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Discovering the Potential Serial Innovators in Our Midst

BY SHANNON DAVIS

Melissa Schilling, PhD, New York University

Steve Jobs. Benjamin Franklin. Albert Einstein. Marie Curie. What do these world-changers all have in common? Where did their drive to innovate come from? Melissa Schilling, PhD, had to find out.

"Innovation and creativity has been a hot area of research for a long time, but we don't tend to study outliers and in part that's because there's methodological challenges with that," she explained to the audience during her keynote address on Tuesday at SEMICON West 2018.

So, the New York University professor created a multiple case study research project to tackle these questions, which are addressed at length in her latest book, "Quirky: The Remarkable Story of the Traits, Foibles, and Genius of Breakthrough Innovators Who Changed the World." Her book invites us into the lives of eight world-famous game-changers — Albert Einstein, Benjamin Franklin, Elon Musk, Dean Kamen, Nikola Tesla, Marie Curie, Thomas Edison, and Steve Jobs – and identifies the common traits and experiences that drove them to make spectacular break-

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DON'T MISS

10:30 am -12:30 pm
Digital Medicine and Remote Patient Monitoring
Moscone North, TechXPOT North

10:30 am - 12:30 pm
Materials & Packaging for Automotive
Meet the Experts Theater Moscone North, Smart Transportation Pavilion

10:30 am - 12:55 pm
Lithography at 5nm and Below
Moscone South, TechXPOT South

10:30 am - 12:30 pm
New Monitoring and Metrology Technologies, Wet and Dry
Meet the Experts Theater Moscone South, Smart Manufacturing Pavilion

1:30 pm - 4:00 pm
Connected Car to Connected World – The Road to Monetization
Meet the Experts Theater Moscone North, Smart Transportation Pavilion

2:00 pm - 4:00 pm
Data and AI: Ahead of the Curve — Applications Already Incorporating Big Data and AI
Moscone North, TechXPOT North

2:00pm to 4:00pm
Scaling Every Which Way!
Moscone South, TechXPOT South

Dr. John E. Kelly, III, Senior Vice President, Cognitive Solutions and IBM Research

AI and Quantum Computing: The Third and Fourth Exponentials

BY PETE SINGER

In a keynote talk on Tuesday in the Yerba Buena theater, Dr. John E. Kelly, III, Senior Vice President, Cognitive Solutions and IBM Research, talked about how the era of Artificial Intelligence (AI) was upon us, and how it will dramatically the world. "This is an era of computing which is at a scale that will dwarf the previous era, in ways that will change all of

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throughs, again and again. Schilling believed that once we understand what makes someone a serial innovator; we can also understand the breakthrough innovation potential in all of us.

The first common trait Schilling identified in her research was a sense of separateness – a discovery that she found remarkable.

"I thought most people would be super connected with lots of diverse connections," she said. "I was wrong about that. Every single person I studied, with the exception of Benjamin Franklin, had this...feeling of detachment."

Einstein, said Schilling, even went so far as to say he didn't need direct contact with individual humans, even his own family. Marie Curie and her husband eventually sent both of their daughters to be raised by their grandparents, so that they could devote more time to their research. Dean Kamen's feelings of separateness helped to shield him when his peers didn't believe it was possible to create a two-wheeled wheelchair (which we now know as the Segway).

What can we learn from this? "First thing we have to learn is that we need norms that permit people to be unorthodox," said Schilling. "We need to be able to embrace weirdness."

Schilling pushed back against the idea of brainstorming teams in the tech world, a practice she says has potential innovators stuck putting out ideas that are more likely to get consensus from the rest of their team. She instead suggested to allow employees to work alone first, to commit to an idea and elaborate on it before sharing it with a team.

"Brainstorming teams cause people to come to mediocre compromises," she said.

The second shared trait of serial innovators Schilling discussed was self-efficacy.

"Self-efficacy is that faith you have that you can overcome obstacles to achieve your goals and it makes you take on bigger projects," Schilling explained.

She pointed to Elon Musks' persistence in developing reusable rockets, in spite of NASA's claims that it couldn't be done, and Nikola Tesla's dream of harnessing the power of Niagara Falls to provide electricity, despite having only seen a picture of Niagara on a postcard when he was a child in Croatia.

"Encourage people to try even if they fail," she said, and warned against rescuing people who could benefit from learning things on their own.

The third trait Schilling outlined was one she said seven of the eight innovators possessed, which was having an intensely idealistic goal that mattered more to them than just about anything else.

"When you have an idealistic goal that people in your company can identify with, they're going to work harder, they're going to work longer, they're going to think bigger, and they're going to love it more," she said.

And while timing and luck often did play an undeniable role in many of the serial innovators lives, Schilling was most surprised to learn that access to capital didn't affect her research subjects' abilities to innovate.

"Every single one of these people... started out flat broke," she said. "They did not become innovators because they had access to capital."

What was more important, she said, was their access to other people who had resources.

"One of the most valuable things you can do is help connect people to the other people they need," she concluded.

AI and Quantum cont'd from p 1

our businesses and all of our industries, and all of our lives," he said. "This will be another 50, 60 or more years of technology breakthrough innovation that will change the world. This is the era that's going to power our semiconductor industry forward. The number of opportunities is enormous."

Kelly, with 40 years of experience in the industry, recalled how the first era of computing began with mechanical computers 100 years ago, and then transition into the programmable era of computing. In 1980, Kelly said "we were trying to stack two 16 kilobis DRAMs to get a 32 bit stack and we were trying to cram a thousand transistors into a microprocessor." Microprocessors today have 15 billion transistors. "It's been a heck of a ride," he said.

IBM's Summit is not only the biggest computer in the world, this is the smartest computer in the world, according to Kelly.

