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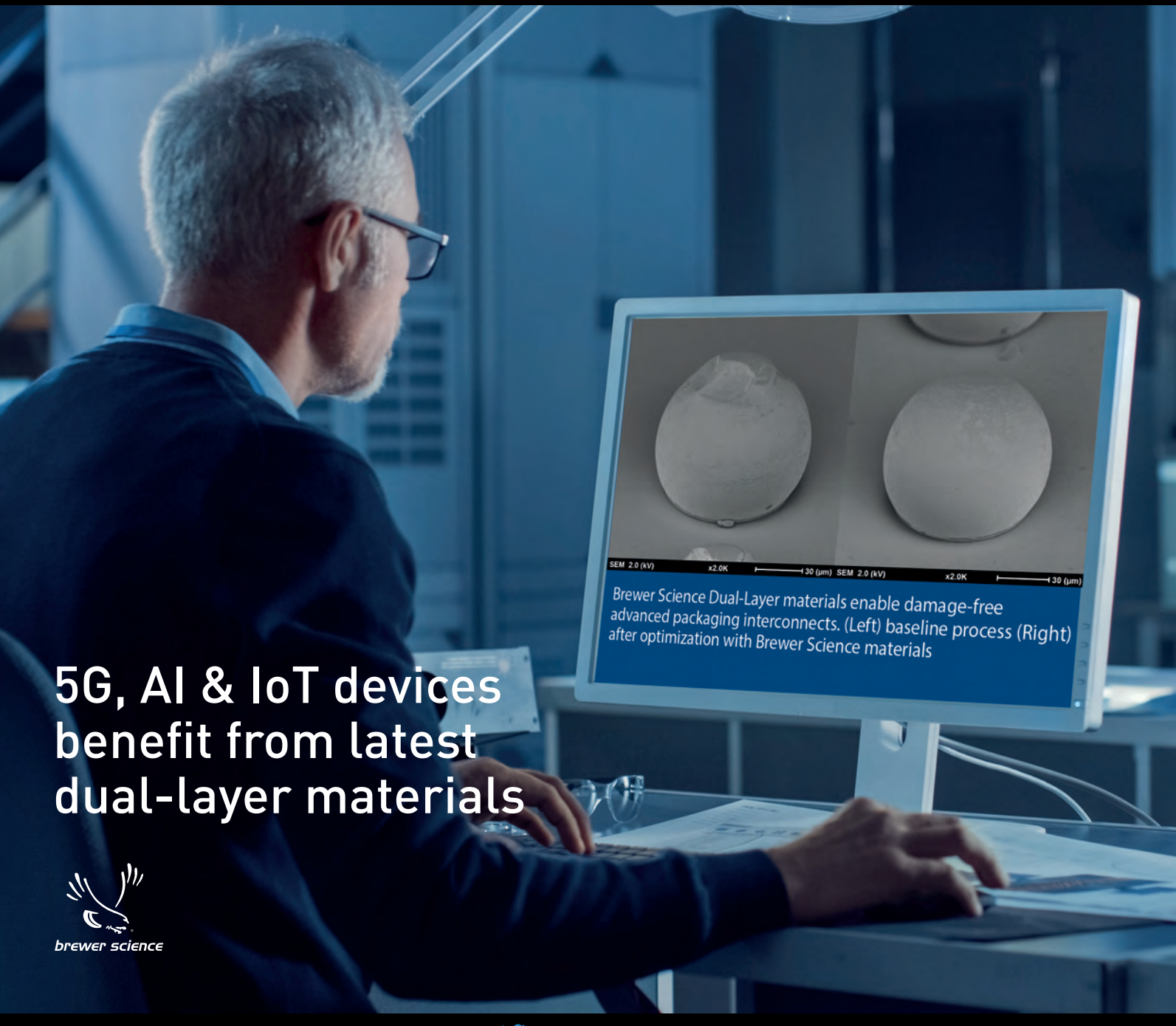

5G, AI & IoT devices benefit from latest dual-layer materials

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INSIDE

MES CAPABILITIES CAN EXTENDS FAB LIFETIMES

Current global microelectronics shortage demonstrates that IC fabs are not created to pivot quickly as much as they are to produce high quality products at low cost

ADDING ML TO APC MANUFACTURING SYSTEMS

With the continual buzz around artificial intelligence (AI) and machine learning (ML), one might think it relatively easy to improve output by adding a 'bit' of AI/ML to one's IC recipe

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VIEWPOINT

By Mark Andrews Technical Editor

Ending the semiconductor shortage will take time, diligence

Anyone working in the semiconductor supply chain cannot miss the mass media drumbeat of oh-so-simple yet often unrealistic solutions for ending the chip shortage. Rarely does mainstream media manage to offer accurate insights into our complicated industry in a package fitting neatly into 60-second news bites.

Some commentators outside of industry almost make it sound as if solutions should be as simple as tossing another log on a fire. Add capacity? Sure—there's an idea. But those working in IC manufacturing know fabs only cost around a billion euros; they take three or more years to build, another year to qualify equipment and 'around' 6-18 months for profitable yields. The same applies to on-shoring production or squeezing more from fabs already operating 24/7. The plain and simple truth won't grab headlines, but you and I know this is going to take time and diligence amongst the myriad suppliers that support manufacturers.

The shortage has at least focused attention on the need for supply chain resilience. Everyone is getting busy. The US wants to on-shore IC manufacturing, yet Intel needs a year-plus to complete its newest Southwest fab. TSMC's US project is not yet 'shovel ready.' The EU is in the game with its European Chips Act, but like other solutions, this will take time. China is pushing its aggressive fab building programmes, but they are also encountering headwinds. Easy and quick? Hardly.

In positive news reported as 2Q ended, SEMI researchers forecast manufacturing equipment

sales will crest $100 billion by year's end. SEMI later reported that wafer shipments will post record growth through 2024; GlobalFoundries is going public and Apple announced its latest 'home grown' processor chips continue to set new performance standards.

In this Silicon Semiconductor edition we look at advanced 3D device materials including those that will be highlighted at SEMICON Europa in November.

Our cover story profiles Brewer Science and its Dual-Layer materials that play a critical role in temporary wafer bonding that facilitates optimized thermal compression bonds. We also explore the benefits of an advanced MES for future-proofing industrial automation and new research innovations.

