Institute for Materials and Energy Sciences (SIMES), a joint SLAC/Stanford institute.

"But in this case," he said, "our simulations show that we could theoretically change the electronic properties of the graphene, flipping it



back and forth from a metallic state, where electrons flow freely, to an insulating state. In digital terms this is like flipping between zero and one, on and off, yes and no; it can be used to encode information in a computer memory, for instance. What makes this cool and interesting is that you could make electronic switches with light instead of electrons."

Devereaux led the study with Michael Sentef, who began the work as a postdoctoral researcher at SLAC and is now at the Max Planck Institute for the Structure and Dynamics of Matter in Germany.

Tweaking a wonder material

Graphene is a pure form of carbon just one atom thick, with its atoms arranged in a honeycomb pattern. Celebrated as a wonder material since its discovery 12 years ago, it's flexible, nearly transparent, a superb conductor of heat and electricity and one of the strongest materials known. But despite many attempts, scientists have not found a way to turn it into a semiconductor -- the material at the heart of microelectronics.

An earlier study demonstrated that it might be possible to take a step in that direction by hitting a material with circularly polarized light -- light that spirals either clockwise or counterclockwise as it travels, a quality that can also be described as right- or left-handedness. This would create a "band gap," a range of energies that electrons cannot occupy, which is one of the hallmarks of a semiconductor.

In the SIMES study, theorists used the DOE's National Energy Research Scientific Computing Center at Lawrence Berkeley National Laboratory to perform large-scale simulations of an experiment in which graphene is hit with circularly polarized pulses a few millionths of a billionth of a second long.

Getting as close to real as possible

"Previous studies were based on analytical calculations and on idealized situations," said Martin Claassen, a Stanford graduate student in Devereaux's group who made key contributions to the study. "This one tried to simulate what happens in as close to real experimental conditions as you can get, right down to the shape of the laser pulses. Doing such a simulation can tell you what types of experiments are feasible and identify regions where you might find the most interesting changes in those experiments."

The simulations show that the handedness of the laser light would interact with a slight handedness in the graphene, which is not entirely uniform. This interaction leads to interesting and unexpected properties, said SLAC staff scientist and study co-author Brian Moritz. Not only does it produce a band gap, but it also induces a quantum state in which the graphene has a so-called "Chern number" of either one or zero, which results from a phenomenon known as Berry curvature and offers another on/off state that scientists might be able to exploit.

Insights go beyond graphene

While this study does not immediately open ways to make electronic devices, it does give researchers fundamental insights that advance the science in that direction. The results are also relevant to materials called dichalcogenides (pronounced dye-cal-CAW-gin-eyeds), which are also two-dimensional sheets of atoms arranged in a honeycomb structure. Dichalcogenides are the focus of intense research at SIMES and around the world because of their potential for creating "valleytronic" devices. In valleytronics, electrons move through a two-dimensional semiconductor as a wave with two energy valleys whose characteristics can be used to encode information.

Possible applications include light detectors, low-energy computer logic and data storage chips and quantum computing. In addition to the work on graphene, members of the research team have also been simulating experiments involving the interaction of light with dichalcogenides.

"Ultimately," Moritz said, "we're trying to understand how interaction with light can alter a material's character and properties to create something that's both new and interesting from a technological point of view."

In addition to SLAC, Stanford, SIMES and the Max Planck Institute for the Structure and Dynamics of Matter, other members of the research team were from Berkeley Lab, the University of Tokyo and Georgetown University. The work was funded by the DOE Office of Science.

Journal Reference

M.A. Sentef, M. Claassen, A.F. Kemper, B. Moritz, T. Oka, J.K. Freericks, T.P. Devereaux. Theory of Floquet band formation and local pseudospin textures in pump-probe photoemission of graphene. Nature Communications, 2015; 6: 7047 DOI: 10.1038/ncomms8047

More than Precision

Meeting the challenge of accurately assembling active optical cables

No one would dispute the fact that active optical cable (AOC) and Silicon Photonics technologies are getting tremendous attention due to the need of transferring more and more data at ever faster data rates. This is putting immense pressure on the assembly equipment suppliers to offer advanced tools and processes that push the envelope of ultra-precise die placement. For Dr. Johann Weinhändler of Amicra there is no end in sight.

AOC is one of the most efficient solutions currently available to meet the rapidly rising demand for bandwidth, performance, capacity and availability in large data centers, which need a flexible configuration of their server racks to keep pace with technology and data traffic conditions in the face of growing volumes of mobile and video content.

The development of active optical modules is attracting an immense development activity – regardless of their transmission capacities, which are on the verge of breaking the 400 Gbps barrier. By 2019, a mere four years from now, worldwide sales of $1.5 bn in AOC modules is predicted by a new market report issued by Communications Industry Researchers (CIR) based in Charlottesville, VA, USA. This exciting, and challenging, prospect mirrors the ongoing adoption of fiberoptic communication gear, replacing the heavy, slow and cumbersome copper assembly plants of old.

Progress in AOC has been fast and furious, challenging the vendors of manufacturing equipment for interconnect components as well. AOC modules operating at 40 Gbps are considered mainstream today. So, more and more vendors are looking to enter the high-performance segments providing up to 100 Gbps, if not aspiring right away up to 400 Gbps.

Main revenue generators, however, still are the 'workhorse' modules of the QSFP (Quad Small Form Factor Pluggable) and the copper-based CXP (InfiniBand) categories. By 2019, however, according to CIR these two will get the lion's share of annual sales generating $1.3 bn in revenue. They will carry the bulk of services in the Ethernet and IB protocol domains as required by most large data centers. The newer CFP (100 Form Factor Pluggable) and CDFP (400 Form Factor Pluggable) devices will reach just a fraction of that, amounting to less than $200m in sales.

A related market segment that is developing alongside the AOC modules is Silicon Photonics, which is promised a very bright future by French market researcher Yole Développement in their 'Silicon Photonics 2014' report. Although revenues are still slight ($25 m in 2013), its growth prospects reveal a CAGR of 38 percent to achieve a market volume of $700m by 2014.

Silicon Photonics, Yole states, will realize the advantages of low cost and high systems integration that come with Si processing, with the added benefit of low power and low weight, plus higher functionality. Another benefit is increased reliability and availability in the face of the relatively short life span of typical rack servers.

Already on the market today are active optical cables from a number of mid-size vendors such as Luxtera, Mellanox and Avago, whereas the heavyweights like Intel, Cisco and IBM are just gearing up to enter the race on their terms. All this has instigated considerable action and investment on the side of equipment vendors to be able to provide adequate assembly and manufacturing tools for chip-to-chip and chip-to-wafer interconnect devices and processes.

Amicra is up to the challenge

Amicra Technologies, founded in 2001 and headquartered in Regensburg, Germany, is one of the worldwide leading providers of assembly tools for the manufacturing of AOC modules. The company is focusing its efforts and resources on extreme accurate placement and bonding techniques for VCSEL (vertical cavity surface emitter) chips and PIN (positive intrinsic negative) diodes. In its chosen field of precision placement processing Amicra offers high-accuracy (down to 0.5µm) micro-assembly cells, high-speed inking systems as well as laser and LED testing systems.

The company's key expertise is in the most exacting placement of VCSELs, pin and laser diodes as well as lenses inside AOC modules to ensure high data throughput rates (Figure 1). Amicra derives its expertise from its original founding mission: to provide first-rate equipment and processing specifically for fiberoptics applications. Targeted markets are the fiberoptic and MEMS manufacturing industries, as well as those making LEDs, optoelectronic and semiconductor devices, and propagating advanced concepts such as TSV, 3-D ICs, and high-fan-out board configurations.

Accordingly, Amicra's state-of-the-art AFCPlus and NovaPlus die and flip-chip bonding platforms are focused on VCSEL, PIN and lens attachment procedures, as well as laser diode attach on Si submounts via non-contact substrate heating. AFCPlus realizes a placement accuracy of up to +0.5µm at 3 Sigma – which is best in class - and a competitive total cycle time of less than 15 seconds.

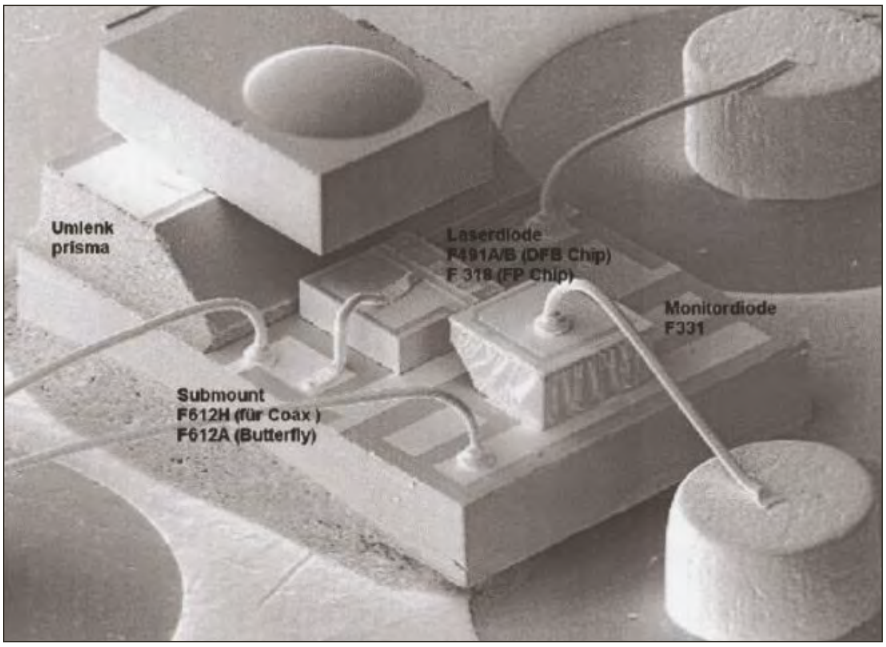


Figure 1: REM-image of a AOC module

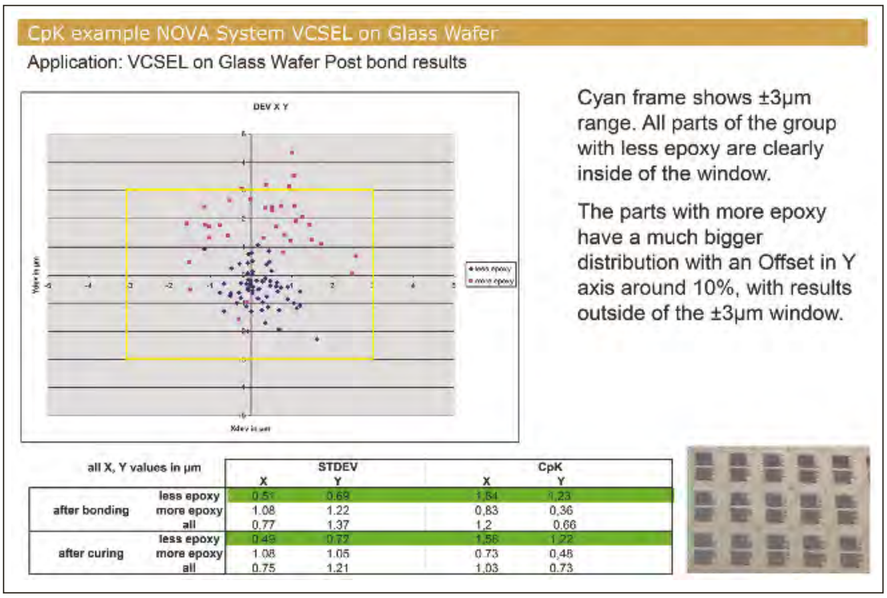
AFCPlus features a bond tool holder for eutectic bonding at temperatures up to 300 °C. Non-contact substrate heating with localized laser impact goes up to 450 °C. Another outstanding feature is active bond force control, which is adjustable between 10 grams and 2 kilograms. Epoxy stamping and volumetric dispensing are standard ingredients of the AFCPlus, as well as UV dispensing and UV curing at the bond location.