Kelly pointed to the power of exponentials, noting that Moore's Law represented the first exponential and Metcalf's Law — which says the value of the network increases as the square of the number of connected devices to the network — is the second exponential. Kelly said there's no end to this second potential, as devices such as medical connected devices and Internet of thing devices get connected.

A third exponential is now upon us, Kelly said. "The core of this exponential is that data is doubling every 12 to 18 months. In fact, in some industries like healthcare, data is doubling every six months," he said. The challenge is that the data is useless unless it can be analyzed. "Our computers are lousy in dealing with that large unstructured data and frankly there aren't enough programmers in the world to deal with that explosion of data and extract value," Kelly said. "The only way forward is through the use of machine learning and artificial intelligence

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New Regulations Coming for Nitrous Oxide

BY PETE SINGER

Nitrous oxide (N_2O) has a variety of uses in the semiconductor manufacturing industry. It is the oxygen source for chemical vapor deposition of silicon oxy-nitride (doped or undoped) or silicon dioxide, where it is used in conjunction with deposition gases such as silane. It's also used in diffusion (oxidation, nitridation, etc.), rapid thermal processing (RTP) and for chamber seasoning.

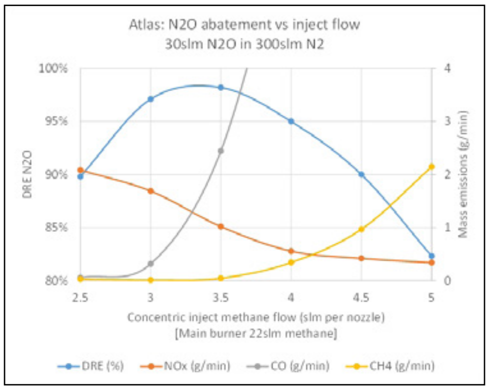
Why these uses — and more importantly what happens to the gas afterward — may soon becoming under more scrutiny because it is being included for the first time in the IPPC (Intergovernmental Panel on Climate Change) GHG (Greenhouse Gas) guidelines. The IPCC has refined guidelines released in 2006 and expect to have a new revision in 2019. "Refined guidelines are actually up and coming and the inclusion of nitrous oxide in them is a major revision from the 2006 document," said Mike Czerniak, Environmental Solutions Business development Manager, Edwards. Czerniak is on the IPPC committee and lead author of the semiconductor section.

Although the semiconductor industry uses a very small amount of N_2O compared to other applications (dentistry, whip cream, drag racing, scuba diving), it is a concern because after CO_2 and CH_4, N_2O is the 3rd most prevalent man-induced GHG, accounting for 7% of emissions. According to the U.S. Environmental Protection Agency, 5% of U.S. N_2O originates from industrial manufacturing, including semiconductor manufacturing.

Czerniak said the semiconductor industry been very proactive about trying to offset and reduce its carbon dioxide footprint. "The aspiration set by the world's semiconductor council to reduce the carbon footprint of a chip to 30 percent of what it was in 2010, which itself was a massive reduction of what it used to be back in the last millennium," he said. Unfortunately, although that trend had been going down for the first half of the decade, it started going up again in 2016. "although each individual processing step has a much lower carbon footprint than it used to have, the number of processing steps is much higher than they used to be," Czerniak explain. "In the 1990s, it might take 300-400 processing steps to make a chip. Nowadays you're looking at 2,000-4,000 steps."

There are two ways of abating N_20 so that it does not pollute the atmosphere: reduce it or oxidize it. Oxidizing it — which creates NO_2 and NO (and other oxides know as NOx) — is not the way to go, according to Czerniak. "These oxides have their own problems. NO_x is a gas that most countries are trying to reduce emissions of. It's usually found as a byproduct of fuel combustion, particularly in things like automobiles and it adds to things like acid rain," he said.

Edwards' view is that it's much better to



minimize the formation of the NO_x in the first place. "The good news is that it is possible inside a combustion abatement system where the gas comes in at the top, we burn a fuel gas and air on a combustor pad and basically the main reactant gas then is water vapor, which we use to remove the fluorine effluent, which is the one we normally try to get rid of from chamber cleans," Czerniak said.

The tricky part is that information from the tool is required. "We can — when there is nitrous oxide present on a signal from the processing tool — add additional methane fuel into the incoming gas specifically to act as a reducing agent to reduce the nitrous oxide to nitrogen and water vapor," he explained. "We inject it at just the right flow rate to effectively get rid of the nitrous oxide without forming the undesirable NO_x byproducts."

Figure 1 shows how careful control of combustion conditions make them reduce rather than oxidizing during the N_2O step by the addition of CH_4. 30 slm N_2O represents two typical process chambers.

"It's not complicated technology," Czerniak concluded. "You just have to do it right."