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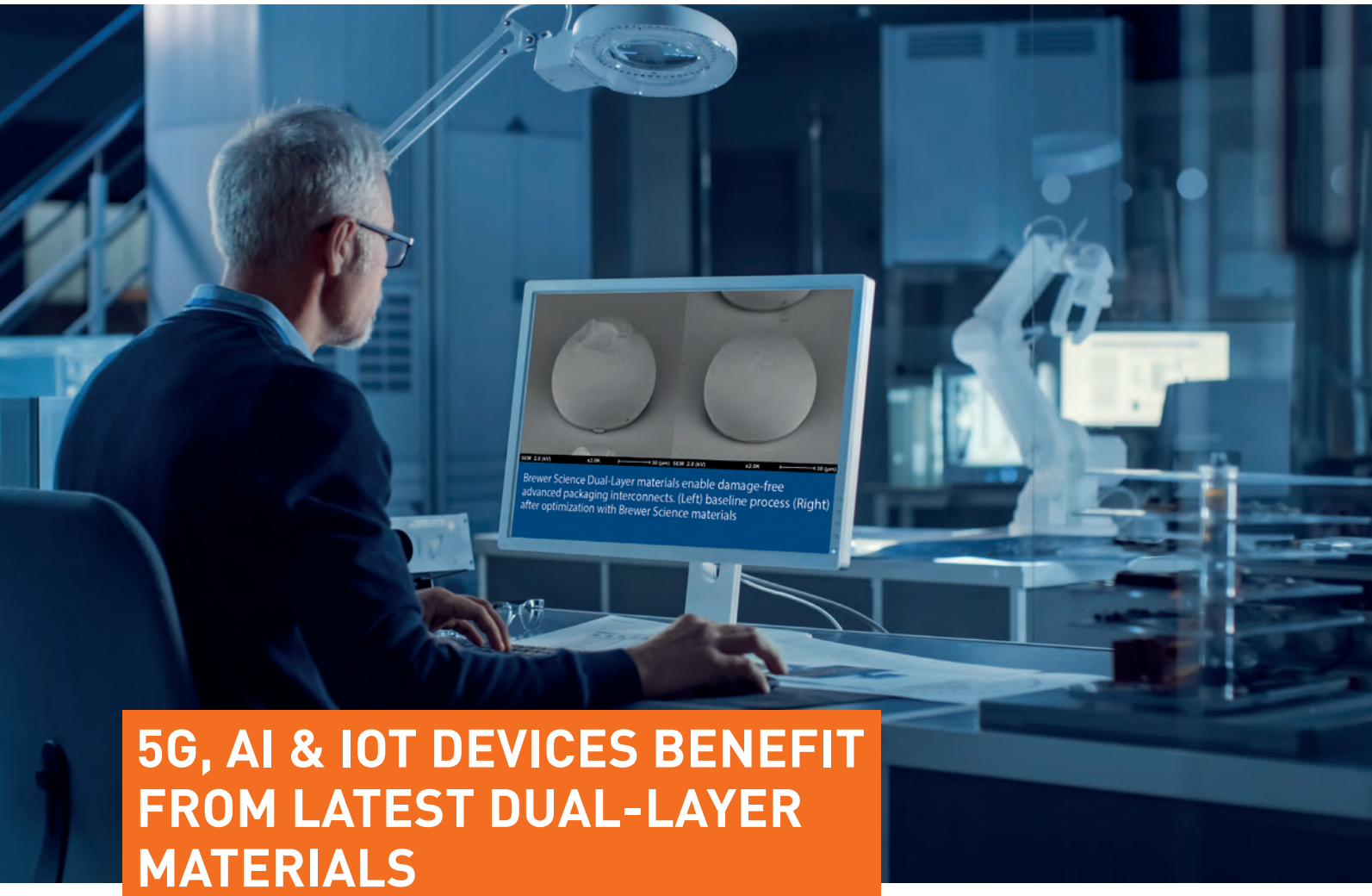

5G, AI & IOT DEVICES BENEFIT FROM LATEST DUAL-LAYER MATERIALS

Wafer-level packaging (WLP) has become the norm for a growing number of 5G, Artificial Intelligence (AI) and Internet of Things (IoT) system components

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Edwards officially opens new flagship Service Technology Centre in Dublin

EDWARDS, supplier of vacuum and abatement services and solutions to the global semiconductor industry, has opened its new flagship Service Technology Centre (STC) in Blanchardstown, Dublin.

The new site and associated field service operations have so far employed a diverse workforce of around 100 people, 90% of whom are engineers, and this is expected to rise to around 120 by the end of the year. The STC, which will help support the semiconductor manufacturing industry in Ireland, represents an investment in the region of US$7.5 million.

Semiconductor manufacturing is essential to supporting developments in the technology, electronics, transport, scientific and healthcare sectors – all of which have been classed as critical industries during the Covid-19 pandemic.

Edwards is the world leader in supplying the vacuum and abatement technology, along with the equipment and services, necessary to support the efficient and environmentally sustainable production of semiconductors.

The new 4,000m^2 facility uses advanced automation and data solutions to disassemble, clean, inspect, repair, replace and reassemble vacuum pumps and abatement equipment. On-site manufacturing will improve responsiveness to customers' needs.

State-of-the-art technology in the new data driven facility brings together innovations developed by the expertise of our STCs around the world, including the automated cleaning system, smart tooling, automated guided vehicles, and a digital pump tracking system which enables Edwards to track progress of products through the STC and provides data to improve planning abilities, while keeping the customer informed.

These new technologies, including the use of a mobile app for employees, significantly remove the amount of paper needed and thus reduce the facility's carbon footprint.

Edwards is supported by IDA Ireland through the Department of Enterprise, Trade and Employment. Tánaiste and Minister for Enterprise, Trade and Employment Leo Varadkar TD said, "Today is a big day for Edwards and I'd like to congratulate all staff on the opening of this flagship centre. I'm sure you will all find a very warm home in Blanchardstown. Today's opening reaffirms Ireland's position as a global leader in the semiconductor industry. I wish Edwards every success in the future."

Troy Metcalf, President of Edwards' Semiconductor Service division formally opened the new facility and welcomed the new employees. Troy commented, "I am delighted to be opening our new Dublin Service Technology Centre, the latest in our global network of STCs that enables us to best support our customers in the safe, productive and environmentally sustainable manufacturing of semiconductors in Ireland and across Europe.

I want to extend my sincere gratitude to everyone involved in helping to facilitate the new site for their enthusiasm and hard work, despite the significant challenges posed during the pandemic.

"I would also like to thank IDA Ireland on behalf of Edwards for the continued valuable support they have provided us in this exciting new venture."

Congratulating Edwards on its official opening, Martin Shanahan, CEO, IDA Ireland said "Despite the challenge of this past year, Edwards has already onboarded 100 new members of staff and opened its new flagship Service Technology Centre (STC) in Dublin. This is a very welcome investment and I wish Edwards continued support and ongoing success with this operation."

Edwards is continuing to recruit for the new Dublin facility. Learn more about the company and emerging roles or send your details to edwardsvac@collinsmcnicholas.ie

Advantest introduces evolutionary V93000 EXA scale SoC test system

SEMICONDUCTOR test equipment supplier Advantest Corporation has announced its next-generation V93000 testers targeted at advanced digital ICs up to the exascale performance class. The systems' new test heads incorporate Xtreme Link technology, and the EXA Scale universal digital and power supply cards that enable new test methodologies, lower cost-of-test and faster time-to-market.

Today's most advanced semiconductor processes allow for technology transformations that enable real-time integration of data from a countless number of sources such as IoT and handheld devices, automobiles and large servers to name a few. As mobile processors, high-performance computing (HPC) and artificial intelligence (AI) ICs evolve, the amount of data being processed continues to grow exponentially. Along with these advancements, new testing challenges, including very high scan-data volumes, extreme power requirements, fast yield-learning, and high-multisite configurations, need to be addressed.

Advantest's new V93000 EXA Scale generation addresses these challenges with innovative advancements on the proven V93000 architecture. All EXA Scale cards are designed with the latest generation of Advantest's test processors with 8 cores per chip, featuring unique capabilities to speed up and simplify test execution. Furthermore, the V93000 EXA Scale system employs Advantest's patented Xtreme Link technology, a communication network designed specifically for automatic test equipment (ATE). The technology provides high-speed data connections, embedded computing power, and instant card-to-card communication.

The system's new Pin Scale 5000 digital card is designed to address the explosion of scan data volumes which are inherent to large digital designs. The Pin Scale 5000 is setting a new standard for scan test with 5Gbit/s speed, providing the deepest vector memory available on the market and using the Xtreme Link technology for the industry's fastest processing of results. With this technology, customers can choose the most efficient scan methodology for their device.

Very high current requirements up to several 1000A at supply voltages below 1V make power delivery capabilities of ATE a differentiating factor. The XPS256 power supply is another industry innovation, covering all power requirements with a single DPS card: fine-granular power, unlimited and flexible ganging and exceptional static and dynamic performance.

With 256 channels on the Pin Scale 5000 digital card and XPS256 power supply card, the density is doubled, while maintaining the industry-leading V93000 highly integrated form factor. High-multisite configurations can be implemented in smaller physical systems, reducing infrastructure cost and floor-space requirements.