A different tack is pursued by Amicra's NovaPlus, a dual-bondhead die- and FC-attach machine. It was conceived for high-volume applications in the realm of opto, WLP, TSV and embedded chip (fan-out) placement tasks. Placement accuracy reaches up to +2.5µm at 3 Sigma. Another of the NovaPlus's advantages is its short cycle time of less than 3 seconds per bond. Accordingly, UPH values of up to 2500 (at +5µm) or up to 1200 (at +2.5µm) are achieved.

NovaPlus is based on a modular concept, including a fully integrated dispensing system that supports multiple dispenser types. A flip-chip option is also available. The machine supports 300mm wafers and rectangular substrates up to 600mm x 600mm in size.

The dynamic alignment capability offered on both machines is achieved by the concept of the camera measuring through the bond head and accurately detecting the positions of die and substrate in relation to each other. Feedback from the vision system during the measurement enables the calculation of the pertaining x-, y- and Θ vectors and die alignment by the appropriate shifts and turns until the final position and preset accuracy are reached. This corrective action is taking place during the entire bonding process. In the end, this method is faster and yields by a factor of 2x higher UPH values than the beam splitter alignment process.

Another concern with AOC is an acceptable Cpk value. Looking at die placement with a given Cpk value is an effective way to analyze the die



all X, Y values in µm		STDEV X	STDEV Y	CpK X	CpK Y
after bonding	less epoxy	0.51	0.69	1,84	1,23
	more epoxy	1.08	1.22	0,83	0,36
	all	0.77	1.37	1,2	0,66
after curing	less epoxy	0.49	0.72	1,56	1,22
	more epoxy	1.08	1.05	0.73	0,48
	all	0.75	1.21	1,03	0.73

Figure 2: Bonding of VCSEL on glass wafer with NovaPlus. Post-bonding CpK results. Cyan colored frame shows the +3µm range. All parts with less epoxy are inside the window.

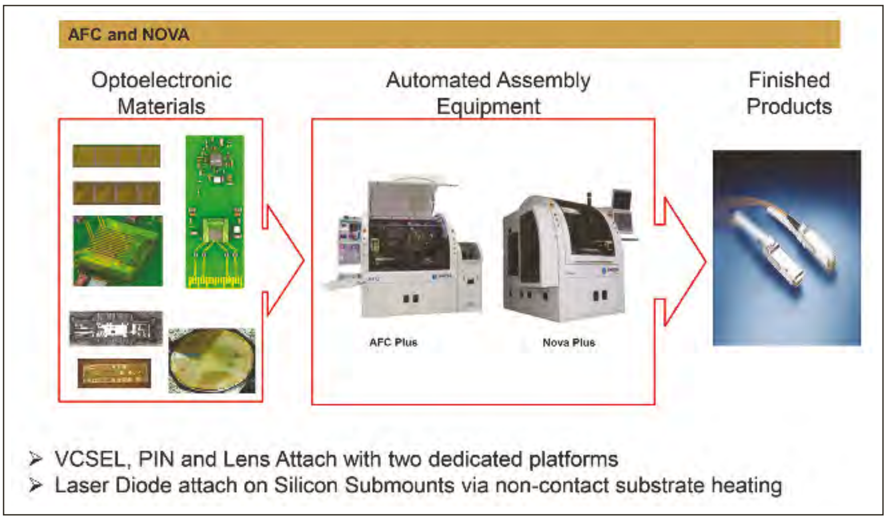


Figure 3: VCSEL placement of QSFP engine on PCB with AFCPlus or NovaPlus.

placement results. Cpk helps to predict with confidence the first-pass yield of the assembly process. Sufficient Cpk values are met by the AFCPlus and NovaPlus machines. An example is the precise placement of VCSELs on glass wafers shown in Figure 2.

Amicra's proprietary concept of dynamic component alignment ensures the most accurate placement at an efficient cycle time, and offers a resolution in the adjustment of components to be placed within <0.1µm. Amicra is leading the pack by being the sole vendor offering this type of dynamic alignment. It is achieved by keeping chips and substrates within the field of view of the camera during the entire placement process for corrective action. The principle pertains to die attach, flip-chip and lens attach.

QSFP assembly is a major application that is rapidly gaining in importance. Those modules require the exact positioning of the transceiver in relation to the optic cable to realize their superior port density as compared to SFP modules. An overview of AOC placement applications for the QSFP optical engine using either the AFCPlus or the NovaPlus is given in Figures 3 and 4, detailing the placement of one to twelve units per array. The principle here is to have the rotation of the Photodiode aligned relative to the rotation of the VCSEL. This yields full control of alignment and placement (all within the FOV of the camera). Typical post-bond measurements results are <120 CPH (+2µm @ 3 Sigma) on the AFCPlus, and 700 CPH (+3µm @ 3 Sigma) on the NovaPlus, using an epoxy process. Now to lens placement, using an UV epoxy. The major process steps as shown in Figure 5 are:

- Correlation of the lower side of the lens to its top side by means of the Amicra's Correlation Stage, and bonding relative to the VCSEL.
- Dispensing of UV epoxy,
- Placement and bonding of the lens via Amicra's dynamic alignment system,
- Post-bond measurement, done within the machine.

AFCPlus achieves a placement throughput of up to 189 lenses per hour at an accuracy of +1 - 2μm at 3 Sigma. NovaPlus moves this number up to 700 to 1200 lenses per hour at an accuracy of +2.5 - 5 μm at 3 Sigma. Slight variations can occur due to different material and process qualities.

Finally a brief look at the eutectic bonding process of laser diodes to wafers. A typical requirement in this regard, which is solved with the AFCPlus is the attachment of flipped, and non-flipped, laser diodes. AFCPlus performs this using an 80/20 AuSn soldering process with +3μm accuracy and contact-less heating from the bottom side and an optional heater from the top. Here, of course, the bonding is not carried out using an adhesive but deploying a contactless local laser heating procedure. Figure 6 shows some actual results of this process.

Gearing up for silicon photonics

A very promising current Silicon Photonics application that is met by the capabilities of both the AFCPlus and the NovaPlus platforms is chip-to-wafer bonding of TOSAs (transmitter optical sub-assemblies), and ROSAs (receiver optical sub-assemblies). The use of these advanced assemblies will lower cost and boost performance, besides improving reliability in high-speed interconnect situations.

Silicon Photonics, discussed and hyped for a long time is slowly gaining traction – now that a major semiconductor manufacturer headquartered in California has committed to start producing Indium-Phosphide chips on Si, using Amicra's equipment. Other major IT gear vendors based in China, such as Huawei, are now hopping on the Si Photonics train as well.

By 2020, as market researcher CIR states in a newly released report, the market for chip-to-chip optical interconnect engines will reach $775m. On-chip optical interconnect, the next evolutionary step of future system configurations, will exceed $210m around 2025. It is envisioned that by then VCSELs will be replaced by silicon-based lasers or even quantum dot lasers integrated on-chip.

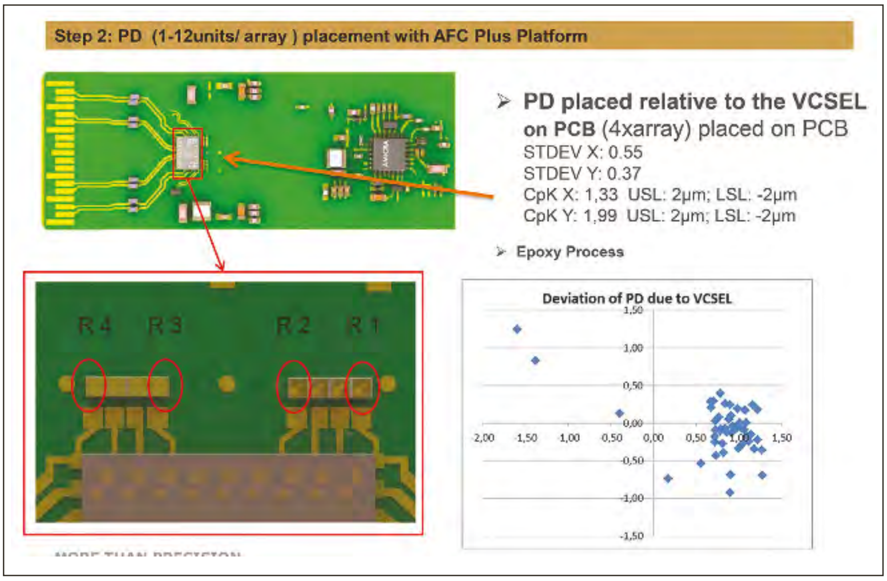


Figure 4: Photodiode placement with QSFP on AFCPlus.

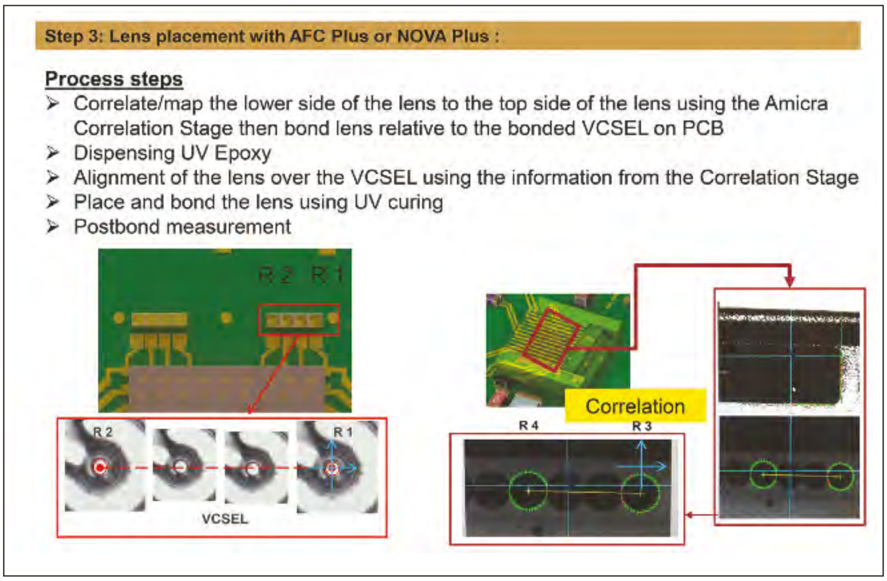


Figure 5: Lens placement process with QSFP on NovaPlus.