AI and Quantum cont'd from p 3

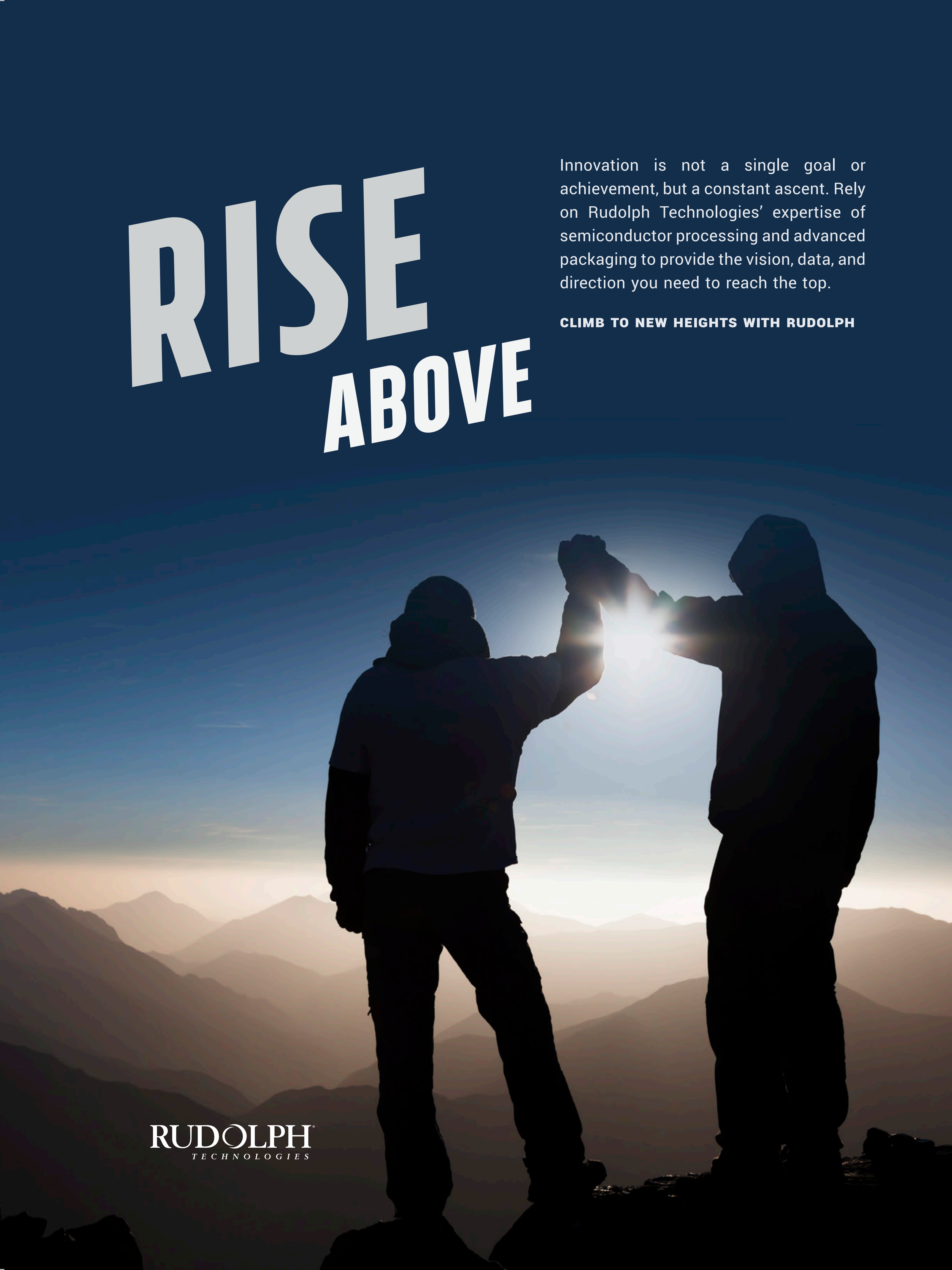
to extract insights from that data."

Kelly talked about IBM's history of AI – teaching early system 600 machines to play checkers, beating chess grandmaster Gary Kasparov with Deep Blue, Watson's Jeopardy wins and most recently, Watson Debater. That can "not only can answer questions but can listen to a person's argument on something, reason and counter-argue in full natural language against that position in a full dialogue, continuously."

What's changed? "We continue to make advances in artificial intelligence, machine learning and deep learning algorithms that are just stunning," Kelly said. "We are now able to learn over smaller and smaller amounts of data and translate that learning from one domain to another to another to another and start to get scale. Now is the time when this exponential is going to really explode."

How does that equate to opportunity? Kelly said that on top of the existing $1.5-2B information technology industry, there's another $2 trillion of decision support opportunity for artificial intelligence. "Literally every industry in the world, whether its industrial products, financial services, retail, every industry in the world is going to be impacted and transformed by this," he said.

Quantum computing, which Kelly describe as a fourth exponential, is also coming which will in turn dwarf all of the previous ones. "Beyond AI, this is going to be the most important thing I've ever seen in my career. Quantum computing is a complete game changer," he said.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China's Semi Capex Forecast to be Larger than Europe and Japan Combined in 2018

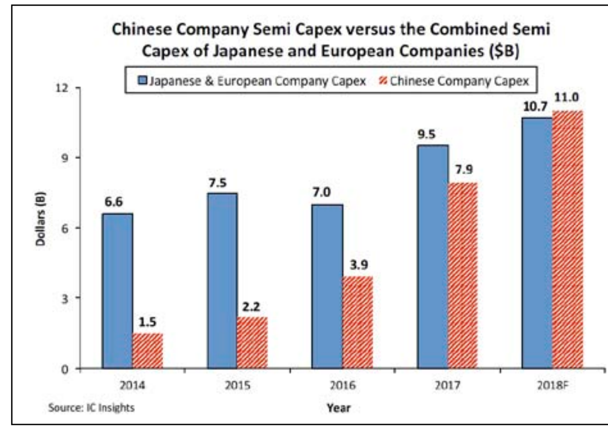
The Mid-Year Update to the 2018 McClean Report revises IC Insights' worldwide economic and IC industry forecasts through 2022 that were originally presented in The 2018 McClean Report issued in January.

The Figure shows that IC Insights forecasts that China-headquartered companies will spend $11.0 billion in semiconductor industry capex in 2018, which would represent 10.6% of the expected worldwide outlays of $103.5 billion. Not only would this amount be 5x what the Chinese companies spent only three years earlier in 2015, but it would also exceed the combined semiconductor industry capital spending of Japan-and Europe-headquartered companies this year.