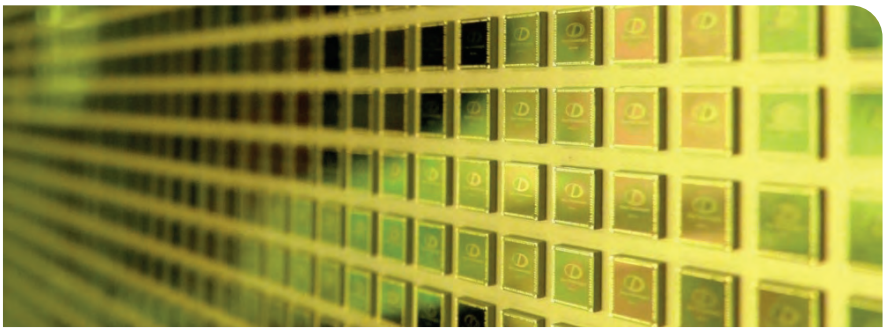
Scalable solutions extend across test heads of different sizes, including the ability to test a mix of device functions, like digital, RF, analog and power on one test system.

The V93000 EXA Scale generation renews Advantest`s commitment to platform compatibility. Existing V93000 load boards and Smart Scale cards are compatible, supporting a smooth transition to the V93000 EXA Scale generation and best asset utilization. With the continued use of the proven SmarTest software, customers benefit from the installed base software infrastructure and tooling.

Advantest has already shipped dozens of the V93000 EXA Scale systems to multiple industry-leading customers.

SkyWater signs technology transfer and license agreement with Deca

SkyWater Technology, technology realization partner and Deca Technologies (Deca), a provider of advanced electronic interconnect technology, has announced an agreement for Deca's second generation M-Series fan-out wafer-level packaging (FOWLP) technology with Adaptive Patterning within SkyWater's advanced packaging facility in Florida. The companies are endeavoring to establish the first high volume FOWLP capability in the U.S. to bring proven solutions for single and multi-die packaging and advanced heterogeneous integration capability for chiplets through 2.5D and 3D implementations.



Deca's first generation technology changed the game with high volume production for leading mobile applications and is well-known for enabling exceptional board-level reliability, end-customer quality and electrical performance.Deca's unique Adaptive Patterning with mask-less laser direct imaging delivers high-density design rules and high production yields in a cost-effective miniaturized format. Deca's second generation FOWLP technology includes 2 μm RDL features combined with industry-benchmark 20 μm bond pad pitch and targets advanced mobile devices, high-performance computing (HPC), high-end networking, artificial intelligence (AI), and edge computing as well as high density 3D integration technology in medical and defense applications.

Cliff Sandstrom, Deca's vice president of technology development, stated, "This is an exciting time for the industry as SkyWater invests in Deca's Gen 2, delivering a cutting-edge packaging technology which is competitive with current industry leaders including advanced silicon interposers. With multiple customers designing into Gen 2, we look forward to working closely with SkyWater to successfully bring these new products to market."

Dr. Brad Ferguson, SkyWater Florida senior vice president and general manager, added, "Through this collaborative work with Deca, we look forward to reaching another milestone in the realization of our vision for state-of-the-art domestic advanced packaging foundry services. We're proud to lead the onshoring of this key technology and expect it to serve customer demand in numerous markets. Deca's powerful integration platform nicely complements our Technology as a ServiceSM model for customers driving leading-edge device architectures that require advanced electronic interconnect solutions."

SEMI applauds European Chips Act

SEMI, the global industry association has applauded the proposed European Chips Act legislation aimed at strengthening semiconductor research, development, and manufacturing in Europe.

Proposed by European Commission President Ursula von der Leyen in her State of the Union speech on September 15, the European Chips Act is part of the Commission's policies to achieve the digital transformation of the region's economy by 2030 under its Digital Decade plan.

"SEMI supports incentives for semiconductor manufacturing and supply chain investments such as those proposed to be included in the European Chips Act," said Ajit Manocha, SEMI president and CEO. "Transparent implementation of such initiatives allows industry participants the opportunity to efficiently strengthen the resilience of the global semiconductor industry and create a more robust supply chain. The current chip shortage has exacerbated backlogs and lead times for semiconductor manufacturing equipment and materials. Given the vital importance of these elements to expanding semiconductor production capacity, incentives should extend to investments in both new and existing semiconductor manufacturing equipment and materials facilities."

Citing the current shortages and Europe's dependency on the global chip ecosystem in a recent blog post, Thierry Breton, the European Commissioner for Internal Market, emphasized the Chips Act must ensure the resilience of the semiconductor supply chain across design, production, packaging and equipment. Breton calls for the legislation to strengthen Europe's ability to develop mega fabs capable of high-volume production of advanced and energy-efficient semiconductors. Additionally, he recommends the Chips Act include strategies for extending the research ambitions of Europe, tightening coordination of chip production among EU member states, and providing a framework for international cooperation and partnerships.

Sivers Semiconductors' Japanese customer takes step towards mass production

SIVERS SEMICONDUCTORS AB has announces that its Japanese lead customer Fujikura, after several successful customer trials, is now preparing the start of full-scale, high-quality volume production of their 60 GHz communication module.

Sivers Semiconductors and Fujikura have worked closely together for several years in a joint effort to offer this competitive 60 GHz communication module. Fujikura has developed a compact communication module including a baseband wireless modem function and an antenna with an included RF front end RFIC from Sivers Semiconductors (TRX BF/01). This module developed by Fujikura is built on their own low loss liquid crystal polymer (LCP) material and Fujikura antenna design. Kiyoshi Kobayashi, Product Owner of the 60 GHz communication module at Fujikura explains: "We have been working very tightly with Sivers Semiconductors for several years and they have provided excellent guidance and support during the development and integration of our new 60 GHz module. Over the last year we have had great success in several trials and pilot projects we have been involved in and now we are taking the next important step to secure our capabilities to provide high volumes and good quality products to the market."

Anders Storm, Group CEO of Sivers Semiconductors says: "Fujikura is a well-known company with many capabilities, and it is an honor to work with their 60 GHz team in this project. With thoroughness and very high-quality standards, they have taken steps to reach a point where they now will take the final leap to commercially pursue the many new opportunities in the 60 GHz communications market. We are very happy to see that they now are entering this phase."

As part of this project, Sivers Semiconductors and Fujikura are now also starting commercial negotiations to reach a long-term volume purchasing agreement, which is expected to be finalized during the autumn.

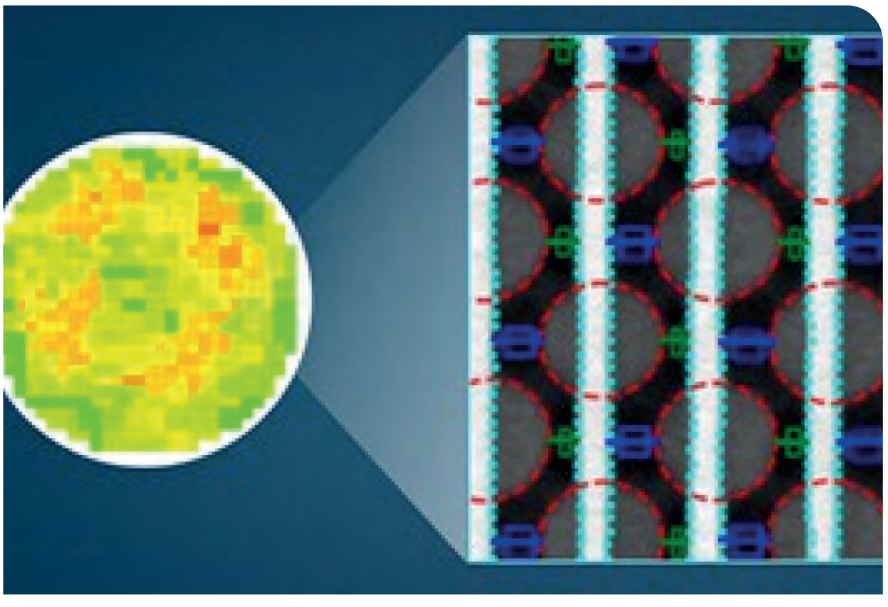
Applied Materials unveils eBeam metrology system

APPLIED MATERIALS has unveiled a unique eBeam metrology system that enables a new playbook for patterning control based on massive on-device, across-wafer and through-layer measurements.