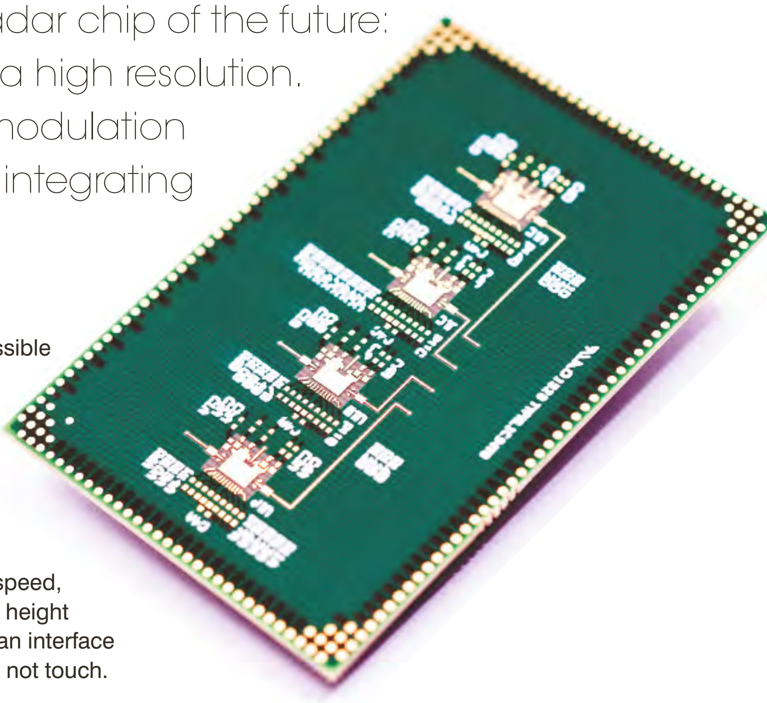
Conclusion

The exact rate at which the market is predicted to grow will always be argued and debated by marketing experts. But no one would question that AOC/silicon photonics production will continue to grow in the foreseeable future and that ultra-precise die placement is the key to success in this market.

Johann Weinhaendler is Managing Director of Amicra Microtechnologies GmbH. He holds a degree in electrical engineering, an MBA from Open University Business School (UK), and a doctoral degree in economics from Trinity College (Dublin, Ireland).

The radar chip of the future?

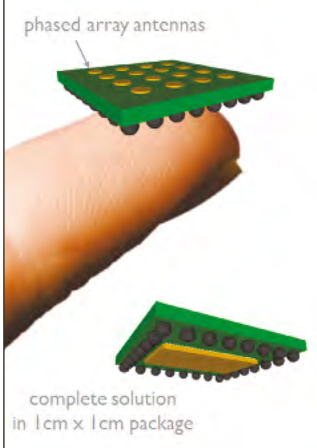
Today, some cars are already equipped with radar modules that assist their drivers. One of the challenges to is to improve radar resolution. Wim Van Thillo, program director at imec, explains how imec researchers are working on the radar chip of the future: cheap, compact, low-power and with a high resolution. Two techniques are key: using phase modulation instead of frequency modulation, and integrating MIMO antennas.



IMEC'S radars make use of the 79GHz frequency band, the band used by automotive applications. These applications today concern parking assistance, detection of pedestrians or other vehicles, collision prevention... But with only a few adaptations, the technique could also be used with other frequency bands (e.g. 60GHz) and applications.

The possibilities are countless. Think of a sensor in all types of objects that is able to detect movement, size, and presence. Where would you use it? For example in smart buildings for lighting management: a wall radar detects two people sitting in a meeting and automatically adjusts to the best-suited lighting level. Today, that would also be possible with cameras but this has of course some privacy issues. Another example is monitoring the breathing of a sleeping baby. Measuring the biking speed, ball velocity, and jump height ... of athletes. Making an interface based on movements, not touch.

Designing a robot that mows grass. Or even adding a radar to a hair dryer, so that the heat can be adjusted depending on the distance to the hair. Come to think of it: most objects would improve with a radar.



Chip technology	28nm CMOS
Sensor size	1cm^3
Power consumption	1W
Antenna paths	1-16
Packaging	PCB
Temperature	up to 125^{o}C
Regulation compliance	ETSI

Fig 1: Around 2020, imec expects its radar-on-chip technology in cars and other products. At this moment, we develop a CMOS-based radar-on-chip with antennas integrated in the package.

Chip technology for radars

"Imec started developing radar technology in 2012. Our research center has a deep expertise in CMOS-based chip technology. We believe this technology is the key to compact, cheap, and energy-efficient radar modules.

Today, most such modules are still made in SiGe technology. We use 28nm CMOS technology and commercially available PCB technologies with the goal to design complete system-on-chip solutions with antennas integrated in the package. To date, we already made a transmitter (2013) and a transceiver (2014) in 28nm CMOS. And we're now working towards the system-on-chip integration with integrated PLL, ADC, correlator, accumulator...

The next steps will be to roll out a lab demo (expected in 2016) and a field demo (2017). We then hope to see the technology in cars by the year 2020.

Radar with high resolution needed to detect people

An important challenge is improving the resolution of a radar. The key is how accurately a radar can distinguish between two objects. So in this case, resolution is not to be confounded with accuracy (how precisely the radar can position an object in a space).

A radar is characterized by its depth, angular, and velocity resolution. The latter is also called Doppler resolution. It allows a radar to see if objects are moving or stationary, and if an object moves in the direction of the radar or away from it.

"Our researchers managed to develop a suitable resolution to detect people. The specifications to do so are really challenging and may vary between applications. An example use case: a maximum range of 30 meters, no blind range (where the radar doesn't see), and a depth resolution of 7,5cm. We used a number of innovative techniques to improve the resolution, especially the depth and angular resolution."

Better depth resolution with phase modulation

Simple radars are based on short high-power pulses. This is difficult to implement efficiently in CMOS technology, so it is better to revert to continuous wave technology. Most of today's radars are therefore FMCW radars (frequency modulated continuous wave). These send out a frequency sweep with a bandwidth of e.g. 100MHz. This wave hits the target and is reflected to the transceiver. Based on the offset of the frequency, the distance to the target can be measured. The disadvantage of this technique is that a high resolution requires a larger bandwidth. And with such a larger bandwidth, it is difficult to realize a linear sweep.

"Imec has chosen another technique: PMCW or phase modulated continuous wave (with additional spillover cancellation). With PMCW, a binary signal is transmitted. The signal that is returned is correlated with offset signals, comparable to how a GPS functions. The advantages of this technique are listed in figure 4, but the major advantage is that PMWC allows designing higher resolution radars."

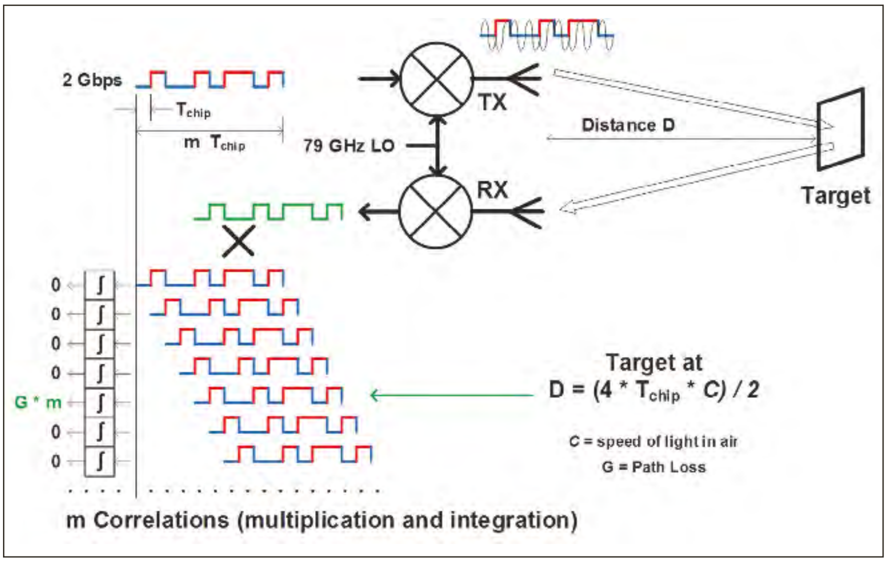


Fig 3: Radars based on phase modulation (instead of frequency modulation) allow for a higher depth resolution.

Better angular resolution with MIMO antennas

"Implementing a higher angular resolution is possible by adding more antennas. This of course will lead to a larger surface, a higher cost, and a higher energy use. As an alternative, it is also possible to use MIMO-technology (multiple input multiple output). Each transmitter sends a number of differently-coded orthogonal signals (one after the other, or in parallel), which are then received by all receivers. This way, you can create a virtual antenna array that is a convolution of a transmitter and a receiver array."

Radar-on-chip prototype

"Thanks to these techniques, we succeeded in making an integrated 79GHz radar system on one transceiver chip, in 28nm CMOS. The chip runs on a mere 260 milliwatt. It features a depth resolution on 7,5cm.

This is an important milestone on the path to complete systems-on-chip with integrated antennas that can be built invisibly into all types of objects that make the environment smarter."

Advantage	Why?
Improved range resolution	No need for highly linear, broadband PLL sweep
Improved angular resolution	Code –domain MIMO possible
High range – Doppller resolution	Sharp ambiguity function
High interference robustness	Orthogonality of codes
Better situation awareness	Data from different cars can be combined
Enables V2V communication	Transmitter supports BPSK modulation
Low –power tracking possible	No FFT required for ranging
Easier market entry	Limited IP and patents
Low-cost, low-power ADC possible	Lower resolution than FMCW

Fig 4: Advantages of a phase modulated continuous wave (PMCW) radar compared with a frequency modulated continuous wave (FMCW) radar.

Critical challenges in gas supply to advanced semiconductor manufacturing fabs

Shrinking device geometries challenge manufacturers to more precisely manage gases and other critical materials. Dr. Anish Tolia, Ph.D., Head of Global Marketing, Linde Electronics, explains why scale, quality, supply chain, and sustainability should dominate production planning.

RAPID CHANGES in the technical and business environment of semiconductor manufacturing have intensified challenges throughout the supply chain. Semiconductor manufacturers are pushing the limits of physics and driving a constant need for new materials. Semiconductor companies and materials suppliers must formulate mutually profitable models for developing new products to achieve continued success.

At the same time, process control and purity demands are reaching unprecedented levels due to increasing complexity of the processes and related yield challenges. Tighter production process control and advanced metrology solutions (aka 'fingerprinting') are key to addressing these issues.

On the business side, industry consolidation continues and fewer customers are building ever larger fabs, which presents materials delivery and environmental challenges. The materials supply chain is increasingly globalized; managing risk and delivering uninterrupted product is critical. Larger scale and more on-site gas generation and delivery schemes are cogent approaches to solve the problems.

Finally, as the global semiconductor industry grows, environmental concerns and limited natural resources, which include rare gases like helium, krypton, and neon become an area of increasing focus. Innovative solutions like materials recycling can be a useful tool in reducing environmental impact.