Since adopting the fab-lite business model, the three major European producers have represented a very small share of total semiconductor industry capital expenditures and are forecast to account for only 4% of global spending in 2018 after representing 8% of worldwide capex in 2005. Although there may be an occasional spike in capital spending from European companies (e.g., the surge in spending from ST and AMS in 2017), IC Insights believes that Europe-headquartered companies will represent only 3% of worldwide semiconductor capital expenditures in 2022.

It should be noted that several Japanese semiconductor companies have also transitioned to a fab-lite business model (e.g., Renesas, Sony, etc.). With strong competition reducing the number and strength of Japanese semiconductor manufacturers, the loss of its vertically integrated businesses and thus missing out on supplying devices for several high-volume end-use applications, and its collective shift toward fab-lite business models, Japanese companies have greatly reduced their investment in new wafer fabs and equipment. In fact, Japanese companies are forecast to represent only 6% of total semiconductor industry capital expenditures in 2018, a big decline from the 22% share they held in 2005 and an even more precipitous drop from the 51% share they held in 1990.

Although China-headquartered pure-play foundry SMIC has been part of the list of major semiconductor industry capital spenders for quite some time, there are four additional Chinese companies that are forecast to become significant semiconductor industry spenders this year and next—memory suppliers XMC/YMTC, Innotron, JHICC, and pure-play foundry Shanghai Huali. Each of these companies is expected to spend a considerable amount of money equipping and ramping up their new fabs in 2018 and 2019.



Due to the increased spending by startup China-based memory manufacturers, IC Insights believes that the Asia-Pac/Others share of semiconductor industry capital spending will remain over 60% for at least the next couple of years.

KLA-Tencor Announces New Defect Inspection Systems

KLA-Tencor Corporation announced two new defect inspection products at Semicon West this week, addressing two key challenges in tool and process monitoring during silicon wafer and chip manufacturing at the leading-edge logic and memory nodes. The Voyager™ 1015 system offers new capability to inspect patterned wafers, including inspection in the lithography cell immediately after development of the photoresist, when the wafer can be reworked. The Surfscan SP7 system delivers unprecedented defect detection sensitivity on bare wafers, smooth and rough films—essential for manufacturing silicon substrates intended for the 7nm logic and advanced memory device nodes, and equally critical for earliest detection of process issues during chip manufacturing. Together the two new inspection systems are designed to accelerate time-to-market for innovative electronic devices by capturing defect excursions at their source.

"With leading IC technologies, wafer and chip manufacturers have very little room for error," said Oreste Donzella, Senior Vice President and Chief Marketing Officer at KLA-Tencor. "Critical dimensions of next-generation chips are so small that the minimum size of a yield-killing defect on bare silicon wafers or blanket-

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The Voyager™ 1015 system

The Surfscan SP7 system

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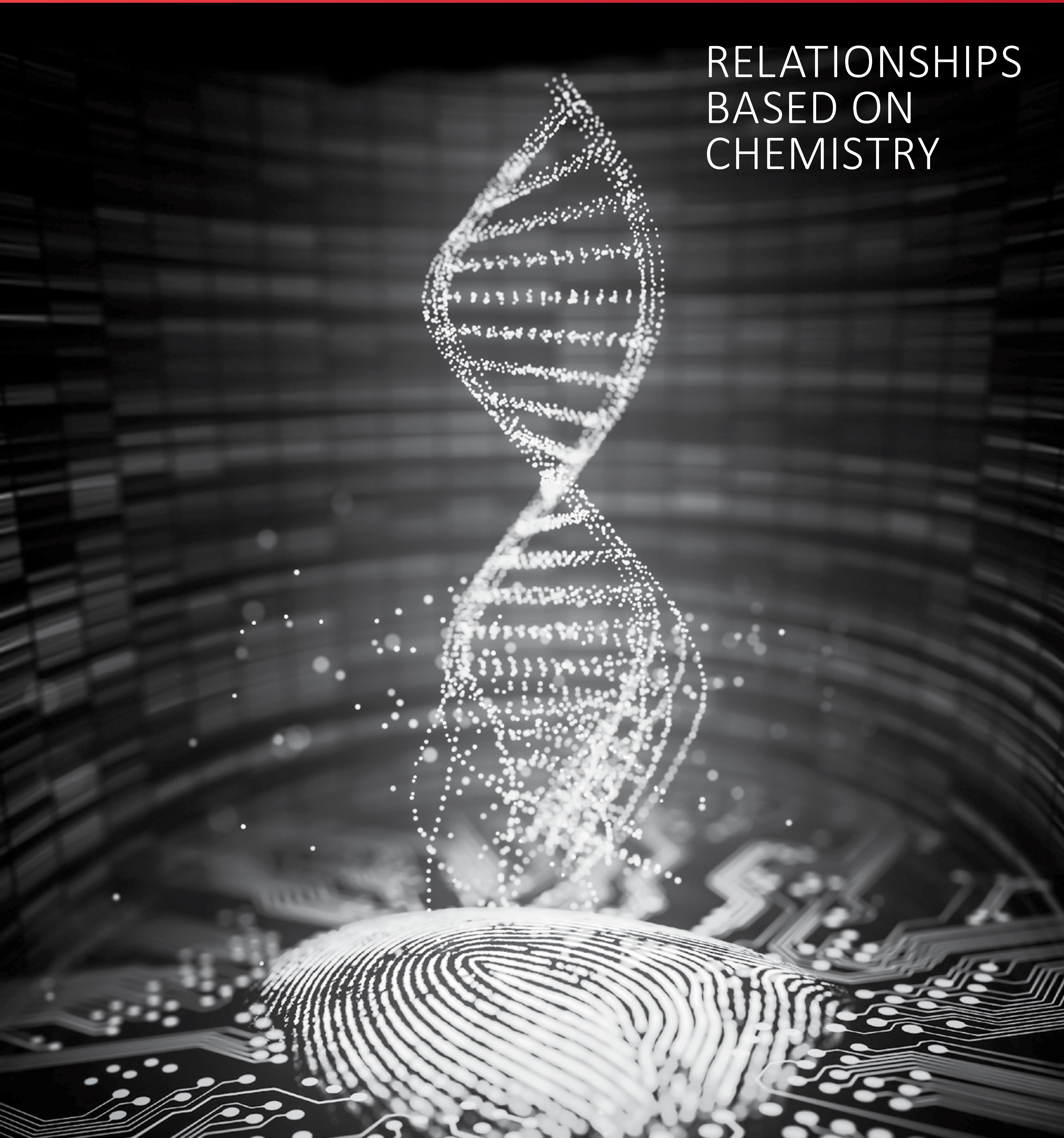
RELATIONSHIPS BASED ON CHEMISTRY