Advanced chips are built one layer at a time, and each of billions of individual features must be perfectly patterned and aligned to create working transistors and interconnects with optimal electrical characteristics. As the industry increasingly moves from simple 2D designs to more aggressive multipatterning and 3D designs, a commensurate breakthrough in metrology is needed to perfect each critical layer and enable the best performance, power, area-cost and time to market (PPACt).

Traditionally, patterning control has been achieved using optical overlay tools that help align die patterns with "proxy targets" which are guide marks printed into the spaces between die that are removed from the wafer during die singulation. Proxy target approximation has been complemented with statistical sampling of a small number of die patterns from across the wafer. However, after successive generations of feature shrinking, broader adoption of multipatterning, and the introduction of 3D designs that cause interlayer distortions, the traditional approach is leading to measurement deficiencies – or "blind spots" – that are making it more difficult for engineers to correlate intended patterns with on-die results. With the arrival of new eBeam system technology that can directly measure semiconductor device structures across the wafer and through layers at high speed, customers are moving to a new patterning control playbook based on big data. Applied's latest eBeam metrology innovation – the PROVision 3E system – is especially designed for this new playbook.

"As the leader in eBeam technology, Applied Materials is giving our customers a new playbook for patterning control that is optimized for the most advanced logic and memory chips," said Keith Wells, Group Vice President and General Manager, Imaging and Process Control at Applied Materials. "The resolution and speed of the PROVision 3E system allows it to see beyond the blind spots of optical metrology, performing accurate measurements across the wafer and between the many layers of a chip. This provides chipmakers with the multidimensional data sets they need to improve PPAC and accelerate the time to market of new process technologies and chips."



Kanthal LPCVD technology opens new deposition opportunities in optical, power and microLED applications

YES (Yield Engineering Systems), a manufacturer of process equipment for semiconductor packaging, life sciences and 'More-than-Moore' applications, has purchased the semiconductor equipment business of Swedish heating technology provider Kanthal.

Under the terms of the agreement, which was signed on October 6th, YES will take ownership of Kanthal's semiconductor-related capital equipment portfolio, system-related upgrades, and service needs. The acquisition will add Kanthal's high-temperature (>800°C) furnace technology as well as Low Pressure Chemical Vapour Deposition (LPCVD) processes to YES's growing capabilities in the thermal processing area.

"We aim to be the semiconductor industry's provider of choice for surface modification, material enhancement, and high-quality deposition," said Rezwan Lateef, president of YES. "With this acquisition of equipment and technical expertise from a leader in industrial heating, we look forward to supporting our global customer base with new high-temperature annealing and bonding systems that leverage Kanthal heating equipment.

"In addition, we feel that the Kanthal LPCVD technology has potential to open exciting deposition opportunities for YES beyond our current monolayer coating systems, particularly in the areas of optical, power and microLED."

PragmatIC Semiconductor secures funding

PRAGMATIC Semiconductor has announced that it has secured $80 million of Series C funding. This scale-up investment will be used to build a second FlexLogIC fab in the North East of England, to meet the growing demand for ultra-low-cost flexible integrated circuits (FlexICs) for the Internet of Everything, and strengthening the position of the UK in its ambition to be a leading designer and manufacturer of next generation semiconductors.

"This successful Series C round is a testament to the potential for our technology to enable trillions of smart items and address key UN sustainable development goals," said Scott White, CEO of PragmatIC Semiconductor.

"Our FlexLogIC-002 fab will deliver significantly higher capacity than our first line, whilst still maintaining our signature ultra-low capex, fast production cycle time and minimal carbon footprint.

In addition to supporting our continued commercial ramp, it provides a template for rolling out a distributed global network of FlexLogIC systems, offering a Fab-as-a-Service (FaaS) for dedicated production on major customer sites to enable efficient and secure semiconductor supply chains."

Erik Langaker, independent Chair of the Board, added: "This capital raise is a fantastic recognition of the achievements of Scott White, Richard Price and their team. The round has been subscribed by a highly qualified select group of industrial and individual investors with significant experience in the semiconductor industry.

Their backing will enable the team to more than double in size over the next 12 months and expand capacity to fulfil the rapidly growing demand for electronics in everyday objects. PragmatIC's development over the past few years has seen the launch of its flagship ConnectIC® product line of ultra-low-cost RFID FlexICs, as well as its FlexIC Foundry® service enabling innovative designers to create more pioneering products and advance them rapidly from concept to reality.

This year it has demonstrated an order-of-magnitude improvement in complexity and compute capability for non-silicon chips by producing flexible microprocessors. These include the iconic 6502 and PlasticArm, an ultra-minimalist Arm® Cortex®-M0 based system-on-a-chip which is 12 times more complex than previous state-of-the-art flexible electronics.

PlasticArm is the result of many years of collaboration between the two companies, a partnership that is set to continue long into the future with semiconductor IP leader Arm participating in this funding round.

Nano Dimension acquires Essemtec

Nano Dimension, an industry leader in Additively Manufactured Electronics (AME) / 3D-Printed Electronics (PE), and Micro Additive Manufacturing (Micro-AM), has announced that it has signed and closed a definitive agreement to acquire Essemtec AG based in Lucerne Canton, Switzerland.

ESSEMTEC's product portfolio is comprised of production equipment for placing and assembling electronic components on printed circuit boards (PCBs). They are a leader in adaptive highly flexible surface mount technology (SMT) pick-and-place equipment, sophisticated dispenser suitable for both high-speed and micro-dispensing, and intelligent production material storage and logistic system. Its products are equipped with a sophisticated software package which makes extensive and efficient material management possible.

ESSEMTEC's equipment and software have been having impact with customers since their first machine was introduced. As their high-tech solution can be adjusted quickly and easily to meet wide ranging requirements, they are able to respond to all manner of customer needs, particularly in high-mix-low-volume production environment. Their portfolio of products will continue to be available to the thousands of organizations that have called themselves a customer of ESSEMTEC, while also being part of the AME revolution that Nano Dimension is driving with its existing technology.

Wuppertal University chooses Tektronix to develop advanced 6G technology

WUPPERTAL UNIVERSITY in Germany has chosen Tektronix instrumentation to help it develop innovative and capable new technologies that will underpin 6G networks. The project will develop components that allow higher data throughputs for 6G, while also cutting the latency of networks to allow applications, such as autonomous driving and remote surgery, with haptic feedback.

Led by Prof. Dr. Ullrich Pfeiffer, the project team was looking for instrumentation that could demonstrate the best vertical resolution, the best residual Error Vector Magnitude (EVM), a large memory and the ability to synchronize multiple instruments. After careful consideration of vendors, Prof. Dr. Pfeiffer and his team settled on Tektronix.

The scope of supply encompassed six DPO77001SX 70GHz Oscilloscopes, six AWG70001B 50 GSa/s Arbitrary Waveform Generators, three AWG Synch Hubs, three SignalVuPC Vector Signal Analysis Software, three SourceXpress Waveform Generation Software, and two water cooled 19" Racks supplied by system integrator ATV (Automatisierungstechnik Voigt GmbH) to reduce acoustic noise and improve thermal stability.