This article explores the four key factors in gas supply to advanced semiconductor manufacturing fabs – Scale, Quality, Supply Chain, and Sustainability – as well as the drivers and solutions for each factor.

SCALE - Larger fabs + more complex and smaller devices = more gases

Consumers want ever more technologically sophisticated smartphones, tablets, smart watches and other wearables, not to mention automotive, household, and medical electronics. Semiconductor companies are increasing capacity to meet this demand – a 10 percent integrated circuits upsurge worldwide in 2014.

This increase has also predicated a move from MiniFabs (monthly production of 10-30,000 wafers) to MegaFabs (30-80,000 wafers a month) to now GigaFabs (80-100,000 wafers a month). A typical logic foundry is now at 80,000 WSPM (wafer starts per month); a typical memory fab now exceeds 120,000 WSPM. Additionally, many large fabs are now concentrated in clusters (science parks).

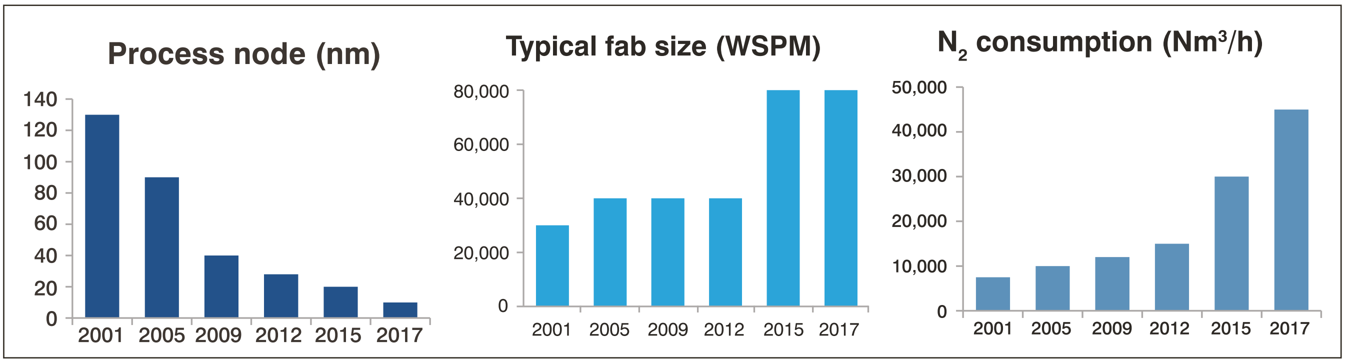
The highly competitive mobile devices market is forcing fabs to ramp to higher volumes faster than ever before. Additionally, development costs for new technology can exceed $2B (USD). In such an environment, economies of scale are essential for profitable operation.

In order to meet the demand and technological challenges, a larger volume and variety of gases is needed. These gases are used in multiple process steps such as etching/cleaning, deposition, doping, purging, and lithography/patterning in the manufacture of semiconductors.

Not only is the increased size of fabs contributing to the need for more gases, the move from single patterning to multi-patterning requires more gases for the production of each wafer.

As feature sizes are driven downward, new challenges emerge in maintaining the cost and performance gains. Until about 2006 at the 65 nm node, gains were obtained by shrinking physical devices using direct optical lithography. After that, more benefits were derived by introducing new materials into the process; for example, germanium in the transistor. By 20 nm, the minimal feature size became smaller than the wavelength of light and necessitated workarounds like multi-patterning to overcome physical limitations. All these factors have increased the consumption of gases per wafer.

Because of the need for low power and high performance, which 2D devices cannot handle, the industry is moving to 3D devices, which increases circuit density. This move to 3D FinFET and 3D NAND and the corresponding move to



increased transistor processing – epitaxy, etch, and ALD (atomic layer deposition) – drive the need for new and increased materials to construct more complex devices.

The gas most consumed in the production of electronics is nitrogen (N_2). Nitrogen is used for purging vacuum pumps, in abatement systems, and as a process gas. As process nodes have been driven down and the typical fab size has increased, nitrogen consumption has grown substantially. In large advanced fabs, there can be as much as 50,000 cubic meters per hour of nitrogen consumed, which compounds the need for cost-effective, low-energy, on-site nitrogen generators.

Another electronics manufacturing gas that is seeing an increase due to larger fabs and increased capacity is hydrogen. Hydrogen is utilized during epitaxial deposition of silicon (Si) and silicon germanium (SiGe), as well as for surface preparation. Significant volumes of hydrogen are also anticipated to be used in extreme ultra violet (EUV) in the future as 450mm wafers enter production streams. Hydrogen can be delivered economically as compressed gaseous hydrogen (CGH_2) or liquid hydrogen (LH_2) for smaller amounts and distances. However, due to the growing need for hydrogen, more fabs are now demanding on-site production through steam reforming or electrolysis. There is also an upswing in the need for rare gases such as neon, krypton, xenon, argon, and helium. This increased usage of gases that are not as readily available as nitrogen has driven sporadic temporary worldwide shortages, particularly helium and neon. Rare gases are also used for wafer cooling (helium), as source gases in lasers (neon), and as sputtering gases (argon and krypton).

So what are the critical challenges for fabs when the volume and type of gases multiplies due to added processes and more complex technology?

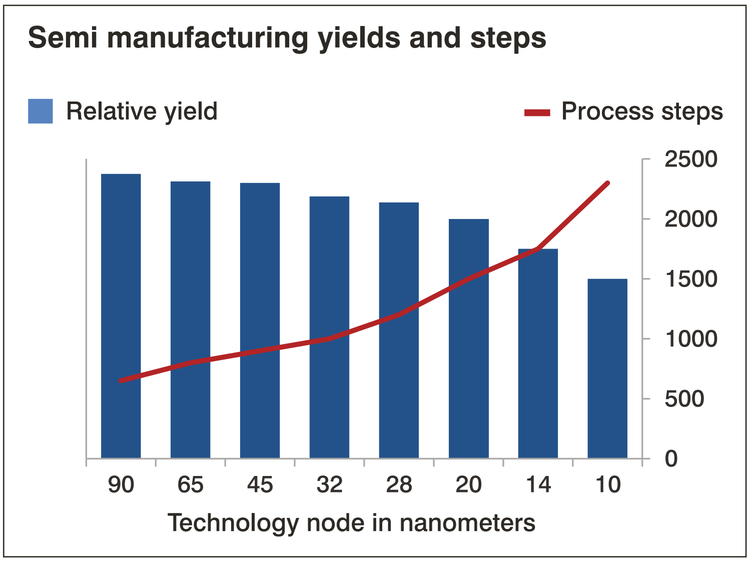
QUALITY - Changing needs due to complex technology

The first consideration for fabs is maintaining quality. Typically as the technology node gets smaller, the number of processes goes up and yield potentially goes down with each added process step. Manufacturers are diligently trying to overcome limits to stay on track with Moore's Law; doing so requires more stringent controls.

Critical process steps in high-volume semiconductor device manufacturing at aggressive feature sizes require stringent control of variability. For a silicon wafer with 100 or more advanced logic chips, each with up to 4 billion transistors and billions of connections, it is critical to remember:

- Essentially all the transistors and connections have to work as intended on each chip.
- The process has to be repeatable from wafer to wafer while chip production proceeds at rates of up to 80,000 wafer starts or more per month through a fab.

Variation among transistors on a chip leads to poorer overall chip performance and must be minimized. Even trace contaminants – including those that are not specified on a standard Certificate of Analysis – can cause measurable shifts in semiconductor processes and affect chip performance in advanced devices. Given that process materials are a critical input in wafer processing, it is easy to see how the quality of electronic materials (EM) products becomes increasingly important for chip manufacturers at leading technology nodes.



Another important consideration is the challenge of the unknown: engineers don't know how a specific impurity might impact performance. This can lead to needing additional processes and controls, which can mean higher operational costs and more risk from higher investments. Any misstep along the way –

an impurity in a gas, for example, might interact in the process in unknown ways. Such a misstep can cost thousands or even millions of dollars per month.

Ensuring consistent product requires a holistic approach to quality. Instead of limiting responsibility to a quality department, it must be a priority that runs through the entire organization. As is seen in this wheel, a comprehensive quality strategy cuts across all functions that touch a product.

To meet the demands for rigorous quality control, organizations may need to hire materials scientists, chemists, and process engineers and change the culture of their organization so that every department has a strategy and plan that contributes to the overall quality vision.

Process stability across the supply chain is made possible through SPC (Statistical Process Control), SQC (Statistical Quality Control), MSA (Measurement System Analysis), and BCP (Business Continuity Planning) systems. Fingerprinting furnishes the means for rigorous measurement, reducing variability, and tightening controls. Gas purity, consistency, and reliability are then delivered as an integral part of the final product.

SUPPLY CHAIN – Drivers reflect complexity

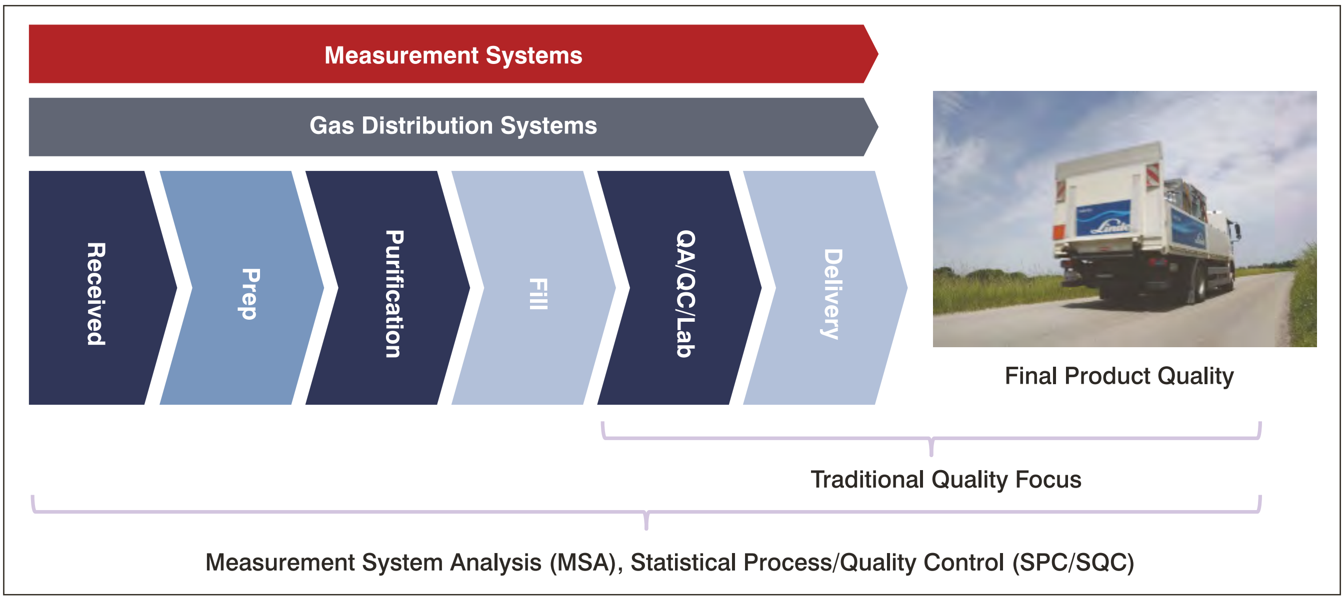
The increased demand and complexity of gases used in electronics manufacturing not only impacts quality, but also the supply chain. Many external factors can affect the supply chain including transportation or labor strikes and natural disasters. For example, after a magnitude 9.0 earthquake and subsequent tsunami hit Japan on March 11, 2011, all shipments coming in and out of Japan had to be checked for radiation.