New Laser-Based Sample Prep Solution

3D-Micromac AG (booth #1645 in the South Hall) this week introduced the microPREP 2.0 laser ablation system for high-volume sample preparation of metals, semiconductors, ceramics and compound materials for microstructure diagnostics and failure analysis (FA).

Built on a highly flexible platform with a small table-top footprint, the microPREP 2.0 allows for easy integration into FA workflows. Developed jointly with Fraunhofer Institute for Microstructure of Materials and Systems (IMWS), the microPREP 2.0 complements existing approaches to sample preparation such as focused ion beam (FIB) micromachining, offering up to 10,000 times higher ablation rates and therefore an order of magnitude lower cost of ownership (CoO) compared to FIB. As the first stand-alone, ultrashort pulsed laser-based tool for sample preparation, the microPREP 2.0 brings additional unique capabilities, such as enabling large-area and 3D-shape sampling to allow for more comprehensive testing of complex structures.

Cutting and preparing samples from semiconductor wafers, dies and packages for microstructure diagnostics and FA is an essential but time-consuming and costly step. The primary method of sample preparation used in semiconductor and electronics manufacturing today is FIB micromachining, which can take several hours to prepare a typical sample. FIB only allows for very small sample sizes, and precious FIB time is wasted by "digging" excavations needed for cross-sectional imaging in a scanning electron microscope or making a TEM lamella. Reaching larger depths or widths is severely restricted by the limited ablation rate.

The microPREP 2.0 laser ablation system.

3D-Micromac's microPREP 2.0 significantly accelerates these critical steps, bringing sample preparation for semiconductor and materials research to a new level. By offloading the vast majority of sample prep work from the FIB tool and relegating FIB to final polishing or replacing it completely depending on application, microPREP 2.0 reduces time to final sample to less than one hour in many cases.

"This award-winning tool brings unprecedented flexibility into sample prep. We at Fraunhofer IMWS are facing the need for targeted, artifact-free and most reliable preparation workflows to be able to serve our industry customers with cutting-edge microstructure diagnostics. Made for diverse techniques like SEM inspection of advanced-packaging devices, X-ray microscopy, atom probe tomography, and micro mechanics, microPREP was developed jointly with

3D-Micromac to close gaps in preparation workflows," said Thomas Höche, Fraunhofer IMWS.

Last month, 3D-Micromac and Fraunhofer IMWS received the prestigious TUV SUD Innovation Award for their collaboration on the development of microPREP 2.0. The annual prize honors successful cooperation between small and medium-size enterprises and research institutions. It is administered by TUV SUD, a leading technical service corporation serving the industry, mobility and certification segments.

KLA Tencor cont'd from p 6

film monitor wafers has shrunk below the detection limit of available tool monitoring systems. A second key gap in the defect detection space has been reliably detecting yield-killing defects introduced early in the lithography process, whether 193i or EUV. Our engineering teams have developed two new defect inspection systems—one for unpatterned/monitor wafers and one for patterned wafers—that provide key capability for engineers to address these difficult defect issues rapidly and accurately."

The Surfscan SP7 unpatterned wafer defect inspection system achieves its high sensitivity through innovations in illumination and sensor architecture that produce decades of improvement in resolution over that of the previous-generation Surfscan tool. This leap in resolution is the key to detection of the smallest killer defects. The new resolution realm also enables real-time classification of many defect types, such as particles, scratches, slip lines and stacking faults—without removing the wafer from the Surfscan tool or affecting the system throughput. At the same time, control over peak power density allows the Surfscan SP7 to inspect thin, delicate EUV photoresist materials.

The Voyager 1015 patterned wafer defect inspection system closes a long-standing industry gap in after-develop inspection (ADI), leveraging novel illumination, collection and sensor architecture. This revolutionary laser scattering inspection system drives sensitivity forward while reducing nuisance signals—and delivers results substantially sooner than the next-best alternatives. Like the new Surfscan SP7, the Voyager system features exceptional control of power density, allowing inline inspection of delicate photoresist materials after develop. High throughput capture of critical defects in the litho cell and other modules of the fab allows process issues to be identified and rectified rapidly.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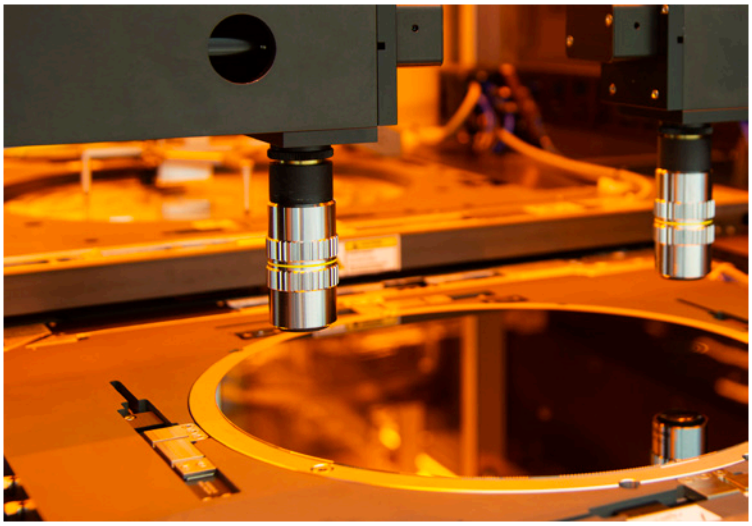