The Tektronix solutions offer synchronization between instruments and the ability to add new capabilities through their modular construction. As well as equipment, Tektronix was also chosen for the engineering support it could offer through its engineers. "We were pleased to have found Tektronix, as access to their technical experts made our team feel safe and supported. Particularly the possibility to scale up the system by synchronizing multiple instruments is crucial for the research on THz MIMO communication" says Professor Dr. Pfeiffer. "Working with the global team of Tektronix engineers in this cooperative way, we feel we can really unlock the 'magic' in Tektronix solutions. We expect the cooperation with Tektronix to produce many breakthrough results" he added.

Maria Heriz, Vice President Commercial Operations EMEAI, commented, "Engineering the Future is Tektronix's motto and every day we enable our customers to develop new technology. With the University of Wuppertal, we take pride to support and enable Prof. Dr. Pfeiffer and his team to develop advanced 6G technology, that will touch every part of our society – socially and commercially; may it be autonomous driving, remote rescue and medical applications, which require the highest resolution 360° video transmission, IoT devices with much quicker data throughput, or smart cities.."

Jenoptik intends to acquire Berliner Glas Medical and SwissOptic

JENOPTIK AG is set to acquire from Berliner Glas GmbH, a 100 percent subsidiary of ASML Holding N.V.

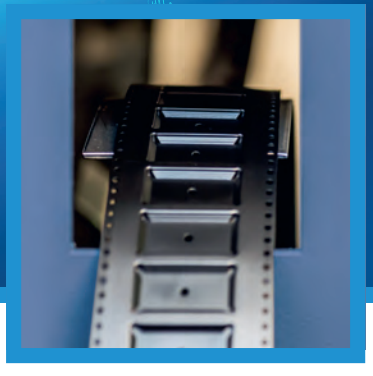
Overall, Berliner Glas Medical and SwissOptic currently employ around 500 people worldwide. The transaction is still subject to approval from the German antitrust authorities. Closing is expected in December 2021.

"With this strategic acquisition we will strengthen our global and fast-growing photonics business thus significantly expanding our already strong semiconductor equipment business, and, in particular, our highly attractive medical technology business," says Stefan Traeger, President & CEO of Jenoptik AG.

"We are pleased to have reached this agreement whereby Jenoptik will acquire the Medical Applications and SwissOptic business of Berliner Glas (part of ASML)," says Andreas Nitze, CEO of the Berliner Glas Group. "We are convinced that the combined businesses are well positioned to realize the potential we see for the business and will offer the best environment for its employees."

CARRIER TAPE ON-DEMAND

The new normal in semi-packing



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Adaptsys

5G, AI & IoT devices benefit from the latest dual-layer materials

Wafer-level packaging (WLP) has become the norm for a growing number of 5G, Artificial Intelligence (AI) and Internet of Things (IoT) system components. Advanced applications require high-performance integrated circuits (ICs) built on substrates that require extreme thinning. The manufacturing of these devices requires minimal total thickness variation (TTV), little to no warpage, and high temperature survivability during downstream processing. The materials experts at Brewer Science explain how their BrewerBOND® Dual-Layer materials and process gives manufacturers the edge they need to lower costs, enhance performance capabilities and increase production throughput.

SUCCESS in creating next-generation electronic devices demands a sound foundation. While the largest IC makers are pushing CMOS scaling to 5 nm and below, other advanced circuit manufacturers are taking different routes to high performance, including the adoption of 2.5D/3D architectures that reduce footprints while increasing processing speed and functionality.

Manufacturers have succeeded in dramatically reducing TTV and warpage while containing costs even as they maintain high throughput. A variety of wafer thinning techniques and material technologies have been developed to enable the support of advanced packaging platforms. One common process is wafer-level chip-scale packaging (WLCSP) that delivers high performance at low cost. But since it utilizes a 'substrateless' package, applications can be limited due to die size. As dies continue to shrink, manufacturers are already seeking alternatives. Fan-out wafer-level packaging (FOWLP) technology is seeing continual development since input/output (I/O) density can be increased by fanning out interconnects to external pad locations – this enables a smaller form factor with decreased power consumption.

An important aspect of advanced wafer-level packaging involves the use of temporary wafer bonding (TWB) materials and processes that enable partially processed wafers to withstand various subsequent steps even at very high temperatures and with high vacuum. If asked to describe their 'ideal' TWB materials solution that can save time and money while maintaining top performance, many manufacturers would ask for materials that can be applied and bonded at room temperature and can deliver protection when thinned wafers are manipulated as part of thermal compression bonding (TCB) steps. The materials should also be sufficiently flexible to support different cure options while preserving device feature integrity. At the same time, materials should enable the debonding of thinned wafers from carriers using a variety of separation technologies.

"Brewer Science is constantly working to improve its materials that are already seeing widespread adoption. A good example is our Dual-Layer materials that continue to see refinements that make them even more adaptable. We are seeing particular interest from manufacturers developing devices and systems for 5G, AI and IoT applications. Since the intial introduction, Brewer Science Dual-Layer materials have demonstrated protection during thin wafer handling in TCB processing. We continue to improve TTV performance in production environments and we have seen Dual-Layer materials successfully support wafers thinned to 10 μm. They can also be applied at room temperature with any of the industry's most commonly utilized dispense equipment," said John Massey, Principal Field Applications Engineer.

Handling thinned wafers is a major challenge within semiconductor manufacturing. Silicon wafers thinner than 50 μm or those with redistribution layers (RDLs) created using a RDL-first process are delicate and expensive to manufacture. Safe handling necessitates the use of support substrates and processing steps that employ temporary bonding and debonding (TBDB) materials designed to enable complex packaging architectures.

Materials created using high-viscosity, low-T_g thermoplastic polymers are commonly used in TBDB processes. When paired with a supportive carrier, these materials offer thermo-mechanical stability and easier handling of thin device substrates. While the extensive selection of TBDB materials offered by Brewer Science supports many bonding/debonding techniques (predominantly: mechanical, laser, and thermal slide), the introduction of higher-temperature steps can cause traditional adhesive materials to behave more like a liquid; as a result, temporarily bonded wafers lose mechanical stability as melt viscosity decreases. This allows some material to soften, weakening bond-line stability. Deformation and delamination of the device wafer can occur at higher temperatures, which leads to downstream processing issues. Brewer Science has developed advanced materials and processes, providing customers a TBDB system that eliminates common material failure points.

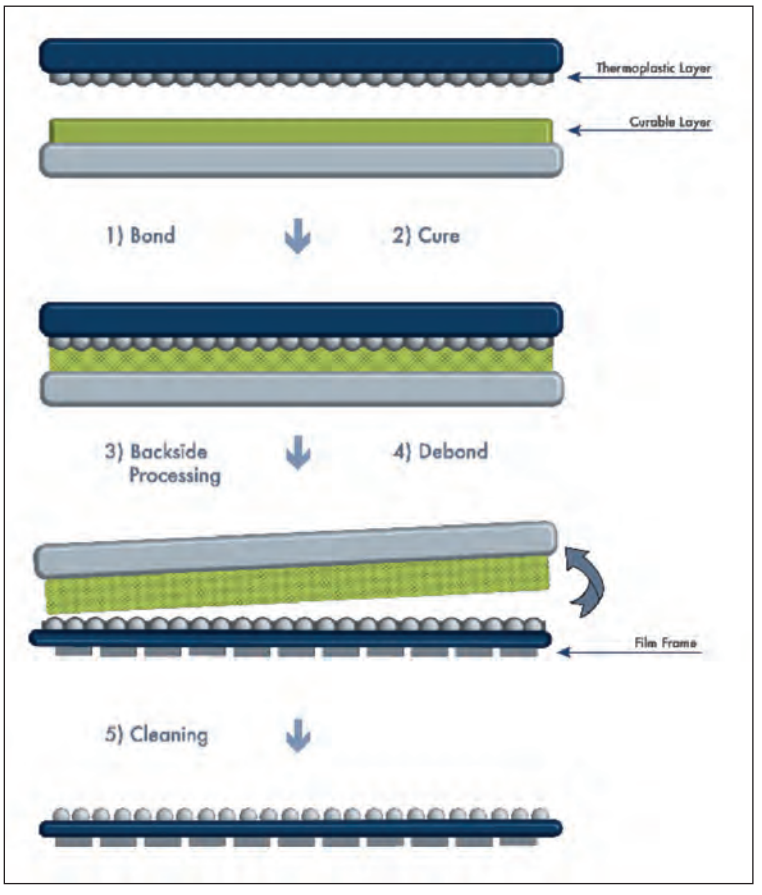


Figure 1: The Brewer Science TBDB process flow using Dual-Layer materials.