A change in government regulations can also affect the supply chain, with an example being the 2008 Olympics. During the Beijing Summer Games, the Chinese government blocked hazardous materials from coming into multiple ports, including chemicals such as sulfuric acid, which is used in semiconductor manufacturing. Materials had to be trucked in, which required a lot of extra planning and two months extra time to deliver.

Limited raw material suppliers can impact availability for manufacturers. In order to secure supply, there is a move toward local and regional suppliers. Semiconductor manufacturers must partner with electronic materials suppliers and allow visibility into ramp demand of materials for new technologies and to do capacity planning so that together they can determine usage volumes for specialty gases.

To successfully maneuver all the complexities and potential pitfalls, it is crucial to cultivate an interlinked, comprehensive, customer-focused supply chain. Manufacturers can address these issues through Business Continuity Planning (BCP). They can start by assessing where and how to invest to diversify their supply chain on multiple continents. This includes doing procurement forecasting and planning with customers and suppliers to meet demand and identifying potential supply gaps by plotting product-source mapping.

It is essential to have at least two sources for raw materials and to have customers qualify both sources. Fabs should create raw materials, manufacturing, transportation, and labor shortage contingency plans and develop supply gap mitigation and implementation plans. Bringing materials closer to customers through localization and on-site plants cuts down on logistics complications and makes materials more readily available. It is essential to coach suppliers along






Water	Electricity	Natural Gas	Greenhouse Gases
10 cubic meters used per wafer at 14 nm node x 80,000 wafers per month x 12 months = **9,600,000 cubic meters** of water used per year (enough for 39,506 people in U.S.)	1220 kilowatt per hour used per wafer at 14 nm node x 80,000 wafers per month x 12 months = **1,152,000,000 kilowatt –** hours or 1,152,000 megawatt – hours electricity used per year (enough for 94,846 people) in U.S.)	61 cubic meters used per wafer at 14 nm node x 80,000 wafers per month x 12 months = **58,560,000 cubic meters** of natural gas used per year (enough for 26,899 people in U.S.)	8 greenhouse gases used, which if unabated, are the equivalent of 4.2 tons of CO_2 per wafer. After 90% abatement at 14 nm node x 80,000 wafers per month x 12 months = **400,000 tons CO_2** equivalents used per year

the whole chain on Statistical Quality Control (SQC), Statistical Process Control (SPC), and customer requirements to show them why and how things that they do can help customers avert disaster at multiple points in the supply chain.

SUSTAINABILITY – Reduce environmental impact

With complex supply chains, a scarcity of key materials, increasing environmental focus, and the need to reduce operating costs, the ability to ensure a secure and reliable supply of materials is intrinsic to staying competitive.

Fabs face several obstacles to being leaders in environmentally sustainable manufacturing, which is being mandated by an increasing environmental focus and concerns of customers as well as heightened governmental regulations. Semiconductor manufacturing is a highly complex energy and resource intensive process. Consequently, fabs are huge users of resources. Electronics manufacturing plants are not always located in the optimum position for materials deliveries, making it vital to think about how materials could potentially be recovered, purified, and re-used on-site, saving shipping costs, reducing logistical risks, and decreasing carbon footprints.

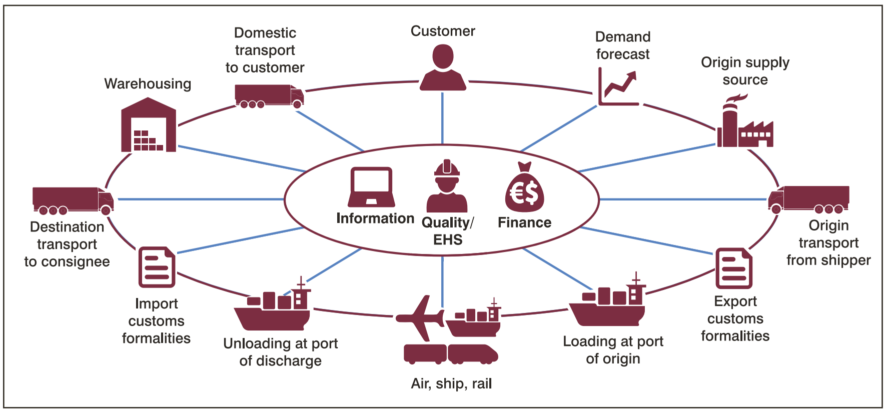
Materials such as helium and argon can be recovered on-site, purified, and returned for re-use in the manufacturing process. Materials such as sulfuric acid can be recovered on-site and be made available for use in other applications. And high-cost materials such as xenon can be recovered, shipped off-site, purified at an external facility, and then made available for reuse.

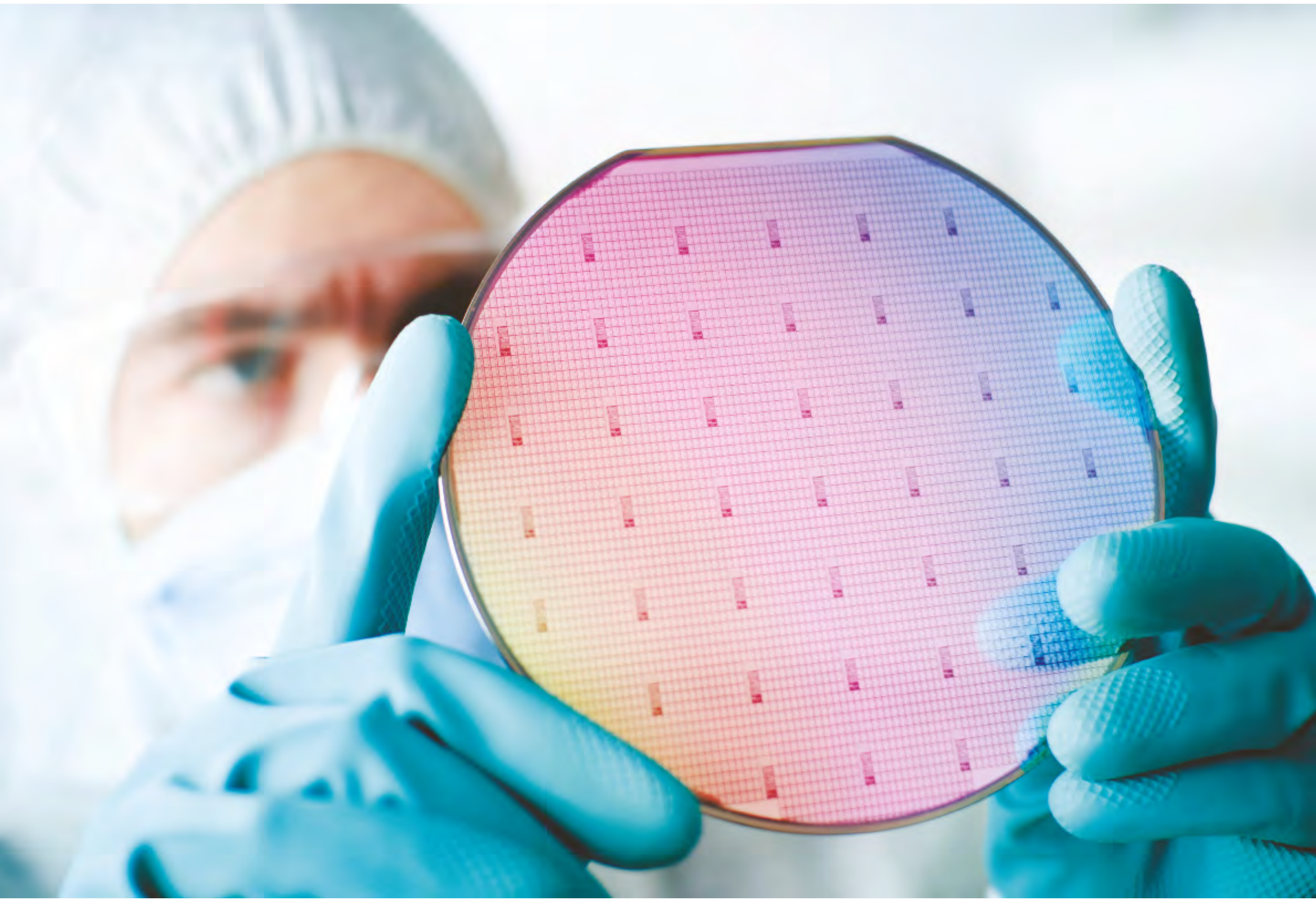
An industry success story illustrates how it is possible to eliminate tens of millions of tons of carbon dioxide (CO_2) emission equivalents per year through the use of fluorine (F_2), with zero GWP (global warming potential), in place of nitrogen trifluoride (NF_3), with a GWP of 17,200 and sulfur hexafluoride (SF_6) with a GWP of 22,800. This case involves a major memory fab, which uses on-site fluorine plants as a safer and more cost-effective alternative to cylinder fluorine for cleaning Chemical Vapor Deposition (CVD) chambers in its manufacturing process. It also uses fluorine to replace other fluorinated cleaning gases such as NF_3 following tests that demonstrated up to 40 percent reductions in cleaning time and a 35 percent decrease in the mass of gas used.

Conclusion

So what are the implications for manufacturers of the following four key factors in gas supply: Scale, Quality, Supply Chain, and Sustainability? They must proactively plan around both short and long-term needs. This requires longer term planning to include CAPEX investments and building on-site gas production and recovery when justified by size and growth expectations.

It is imperative that fabs do long-term planning in partnership with suppliers who commit to their needs – suppliers who value and implement process control and measurement and provide security and diversity of supply. It is only through this type of partnership that mutual needs can be truly understood and that the ever-evolving demands of consumers and the needs of manufacturers can be continually met.





Managing change can maximize profits

Silicon Semiconductor's Mark Andrews explores manufacturing execution system (MES) applications including Siemens PLM Software's highly capable Camstar Semiconductor Suite. This Siemens MOM product enables control, visibility and continuous improvement across all levels of semiconductor manufacturing.

ARE YOU losing business to competitors?

The answer may be 'yes' if your company's MES is more than seven years old. A new MES can enable rapid change without compromising quality – decisive advantages in today's global markets.

The semiconductor industry is experiencing solid growth. According to Gartner Research, worldwide semiconductor sales are expected to grow 5.4 percent in 2015, reaching $358 billion. [http://www.gartner.com/newsroom/id/2962117] Researchers say this growth will be driven by automotive, communications and smart consumer products.

Traditional innovation cycles for new products are accelerating rapidly at the same time customers are more price-sensitive and demand faster results with higher quality. To compete, semiconductor manufacturers must be highly capable, responsive and also ready to deliver innovative, complex products consistently, at high quality and at high volume.