The new SmartView® NT3 aligner on EV Group's GEMINI® FB XT fusion bonder enables a 2-3X improvement in wafer-to-wafer alignment accuracy over EVG's previous-generation aligner.

EV Group (EVG) — Booth #623 in the South Hall — recently unveiled the new SmartView® NT3 aligner, which is available on the company's industry benchmark GEMINI® FB XT integrated fusion bonding system for high-volume manufacturing (HVM) applications. Developed specifically for fusion and hybrid wafer bonding, the SmartView NT3 aligner provides sub-50-nm wafer-to-wafer alignment accuracy — a 2-3X improvement — as well as significantly higher throughput (up to 20 wafers per hour) compared to the previous-generation platform.

With the new SmartView NT3 aligner, the GEMINI FB XT provides integrated device manufacturers, foundries and outsourced semiconductor assembly and test providers (OSATs) with wafer bonding performance that is unmatched in the industry and can meet their future 3D-IC packaging requirements. Applications enabled by the enhanced GEMINI FB XT include memory stacking, 3D systems on chip (SoC), backside illuminated CMOS image sensor stacking, and die partitioning.

Vertical stacking of semiconductor devices has become an increasingly viable approach to enabling continuous improvements in device density and performance. Wafer-to-wafer bonding is an essential process step to enable 3D stacked devices. However, tight alignment and overlay accuracy between the wafers is required to achieve good electrical contact between the interconnected devices on the bonded wafers, as well as to minimize the interconnect area at the bond interface so that more space can be made available on the wafer for producing devices. The constant reduction in pitches that are needed to support component roadmaps is fueling tighter wafer-to-wafer bonding specifications with each new product generation.

"At imec, we believe in the power of 3D technology to create new opportunities and possibilities for the semiconductor industry, and we are devoting a great deal of energy into improving it," stated Eric Beyne, imec fellow and program director 3D system integration. "One area of particular focus is wafer-to-wafer bonding, where we are achieving excellent results in part through our work with industry partners such as EV Group. Last year, we succeeded in reducing the distance between the chip connections, or pitch, in hybrid wafer-to-wafer bonding to 1.4 microns, which is four times smaller than the current standard pitch in the industry. This year we are working to reduce the pitch by at least half again."

> Vertical stacking of semiconductor devices has become an increasingly viable approach to enabling continuous improvements in device density and performance.

At SEMICON West, Dr. Thomas Uhrmann, director of business development at EV Group, will highlight the GEMINI FB XT and other developments in wafer bonding in his presentation "Collective Bonding for Heterogeneous Integration in Advanced Packaging" at the Meet the Experts Theater Smart Manufacturing Pavilion Thursday, July 12 from 3:00-3:30 p.m. in the South Hall.

Microelectronics Sector Extends AI from Pattern Recognition to Prediction and Control

BY PAULA DOE, SEMI

The fast-maturing infrastructure now enabling analysis of exponentially larger data volumes brings the microelectronics industry to an inflection point, where the winning companies will be the first to master the use of this data to solve the industry's emerging challenges. SEMI expands its coverage of these vital issues with a Smart Manufacturing Pavilion and three days of talks SEMICON West.

While deep learning is starting to be applied to image recognition for wafer inspection, it also being considered for sequential pattern recognition to evaluate equipment parameter traces. The next emerging applications will start to use those learned patterns to predict outcomes, and then to use those predictions to automate process control. One early application of deep learning is IC process development.

"People don't think of research and development as the first place to automate, but it's where applying our digitization and simulation has first had impact," says David Fried, Coventor, a Lam Research Company, vice president of Computational Products. He noted that insertion is easier in the lab than in the fab.

Technology at 10nm and beyond is now so complex that companies at the leading edge must use process modeling to understand the effect of process variation on their designs. Learning cycles can now be accelerated during development by simulating 10,000 digital wafers instead of running 25 actual wafers during screening, Fried says. Applying structured analysis and machine learning to the data simplifies optimization across the 500 or more interrelated process steps. Coventor has recently introduced a statistical analysis package that aids the design and analysis of process variation experiments, using large volumes of data from its models. Fried says these models are next being used to accelerate the yield ramp in manufacturing (Figure).

Digital simulation also could speed development of high-mix, lower value products

While digital twins are best known for their use in complex, high value products like jet engines, the simulation technology could also enable the electronic manufacturing services (EMS) sector to reduce the time, cost and risk of developing its high mix of products. "The EMS sector's use of digital twins will be vital for it to smooth the move of CAD/CAM digital design data for so many different products into manufacturing, and to accelerate the validation testing of designs and products by do-

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SEMICON WEST PREVIEW

New Infrastructure and Sensors Extract Actionable Information from Maturing IoT

BY PAULA DOE, SEMI

For medtech applications to flourish, sensors need a supporting infrastructure that translates the data they harvest into actionable insights, says Qualcomm Life director of business development Gene Dantsker, who will speak about the future of digital healthcare in the Medtech program at SEMICON West. “Rarely can one device give a complete diagnosis,” he notes. “What’s missing is the integration of all the sensor data into prescriptive information.”