BrewerBOND® Dual-Layer materials for TBDB

The latest Brewer Science Dual-Layer materials deliver next-generation bonding system performance for high throughput and thermal stability. The materials also provide room-temperature bonding and debonding for both wafer-level and panel-level processing. Dual-Layer materials support wide-ranging manufacturing requirements, enabling more uniform post-grind device thicknesses of < 50 μm while also enabling device structures (and the temporary bond) to survive high-temperature treatments under vacuum. Figure 2 shows a scanning electron microscope (SEM) image of damage-free device features enabled by Brewer Science Dual-Layer materials and process optimization (left). The same size features using the baseline process are shown on the right.

According to Kim Yess, Brewer Science Executive Director for Wafer-Level Packaging Materials, the Dual-Layer approach of BrewerBOND materials has key advantages compared to the previous solutions offered to the industry.

"The BrewerBOND T1100 series materials are designed to conformally coat the device structures before bonding; the materials have specific rheology attributes for exceptional conformal coating for protection of device structures. The BrewerBOND C1300 material is a curable thermoset layer used in

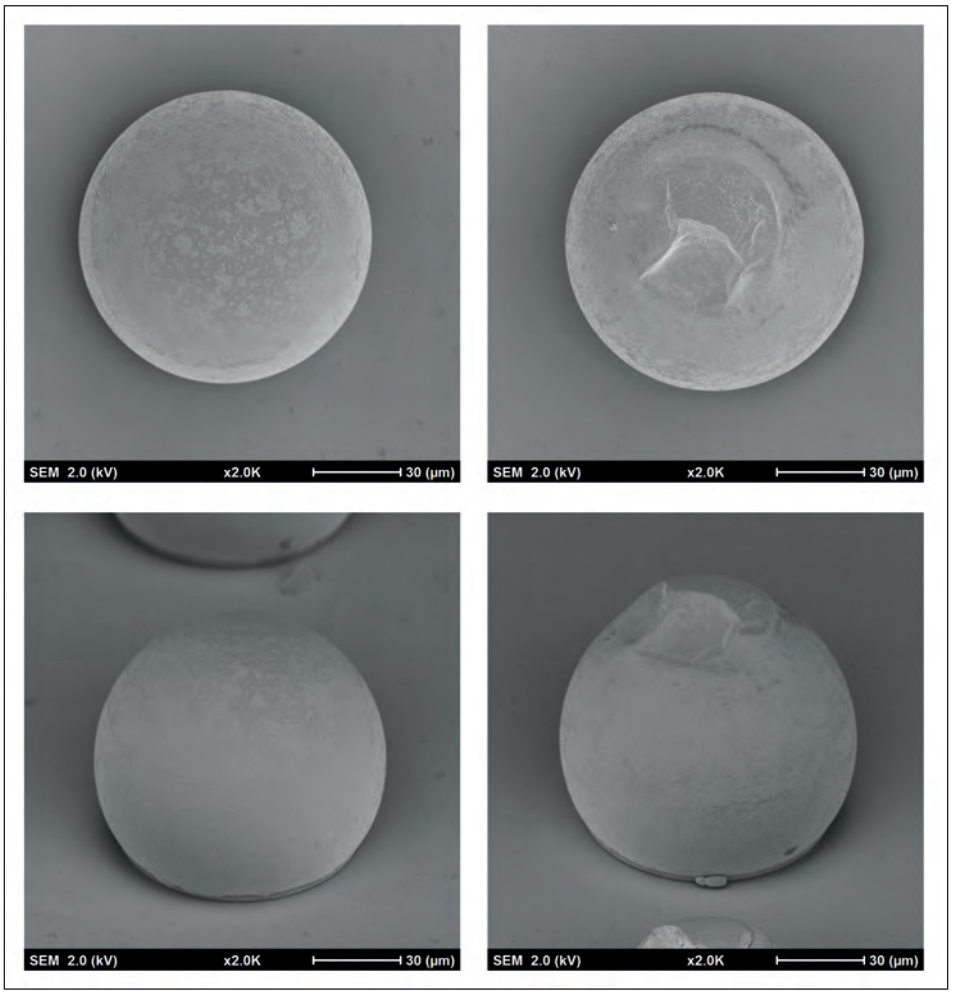


Figure 2: Scanning electron microscope images showing damage-free device features enabled by Brewer Science Dual-Layer materials and process optimization (left) and defects found in the same-sized features (right) that were made using the baseline process.

conjunction with the T1100 series material, which remains malleable until final cure. This will enable the bonded pair to have very low TTV and also survive downstream processes approaching 400°C," she said. Yess explained that the Dual-Layer system includes a low-glass-transition-temperature (low-T_g) thermoset material (BrewerBOND C1300) applied to a carrier. This assembly is then bonded to the device wafer that has been processed with the corresponding higher-T_g bonding material (BrewerBOND T1100) that coats device structures. After bonding and processing at room temperature, the pair can then either be UV exposed or hotplate baked to cure the thermoset material. When processed below 350°C, the BrewerBOND T1100 series material remains solvent-soluble with little to no melt flow up to 300°C. When coated, this material is highly conformal and can cover severe topography even when applied thinly. Figure 3 shows a scanning electron microscope (SEM) cross-section of a 2.15 µm film of BrewerBOND T1100 series material processed over 80-µm solder bumps.

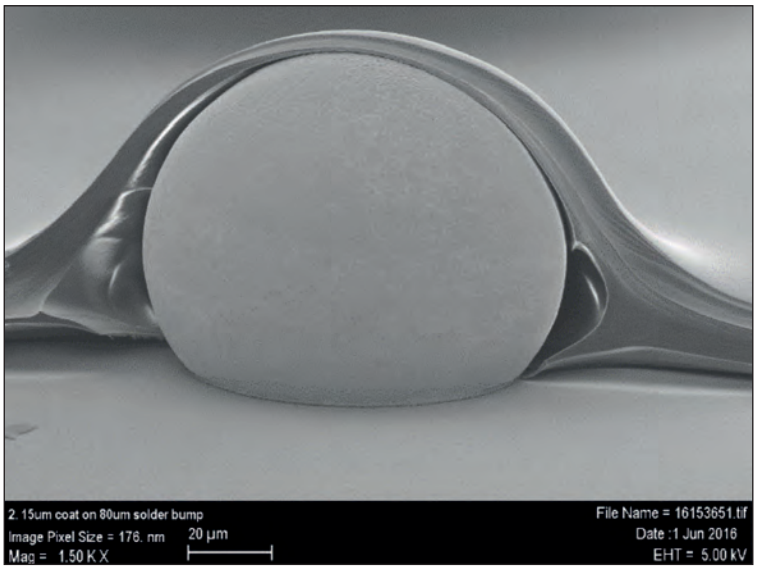


Figure 3: The BrewerBOND T1100 material delivers highly conformal coating and adhesion preperties.