The ability to innovate, at an accelerated pace, is the most important capability that distinguishes successful companies from their competitors. More than ever before semiconductor companies must stay ahead of the technology curve to deliver to their customer's expectations. One pathway for achieving objectives is the elimination of obstacles that can keep even the best companies from succeeding. While everything from business development to warranty work plays a role, companies that update and maximize the effectiveness of their manufacturing execution system (MES) have key advantages over competitors that are 'getting by' with systems that are outdated, and inefficient.

Current state

After the global recession that started in 2008, semiconductor companies resumed measured growth and today are recognizing they need to replace legacy MES applications because old systems lack the flexibility needed for today's products. Semiconductor manufacturing consists of hundreds of detailed and delicate process-ordinated steps distributed across multiple, physically separated locations. Mistakes could cost a manufacturer hundreds of thousands of dollars in lost revenue due to scrap lots and production delays.

Harold Caldwell, IT Director for Global Manufacturing Systems at Fairchild Semiconductor said in MES for Processes that Evolve at the Speed of Business, by Iyno Advisors, "[The old system] was challenged to quickly meet the evolving needs of our users in Manufacturing, Engineering, Quality, Supply Chain, Finance and other groups."

Many semiconductor companies find their biggest MES problem is continued reliance on disparate manufacturing systems for frontend and backend operations. This 'system disconnect' creates multiple problems with process flow, traceability and time-to-market performance.

Manufacturers need increased global visibility into manufacturing operations and higher quality of interactions to adapt their processes faster and respond effectively to rapid changes. In order to ensure they can meet these high quality expectations in diverse markets with less effort and less cost, manufacturers must seize the opportunity to change and adapt that presents itself now that growth is occurring more evenly across global markets.

Leading semiconductor manufacturers are embracing the change and investing in one (unified) global manufacturing enterprise system that is capable of managing end-to-end processes from wafer to finished goods. Semiconductor manufacturers with multiple sites, varying manufacturing environments and a global customer base who have invested in modern MES technology are no longer hindered by islands of automation and disjointed systems; they can now innovate, adapt and succeed.

What to look for in a modern, global MES

Semiconductor companies that want to modernize with a single solution designed for frontend and backend operations should look for critical features when selecting a global MES platform. A solution must include out-of the-box industry functionality; it needs to offer the highest level of configurability and complete interoperability with other business systems. It is necessary to provide instant intelligence ranging from test results and yields to statistical

Recommended Features Include:

Manage Complex Processes	Track complex processes that include bins, rework, and lot splits with full traceability – even when processing requires many-to-many relationship between lots and equipment without splitting.
Complete Traceability	All manufactured lots, wafers and serialized units should be traceable by the system, spanning production across Fab, Probe, Assembly, Test and Packaging operations. Provides unprecedented visibility and control over production processes. Data can be collected by lot, wafer, serial number, as well as in combinations of these categories.
Integrated Equipment Maintenance Management	Supports proactive problem resolution and optimal equipment scheduling for both primary and sub tools.
Control Flexible Preventative Maintenance	Provides overriding and cascading preventive maintenance E.g. Monthly PM overrides weekly maintenance.
Change Management	Quickly accommodate high volumes of manufacturing changes. This feature is a game changer for manufacturers of complex products who must orchestrate changes across multiple global sites.
Advanced Planning and Scheduling Capabilities	Flexible data model and scheduling logic can be configured to meet the needs from small to large corporations. Fields and data tables can be added or changed. Unique sequencing rules can be installed for tight integration with other systems across multiple sites.
Statistical Process Control (SPC)	Defect data that is collected during the manufacturing process allows manufacturers to identify, analyze and solve potential problems while production continues before equipment is shut down, material is scrapped and production time is lost.
Process Automation Control	Integrates multiple pieces of equipment within the factory infrastructure into the MES, providing fully automated control, status monitoring, material tracking and data collection.
Equipment Automation	Detailed resource tracking supports the Semiconductor Equipment Materials Initiative (SEMI E10).
Workflow Modeling	Employs drag-and-drop tools in user interfaces, making it easy to set up dynamic routings, add new steps, vary production requirements and make customer order changes, all with revision control and an audit trail.
Dispatch Management	Shows operators the work-in-process priorities prescribed by production planners and schedulers. It eliminates guess-work by instructing the operator to work on appropriate units first. It improves manufacturing efficiency by enforcing the dispatching rules.
Automatic Certification Verification	Ensures that only qualified employees perform prescribed shop floor functions. Operators use simple forms to view instructions and record data and events.
Automatic Quality Detection	Control of parametric data results combined with structured data, reporting and analysis tools make it possible to solve problems quickly, which easily prevents recurrences.
Automatic Quality Control	Enables Automatic Future Hold and/or nonconformance report generation based on specific loss codes, SPC fail or yield limit fails.
Nonconformance Management	Enforces structured failure analysis, root cause identification, quarantine and final disposition, and prevents product shipment or processing beyond a prescribed step until all issues are resolved.
Event Management	Monitors the enterprise and identifies quality incidents, enables the necessary investigation and enforces quality processes.

Recommended Features Include (continued):	
Label Printing	Automatically prints product labels from actual specification and manufacturing data, ensuring that labels are accurate, produced in a timely manner and are attached to the proper lot, wafer or unit.
Multiple Interface Languages	The ability to change your interface language preference per site.
Wafermap Visualization	Be able to indicate rejects on a picture of a product by reason and 'x/y' position. This includes building the picture dynamically from data in the system (wafer map) or using an existing picture. View / edit existing scrap.
Pilot Wafer Tracking	Mother lot waits for wafers to reach step 'x' and makes certain it has passed requirements 'y' before being allowed to proceed. If pilot wafers rejoin mother lot then they should not require processing at steps they have already successfully passed.
Experiment Management	Be able to override standard workflows for engineering and R&D lots

quality control. Further, its ability to integrate with automated equipment and cell controllers improves quality and productivity. Any new MES application for semiconductor manufacturers should include the capability to evolve as markets change. Look for Manufacturing Operations Management (MOM) packages that integrate with the MES and add useful quality and production flow management capabilities as well as advanced planning and scheduling.

Change management is another key consideration. Semiconductor companies make literally hundreds of product and process changes per week. With a single, modern enterprise platform architecture, companies can support change management by centrally authoring manufacturing process changes once and smoothly deploy them globally to one site or many. This ability saves time and increases collaboration and consistency across an entire enterprise.

Reducing risks when upgrading a MES

In a highly complex semiconductor manufacturing environment, it is essential to have a migration plan in place in order to track and verify the transfer of data from the legacy systems to the new application – without production downtime. The MES vendor should supply tools that enable operating parallel systems during migration.

Recommendations

The essential infrastructure in this new landscape of rapid change across a global plant network requires high agility while maintaining control, and deep intelligence to constantly improve.
It is necessary to research MES options. Start by identifying seasoned vendors who have experience working with the semiconductor industry. Make sure the vendor has 'reference-able' customers. In some cases, you can coordinate an on-site visit to see the vendor's system implemented at another location in a non-competitive field.

Benefits

One of the biggest benefits found in a modern MES is the ability to easily integrate with core business systems and shop floor equipment, enabling standardization on a single solution for true global operations. The new enterprise infrastructure must support 6 key functions:

Standardize: Establish a unified platform enabling centrally authored manufacturing process master data, with guidelines for local variation.

Connect: Establish a common communication foundation on which to operate seamlessly as a global virtual factory.

Control: Manufacture products as designed, with variations captured that detects and rapidly contains defects.

Continuous Process Improvement: Support an international global continuous process improvement network. When improvements are made, the approved change is made in one place, and synchronized across the global plant network.

Simplify: Create an intuitive system that's easy to use, which increases adoption across all levels and backgrounds of users, and fosters collaboration.

Accelerate: Leverage all aspects of the new platform to accelerate the delivery of quality products to market and relentlessly improve them.

A global manufacturing enterprise platform offers many new opportunities and overcomes the costs, limitations, and risks of a legacy MES, which is frequently bolted to multiple homegrown and siloed systems. One system for all operations enables streamlined, lean operations and reporting across entire processes.

A new system ensures that no data is lost between fab and backend operations. Time to market is decreased and lower cost of ownership occurs with one global system. Transformed semiconductor manufacturers utilizing their new MES can rapidly implement a manufacturing execution system platform for maximum ROI. Flexible and powerful manufacturing systems make it possible for multiple sites to connect on a global scale. Companies using a modern MES paired with an effective MOM can be market leaders, raising the bar. Their MES-based efficiencies will help them to surpass customer demands and innovate into the fast future.

Annie Mullen of Siemens PLM Software contributed to this article.