The maturing medtech sector has developed to the point where sensors can now capture massive amounts of data, conveniently collected from people via mobile devices. The sector now has higher compute capacity to process the data, and improving software can produce actionable insight from the information. The next challenge is to seamlessly integrate these components into legacy medical systems

Getting actionable healthcare information from sensors requires integration into the existing medical infrastructure. Source: Qualcomm Life without disrupting existing workflow (Figure). "Doctors and nurses don't have time for disruptive technology — a new system has to be invisible and frictionless to use, with one or fewer buttons, no training and truly automatic Bluetooth-like pairing," he says. "So device makers need to pack all system intelligence into the circuits and software."

One interesting example is United Healthcare's use of the Qualcomm Life infrastructure to collect data from the fitness trackers of 350,000 patients. The insurance company then pays users $4 a day, or ~$1500 a year, for standing, walking six times a day and other behaviors that clinical evidence shows will both improve patient health and reduce healthcare costs. "It's a perfect storm of motivations for all stakeholders," he says.

Next hot MEMS topics: Piezoelectric devices, environmental sensors, near-zero power standby

With sensor technology continuing to evolve, look for coming innovations in MEMS in piezoelectric devices, environmental sensors and near zero-power standby devices, says Alissa Fitzgerald, Founder and Managing Member of A.M. Fitzgerald and Associates, who will provide an update on emerging sensor technologies in the MEMS program at SEMICON West.

Piezoelectric devices can potentially be more stable and perhaps even easier to ramp to volume than capacitive ones, with AlN devices for microphones and ultrasonic sensors finding quick success. Now the maturing infrastructure for lead zirconate titantate (PZT) is enabling the scaling of production of higher performing piezo material with thin film deposition equipment from suppliers like Ulvac Technologies and Solmates and in foundry processes at Silex and STMicroelectronics, she notes.

In academic research, where most new MEMS emerge, market interest is driving development of environmental sensors and zero-power standby devices. With demand for environmental monitoring growing, much work is focusing on technologies that improve the sensitivity, selectivity and time of response of gas and particulate sensors. Research and funding is also focusing on zero or near-zero power standby sensors, using open circuits that draw no power until a physical stimulus such as vibration or heat wakes them up.

MEMS, however, likely won't find as much of a market in autonomous vehicles as once thought. "While the automotive sensor market will need many optical sensors, MEMS players are competing with other optical and mechanical solutions," says Fitzgerald. "And here the usual MEMS advantage of small size may not matter much, and the devices will have to meet the challenging automotive requirements for extreme ruggedness."

MIcroelectronics cont'd from p 11

ing more of it in the virtual world," says Dan Gamota, vice president of Engineering and Technical Services at Jabil.

Gamota also highlights the push for traceability from the automotive and healthcare markets, where the digital models could be used to quickly assure that the design was built exactly as specified. "In the past year, traceability has evolved from just 'nice to have' to 'how to achieve,'" he adds. "Companies are expecting it, but aren't willing to accept the cost and risk of doing it alone. We need the community to discuss realistic implementations, identify the most critical elements and to bring together the ecosystem partners to build baseline reference architectures for key digital building blocks. The community also needs to assure the reliable flow of data among the electronic manufacturing segments from semiconductor to OSAT to EMS."

Predictive maintenance and virtual metrology applications could mature in next few years

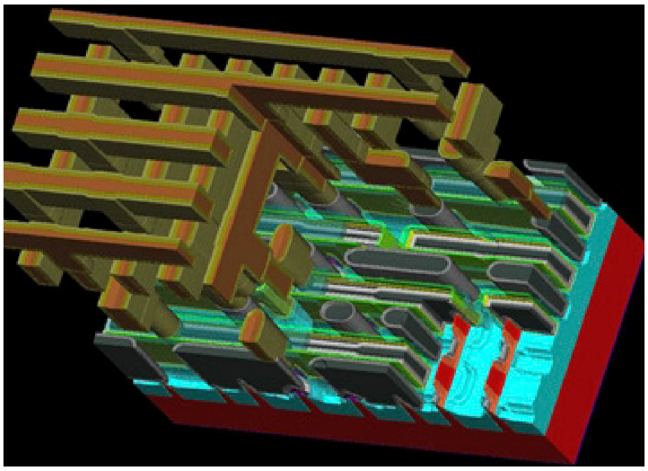
While predictive maintenance initially seemed a likely early application of machine learning in factories, it remains a challenging problem for the electronics sector. "The difficulty is that it's not clear where to get the most bang for the buck," says Tom Ho, president of BISTel America, noting that it may make the most sense to track the failure performance of a single expensive part, like an electrostatic chuck, since predicting the failure performance of a whole complex system like an etcher is much harder.

"Collecting enough data from all failure types, including especially the rare events, is difficult unless you have a long history of a lot of tools," adds Doug Suerich, PEER Group product evangelist. "The gain from collecting performance information from many tools across the industry could be big, but many companies still need to overcome concerns around exposing their IP."

Another big opportunity for prediction is virtual metrology — predicting the wafer outcome from the process or sensor data with enough accuracy to replace the physical metrology. "Virtual metrology is improving, and since metrology can be slow and expensive, any reduction could be a huge potential savings," says Suerich. "But it is still seen as too scary for many companies. Two to three years from now, companies will expand the practice from lower risk areas into processes that require more confidence in the results."