Yess explained that the exceptional performance achieved by their Dual-Layer approach was developed by Brewer Science to optimize the coatings' most essential qualities while making various application steps fit into typical process flows at high throughput levels. (See Table 1 for key materials properties.)

"The BrewerBOND T1100 and C1300 materials need each other to perform to their optimal potential. The BrewerBOND T1100 material is thinner, relatively speaking, and more conformal, which manufacturers need to address ever-shrinking device geometries. It also enables easier downstream cleaning of

Property	Curable Material	Thermoplastic Materials		
	BrewerBOND® C1301-50	BrewerBOND® T1107	BrewerBOND® T1105	BrewerBOND® T1101
Solution viscosity	4675 cP at 24.5°C	160 cP at 24.5°C	100 cP at 24.5°C	75 cP at 24.5°C
Target thickness	25-60 µm	2 µm	2 µm	2 µm
Young's modulus	3.3 MPa	2500 MPa	2500 MPa	2550 MPa
CTE	394 ppm/°C	63 ppm/°C	63 ppm/°C	53 ppm/°C
T_d	420°C	465°C	465°C	375°C
T_g	< -50°C	328°C	328°C	82°C

Table 1: Properties of BrewerBOND advanced materials

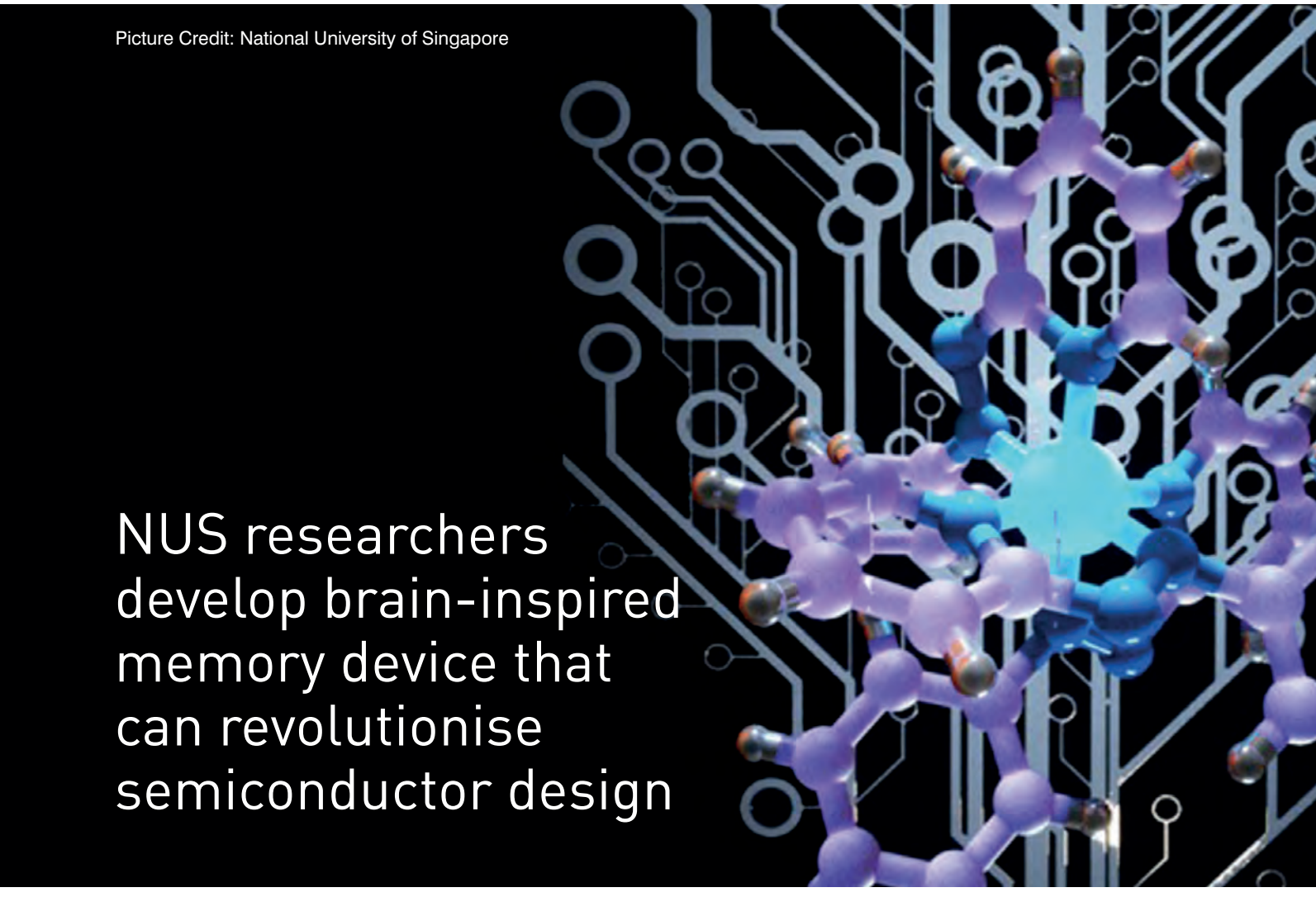
the device. Our BrewerBOND C1300 material creates better stability during higher-temperature processes, which reduces warpage and helps ensure post-processing functionality of the devices being packaged," she said, noting that using the BrewerBOND C1300 material by itself is only one piece of the process and that the thermoplastic is required for the mechanical debond processes.

"Creation of new device structures and their extreme requirements are stretching the limits of the techniques and materials used up to this point. This is why Brewer Science is focusing on developing better materials and processes to enable device manufacturers to achieve the stability and temperature resistance they need for downstream processing, but still retain the ability to remove the coatings as needed simply by using industry-standard cleaning processes and chemicals. By using the right coatings, semiconductor manufacturers can achieve the stability and temperature resistance they need at nano-scale while still retaining the ability to remove coatings as needed," she explained.

Summary

Brewer Science brings leading-edge materials expertise to advanced packaging that is paving the way for innovation through the use of new temporary bonding/debonding materials that uniquely support FOWLP technology requirements. When combined into a system, Brewer Science Dual-Layer materials impart improved mechanical stability that reduces the hazards of handling thinned bonded wafers that need to undergo high-vacuum or high-temperature processing. The materials' conformal nature, room-temperature bonding/debonding characteristics and chemical resistance provide added value and improved performance while reducing cost of ownership.

Dual-Layer materials from Brewer Science also facilitate low-energy laser debond processes that deliver improved protection for the device wafer with low carbon residues, and can also facilitate other debonding methods. As packaging techniques continue to evolve and device geometries shrink even further, Dual-Layer materials have evolved as well, enabling processing wafers thinned to 10 µm. They also protect 3D device structures that are capturing an increasingly large share of overall semiconductor production. Brewer Science continues to develop and deliver advances in temporary bonding and debonding materials to facilitate manufacturers' requirements while formulating new materials to support emerging device packaging technologies now under development.



Picture Credit: National University of Singapore

NUS researchers develop brain-inspired memory device that can revolutionise semiconductor design

Reconfigurable device can simplify semiconductor circuit design and enhance computational power and speed

MANY ELECTRONIC DEVICES TODAY are dependent on semiconductor logic circuits based on switches hard-wired to perform predefined logic functions. Physicists from the National University of Singapore (NUS), together with an international team of researchers, have developed a novel molecular memristor, or an electronic memory device, that has exceptional memory reconfigurability.

Unlike hard-wired standard circuits, the molecular device can be reconfigured using voltage to embed different computational tasks. The energy-efficient new technology, which is capable of enhanced computational power and speed, can potentially be used in edge computing, as well as handheld devices and applications with limited power resource.