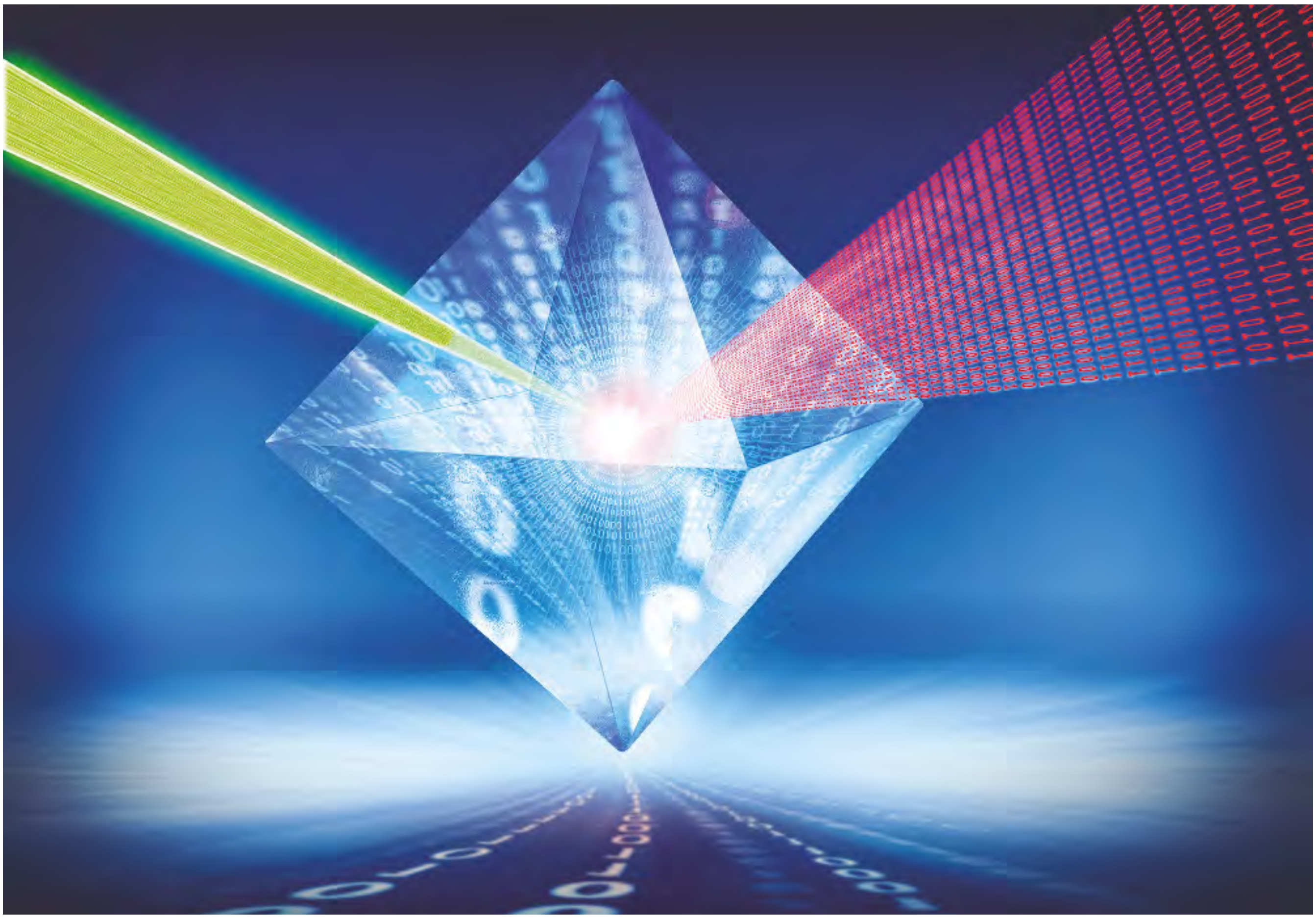
Inching closer to Quantum computing

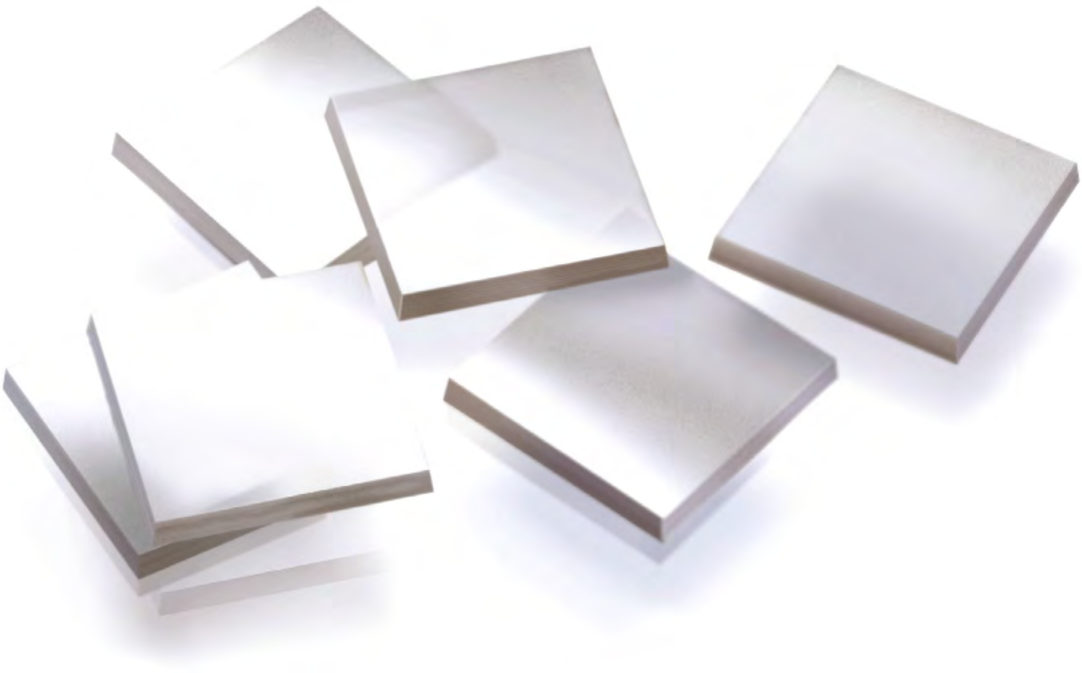
While creating practical quantum computing remains a stretch goal, recent achievements at MIT and UC Santa Barbara show that beating Moore's Law may be in the cards after all.

RESEARCHERS AND MANUFACTURERS continue to strive towards resolving conundrums around Moore's Law and its observation that transistors and device technologies critical to practical logic circuits will reduce in size and increase in power at predictable rates. Moving from 14nm to 10nm and beyond carry heavy baggage as processing steps become increasingly complex and costly. Research into quantum computing offers tantalizing possibilities to sidestep today's approaches to reduce transistor size and increase performance.

Quantum theory moves one's perspective into realms where structures can simultaneously occupy different spaces and represent both a zero and a one. These 'superpositions' are the foundation of quantum-based product concepts a fraction the size of today's smallest logic circuits.

Quantum computing has remained out of reach for a number of reasons because quantum bits ('qubits') have remained





unstable; encoded information held its state for miniscule fractions of a second. It was also not possible to stabilize positions of qubits and predict how they might interact in entangled states and correct for errors the way conventional computers 'self-check' their operations.

Research has pursued a number of fundamental process advances to enable qubits to retain encoded information when placed in an entangled state in which they are physically separate yet act as if they are connected.

Recent advances on university campuses, the Brookhaven National Laboratory, Google and in materials fabrication by Element Six have contributed to solving key challenges.

The University of California at Santa Barbara in conjunction with Google reported in March that they created an error-correction system that stabilized a fragile array of nine qubits. They reported creating circuits in which non-computational qubits were used to observe the status of computing qubits without altering their state.

A month earlier researchers at the Massachusetts Institute of Technology and Brookhaven National Laboratory utilized extremely refined synthetic diamond from Element Six to create more stable qubits.

These qubits have exceedingly long-lived quantum coherence compared to other materials even when observed at room temperature, an important quality if quantum computers are to become practical.

Silicon Semiconductor spoke with MIT lead researcher Professor Dirk Englund to explore the ramifications of his team's work and how the nano-engineered synthetic diamond created by DeBeers' Element Six aided in extending the 'lifetime' of qubits.

Silicon Semiconductor put a few questions to Professor Dirk Englund, MIT:

Q Now that synthetic diamond is enabling much longer quantum coherence, what does the research team believe are other key steps that need to be achieved to advance the process?

A

So far, we have only shown one part of a much larger system: a stationary quantum memory positioned in a device (the cavity) that allows for efficient interfacing to photons. You can think of this by analogy as one bit of memory in a classical computer connected to a wire that can carry current. Next, the challenge is to devise ways of fabricating not one, but hundreds of such cavity-enhanced quantum memories that are all nearly identical.

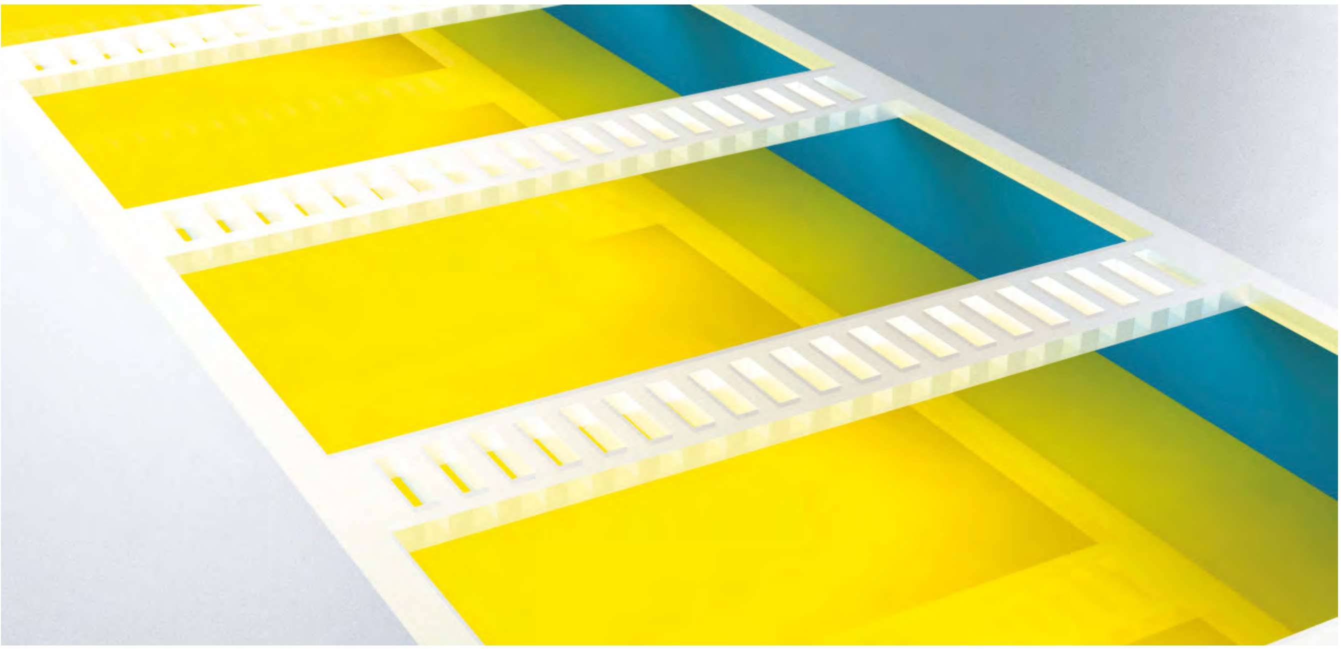
Luckily, we really only need hundreds, and not millions or billions of transistors that are in (today's) classical computer chips. That's because of the superposition principle of quantum mechanics – even one hundred quantum bits (qubits) can simultaneously represent 2^100 states of the machine. So although each of these machines is much smaller than a classical computer, one could exploit a huge parallelism to do useful things with a very small number (compared to classical computers) of quantum bits.

Q Any estimate as to when we can say practical quantum computing may be within reach?

A

There are many types of computers under construction. Probably within the next five years or so, there will be quantum systems that can be precisely measured in the lab, but that can't be simulated by classical computers. This is the idea of a quantum simulator, which maps the quantum physics problem of an unknown—and very hard to simulate – system onto a well-controlled quantum system in the laboratory.

Another flavor of quantum computers is analog quantum computers that use simulated annealing—while it's not yet totally clear how well this approach can scale, it could do some classically hard computations in the next decade or so. Beyond that, a full digital quantum computer with error correction, will probably take somewhat longer.



Q What are perhaps some of the more near-term possibilities of using quantum properties? For example, could they be utilized to advance communications by acting as network repeaters?

A Small quantum systems like the NV (nitrogen-vacancy centers) in diamond could enable repeater stations of quantum communication. This opens the prospect of exciting new applications, such as provably secure communications over long distance – a kind of ultra-secure quantum internet.

This kind of internet could also enable other applications, such as teleportation of quantum states over long distances, or precision sensors.

Even ultra-stable clocks were recently proposed to be run over such networks, which could allow for better GPS for example. All of these networking applications require quantum repeaters, and the NV-cavity system, like the one we demonstrated with Element Six, is a promising candidate for them.

Q What other materials have been tried?

A Many other materials have been tried, but diamond is very unique in the exceptional purity that's possible. Among optically addressable quantum memories, diamond may well be the material with the best intrinsic qualities.

Q How has diamond proved superior to these other materials?