Moving beyond prediction to automated control needs digital models

Once the results are predicted, the model can be used to control or automatically optimize a process and enable the system to learn by itself, usually by reinforcement learning on a digital model. The model can then independently make adjustments to optimize the manufacturing process. "Automated process development is getting close now. Instead of smart guys turning the knobs, deep learning is automating the smart tuning," says Suerich, suggesting the industry could see widespread adoption in as little as two to three years. This type of machine learning needs a good digital model, and masses of data for learning. One approach uses human experts to build a physics-based model of the clearly understood parts of the process, then turns to deep machine learning to optimize the lesser-understood variables. The alternative, the data-first approach, runs a computer algorithm to suggest the solution purely from data, without human input, and then rely on the human to evaluate the usefulness of the results.



SRAM Metal-3 cutaway model view. Source: Coventor

Modeling digital twins of wafers could enable automated process control, chamber matching, and fleet matching, says Fried. If every wafer had its own virtual twin with all the upstream metrology and structural information needed to make equipment control decisions, it could feed forward that information to enable the seamless transition from one step to another in the process based on understanding their complex interrelationships. This could potentially improve uniformity across wafers and equipment, and reduce the need for metrology, he argues.

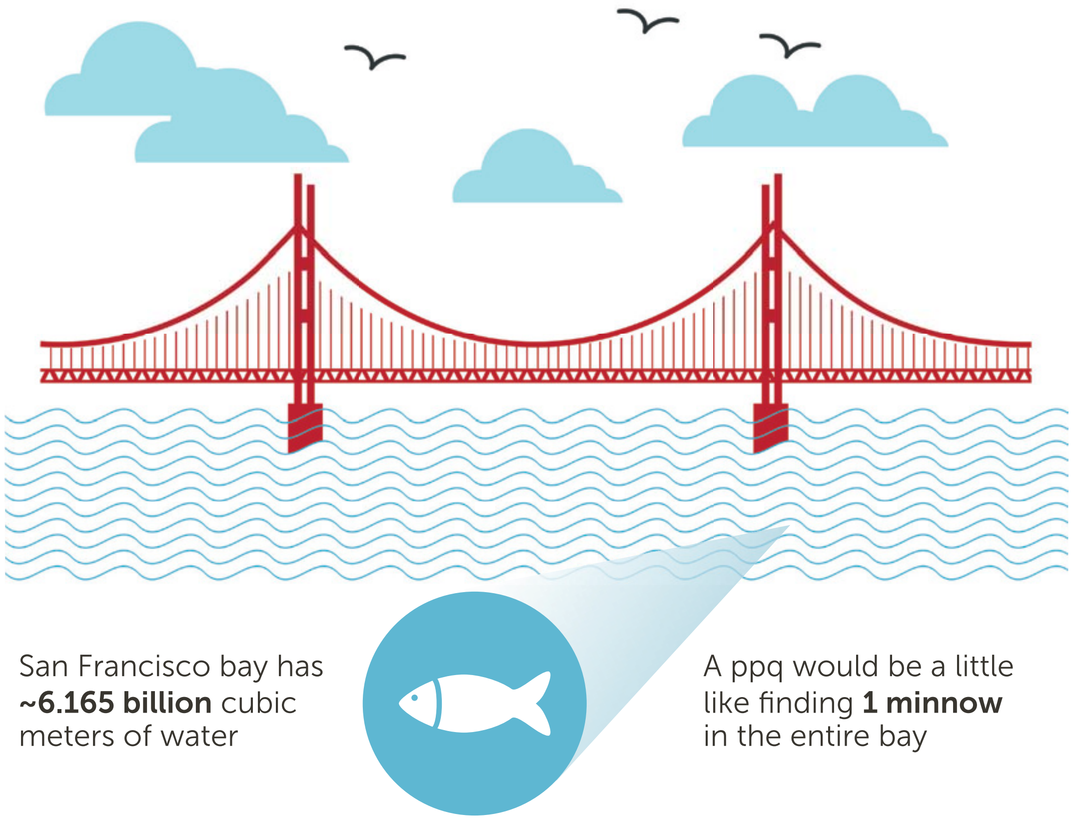
Moving metrology sensors into the chamber will also require model-based algorithms to enable dynamic process control in close to real time, says Fried. These algorithms will be needed to acquire, parse, and process the data at high speed, and then to choose how to adjust the controls. "There will be a model behind collecting and interpreting the metrology data," he notes. "That's a really rich vein for improvements in process control."

"The end goal is to collect equipment data in real time, analyze it with AI, and send back controls to optimize manufacturing processes," Jabil's Gamota says. "This requires a robust architecture for communication between equipment and consistent formats for data collection and analysis. But the cost and complexity of this heavy lifting is too great for any one company to do alone. We need a consensus-based architecture for ingesting, analyzing and acting on the data."

SEMI tests data transfer protocols, benchmarks best practices

SEMI is launching a smart data project to identify the various data transfer protocols needed for inter-company communications. The project will feature a proof-of-concept model in a development fab to produce verifiable results so SEMI can better understand how different approaches meet member needs. SEMI's smart manufacturing technology communities and the Fab Owners Alliance are also benchmarking current smart manufacturing practices in the microelectronics industry to help SEMI members better understand the path forward and potential return on investment.

Clean Chemical Delivery



As logic devices go to smaller line widths, 3D NAND architectures add layers, and DRAM memory increases density, sensitivity to contamination is amplified, and defects can have a greater impact on device performance.

To be successful, organizations need to implement safe and efficient chemical storage and delivery systems that include a broad range of fluid handling products and filtration and purification technologies.

To learn more, read the white paper, "Reducing Contamination Points in Clean Chemical Delivery from Manufacture through Point of Use" at *www.entegris.com/ccd*.

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