A

Diamond has a very high bandgap, very high purity and nuclei (carbon 12) that have no net magnetic momentum – i.e., the crystal is very magnetically "quiet." In addition, the material has good phonon properties, high thermal conductivity, etc. Synthetic diamond is an ideal host material for such atom-like qubits. Element Six has led the way in producing high-purity synthetic diamond that has made this advance possible for our team.

Q The role of the synthetic diamond seems critical in this latest advancement. How was Element Six chosen to participate in the research project?

A

Element Six is really exceptional. The company produces diamond of exceedingly high quality in which the defects are so sparse that the nitrogen vacancy spin states – the quantum memory – are minimally perturbed by them. In addition, Element Six is unique in having a very strong research team that continues to push what's possible with diamond. So, they're a terrific partner for us.

> "Small quantum systems like the NV (nitrogen-vacancy centers) in diamond could enable repeater stations of quantum communication. This opens the prospect of exciting new applications, such as provably secure communications over long distance – a kind of ultra-secure quantum internet"

CD-SEM metrology challenges below 10nm

Semiconductor Technology Symposium (STS) sessions on lithography and transistor scaling on July 15 will be held in conjunction with the upcoming SEMICON West (July 14-16). These programs will focus on the challenges for high-volume manufacturing at advanced process nodes, including EUV, other lithography strategies, and new wafer processing approaches. Debra Vogler, SEMI explains.

TWO SPEAKERS from the Semiconductor Technology Symposium (STS) sessions, Benjamin Bunday (lithography session) and Ofer Adan (transistor scaling session), were interviewed by SEMI and discussed the need for innovation in CD-SEM metrology as the industry looks ahead from 10nm to 5nm. The lithography session will cover a broad range of issues, including CD-SEM.

CD-SEM: Not going away

"There is still a big need for imaging metrology in the fab that isn't going away," Benjamin Bunday, project manager, CD Metrology and senior member Technical Staff at SEMATECH, told SEMI. "For a long time, people were talking about scatterometry replacing CD-SEM — no way! They do different things." While scatterometry provides average profile and CD information, Bunday explained that an imaging tool is still needed to identify what's there and to measure roughness, variations, shapes, and the like, plus the qualitative information that only images provide.

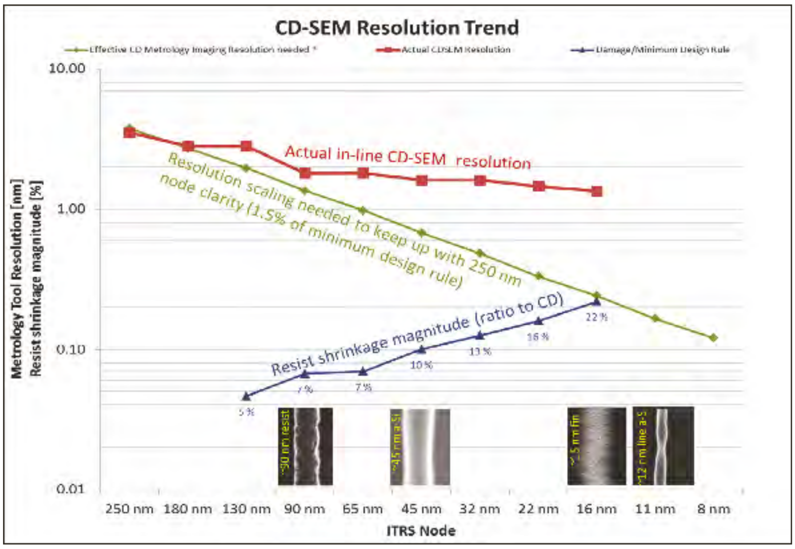
SEMATECH has been exploring what will be needed for CD-SEM tools going forward and issued a gaps analysis for CD metrology below the 22nm node. The consortium has looked at helium but found that it causes too much physical damage to the surface, and possibly even electrical damage, so that will not be useful in the inline, non-destructive CD metrology role. Bunday noted that while high-voltage SEM (HV-SEM) does improve resolution, in the past, it was found to cause local electrical damage to devices — an important consideration 10 years ago.

"Today, however, focused-ion beam (FIB) tools are being used to look at wafers in-line, and they do cause damage to wafers," commented Bunday. With that in mind, he believes that there might be a role for HV-SEM on sacrificial die or kerf features. "We may be at a point where it is more palatable to accept the damage that can occur with HV-SEM than it was 10 years ago. The industry needs to discuss this."

Bunday also addressed the CD-SEM resolution challenge facing the industry in the consortium's gaps analysis paper. "We need significantly improved resolution for the smallest features to reveal the key process details that are required for high-volume manufacturing," Bunday told SEMI. Figure 1 shows the CD-SEM imaging resolution trend with respect to device dimension scaling and the degree of photoresist shrinkage.

According to Bunday, the industry will need to address the meaning of the term "resolution," which, by itself doesn't accurately describe all of the other conditions that contribute to the production of a good image, including the size of

Figure 1. CD-SEM image resolution trend with respect to device dimension scaling and the degree of photoresist shrinkage. The effective resolution means not only resolution, but other competing effects like interaction volume, charging, etc. Note that there is no industry standard methodology for evaluating SEM resolution.



SOURCE: used with permission; Eric Solecky, IBM the probe, interaction volume, as well as material charging and other particle/solid interactions. "There is potential for significant improvement to the existing technology."

CD-SEM: Not stopping with top-down measurement

Ofer Adan, Global Product and Technology manager, Process Diagnostics and Control at Applied Materials, told SEMI that while many of the traditional CD-SEM tools, which measure features from the top down, can be used for about 60 percent of the new devices in 3D logic and memory, but pose problems when trying to measure the high-aspect ratio slits at 3D NAND or the height and sidewall of FinFETs. "If you want to image a FinFET, the gate is not only on top of the fin, but also on both sides of the fin," explained Adan. "So if you take a top down CD-SEM that you've had for 20 years, it uses an electron beam that goes down to the device and returns with a signal, but it cannot detect the dimensions of the sidewall."

These dimensions, which measure the vertical slope of the fin, are critical. Applied Materials recently addressed this challenge with a new CD-SEM tool for performing in-line metrology on 3D devices – both FinFETs and 3D NAND.

An important development in the drive to take CD-SEM measurements beyond the top-down only capability, is the use of tilted electron beam. In a recent SPIE publication, GLOBALFOUNDRIES and Applied Materials were able to show that the use of electronic tilt enabled excellent correlation between measurements obtained using both OCD and AFM tools when measuring FinFETs. "The measurements done using OCD in-scribe, which is the process of record for FinFETs, did not match those measurements taken in-die by CD-SEM using electronic tilt technology," said Adan (see Figure 2). "We are confident in the CD-SEM in-die measurements as they were correlated with those using an atomic force microscope (AFM)."
Even more interesting, according to Adan, is that measurements taken with OCD did not correlate with in-die measurements using the CD-SEM or the AFM. "That's a potential issue. The industry spends a lot of money on metrology and it does not always get a full return on its investment."

Register now for SEMICON West 2015. The Semiconductor Technology Symposium (STS) sessions on Lithography (July 15, 10:00am-12:30pm) will offer expert perspectives from Bunday plus speakers from ASML, Canon Nanotechnologies, CEA Leti, GLOBALFOUNDRIES, Nikon, and Photronics. The Transistor Scaling session offers viewpoints from Adan plus speakers from imec, Intermolecular, Lam Research, Mentor Graphics and Soitec.

Other SEMI exhibitions coming up include: SEMICON Russia 2015 (June 17-18), SEMICON Taiwan 2015 (September 2-4), SEMICON Europa 2015 (October 6-8), and SEMICON Japan 2015 (December 16-18).

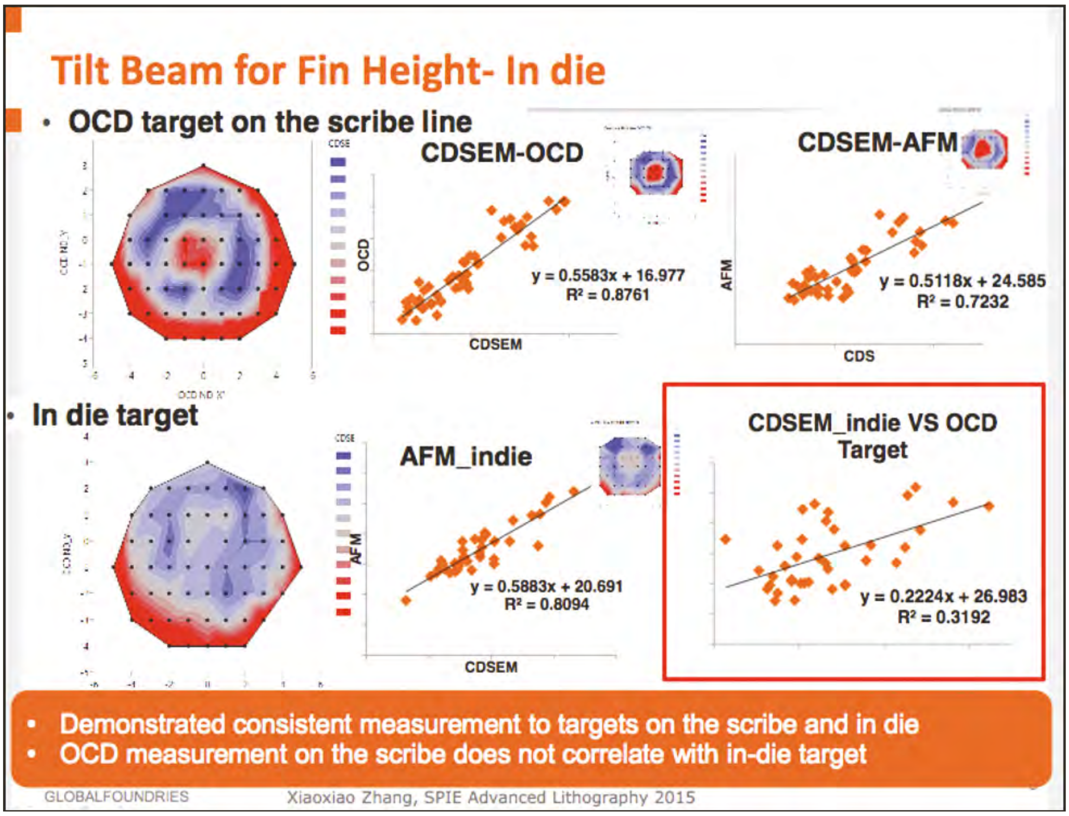


Figure 2. Tilt beam for fin height: in-die. SOURCE: Applied Materials. Paper presented at SPIE, "Solving next generation (1x node) metrology challenges using advanced CDSEM capabilities: tilt, high energy and backscatter imaging" by Zhang, Snow, Vaid, and Solecky (GLOBALFOUNDRIES Inc. U.S.); Zhou, Ge, and Yasharzade (Applied Materials, Inc. U.S.); and Shoval, Adan, Schwarzband, and Bar-Zvi (Applied Materials Israel).

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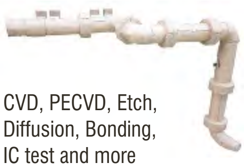

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