"This work is a significant breakthrough in our quest to design low-energy computing. The idea of using multiple switching in a single element draws inspiration from how the brain works and fundamentally reimagines the design strategy of a logic circuit," said Associate Professor Ariando from the NUS Department of Physics who led the research.

The research was first published in the journal Nature on 1 September 2021, and carried out in collaboration with the Indian Association for the Cultivation of Science, Hewlett Packard Enterprise, the University of Limerick, the University of Oklahoma, and Texas A&M University.

Brain-inspired technology

"This new discovery can contribute to developments in edge computing as a sophisticated in-memory computing approach to overcome the von Neumann bottleneck, a delay in computational processing seen in many digital technologies due to the physical separation of memory storage from a device's processor," said Assoc Prof Ariando. The new molecular device also has the potential to contribute to designing next generation

Left: The novel memory device is based on a molecular system that can transition between on and off states at several discrete sequential voltages.

processing chips with enhanced computational power and speed.

“Similar to the flexibility and adaptability of connections in the human brain, our memory device can be reconfigured on the fly for different computational tasks by simply changing applied voltages. Furthermore, like how nerve cells can store memories, the same device can also retain information for future retrieval and processing,” said first author Dr Sreetosh Goswami, Research Fellow from the Department of Physics at NUS.

Research team member Dr Sreebrata Goswami, who was a Senior Research Scientist at NUS and previously Professor at the Indian Association for the Cultivation of Science, conceptualised and designed a molecular system belonging to the chemical family of phenyl azo pyridines that have a central metal atom bound to organic molecules called ligands. “These molecules are like electron sponges that can offer as many as six electron transfers resulting in five different molecular states. The interconnectivity between these states is the key behind the device’s reconfigurability,” explained Dr Sreebrata Goswami.

Dr Sreetosh Goswami created a tiny electrical circuit consisting a 40-nanometer layer of molecular film sandwiched between a top layer of gold, and a bottom layer of gold-infused nanodisc and indium tin oxide. He observed an unprecedented current-voltage profile upon applying a negative voltage to the device. Unlike conventional metal-oxide memristors that are switched on and off at only one fixed voltage, these organic molecular devices could switch between on-off states at several discrete sequential voltages.

Using an imaging technique called Raman spectroscopy, spectral signatures in the vibrational motion of the organic molecule were observed to explain the multiple transitions. Dr Sreebrata Goswami explained, “Sweeping the negative voltage triggered the ligands on the molecule to undergo a series of reduction, or electron-gaining which caused the molecule to transition between off and on states.” The researchers described the behavior of the molecules using a decision tree algorithm with “if-then-else” statements, which is used in the coding of several computer programs, particularly digital games, as compared to the conventional approach of using basic physics-based equations.

New possibilities for energy-efficient devices

Building on their research, the team used the molecular memory devices to run programs for different real-world computational tasks. As a proof of concept, the team demonstrated that their technology could perform complex computations in a single step, and could be reprogrammed to perform another task in the next instant.

An individual molecular memory device could perform the same computational functions as thousands of transistors, making the technology a more powerful and energy-efficient memory option.

“The technology might first be used in handheld devices, like cell phones and sensors, and other applications where power is limited,” added Assoc Prof Ariando.

The team in the midst of building new electronic devices incorporating their innovation, and working with collaborators to conduct simulation and benchmarking relating to existing technologies. Other contributors to the research paper include Abhijeet Patra and Santi Prasad Rath from NUS, Rajib Pramanick from the Indian Association for the Cultivation of Science, Martin Foltin from Hewlett Packard Enterprise, Damien Thompson from the University of Limerick, T. Venkatesan from the University of Oklahoma, and R. Stanley Williams from Texas A&M University.

Developments in the high-end inertial sensor market for harsh environments

The rise of inertial systems used in industrial applications during the last years is driven by the possibility of integrating new functionality at low cost and good performance, mostly thanks to the recent developments in MEMS accelerometer and gyroscope technology.

BY DIMITRIOS DAMIANOS, PHD,SENIOR ANALYST, YOLE DÉVELOPPEMENT

HIGH PERFORMANCE motion sensing is useful in many industries considered to have harsh environments. In the military & aerospace areas, the use of Inertial Measurement Units (IMU), Inertial Navigation Systems (INS) and other systems based on high-performance accelerometers & gyroscopes has been widespread for critical navigation, flight control or stabilization functions for decades, especially in cases where GNSS and GPS signals are lost or not available. In the naval area, navigation through gyrocompassing is a historical application of gyro assemblies.

The rise of inertial systems used in industrial applications during the last years is driven by the possibility of integrating new functionality at low cost and good performance, mostly thanks to the recent developments in MEMS accelerometer and gyroscope technology.

To name a few, structural and machine health monitoring, train tilting and vibration monitoring, autonomous cars and robots, are all benefiting and will continue to do so in the future, as less human intervention is driving innovations.

Figure 1: Application space for high-end inertial systems

The market for accelerometers, gyroscopes, IMU, INS is still a very fragmented market, with many applications, as seen in Figure 1 that can be categorized in four big groups: industrial, commercial aerospace, commercial naval and defense applications. The high-end inertial system market is estimated to be ~$3.2B in 2019, dominated by defense and aerospace applications. In 2020 the market suffered due to the negative impact of covid-19 on cruise ships and logistics ships (tankers, etc), the paralysis of civil aviation and also supply chain problems, causing delays in deliveries across all markets. Commercial aerospace has been the hardest hit, with aircraft orders getting slashed, and with an outlook that doesn't look as bright as before.

Recovery is not expected before 2024. Yole sees the global high-end inertial market growing at a 2.7% annual growth rate, reaching $3.8B in 2025 (Figure 2). Industrial applications will be the most dynamic with more than 11% yearly growth, while the defense and commercial aerospace markets will be pretty much stable, with commercial naval applications growing at a 2% CAGR in the same period (2019-2025). Besides that, rising geopolitical risks could impact the defense market mostly through changes in military spending, however the need for resilient and assured position, navigation and timing (A-PNT) will create opportunities for inertial sensors, as more systems go autonomous.

The industrial market, on the other hand could really rejuvenate the high-end inertial business. In the long term, the market could be pushed by long-awaited industrial applications that have already made their first baby steps: robotic cars, autonomous robots, industrial IoT and and new space applications. During 2020 and 2021, there were a lot of investments and M&A's related to all kind of robotics companies (last-mile delivery, AGV & warehouse logistics, automation, autonomous vehicles, etc) and space companies (launchers, nano-satellites, services, etc). New actors in these domains are coming from various backgrounds who are ready to adopt inertial technologies. In these high-volume applications, integrators will be probably technology-agnostic which could prove beneficial for inertial systems that can achieve a good C-SWAP.

It is key for the companies involved in those markets to invest in the right technologies and partners, depending on the end-markets which are targeted. Different strategies are observed: some companies carefully invest in select technologies like the market leader Honeywell, while others love all inertial technologies, like Northrop Grumman and Safran. Most companies though follow the example of Honeywell, having product lines of a single technology supplying carefully selected integrators. Still, all technologies have a long lifetime and no abrupt shift from one technology to the others is expected, required that players keep their technology up to date.

Several gyro and IMU technologies are currently on the market, with Ring Laser Gyroscope (RLG) and Fiber Optic Gyroscope (FOG) based systems being the most widespread and still benefiting from advances in photonics. FOG has a great reach in various tactical and navigation-grade applications (missile guidance, antenna and platform stabilization, etc), as well as some industrial-grade applications (agriculture, pipeline monitoring, borehole drilling, etc). Integrated solutions are underway, driven by the need for smaller form factor in industrial and tactical grade applications. Such examples are an integrated photonic FOG by KVH or a resonator FOG with integrated Silicon Photonics laser

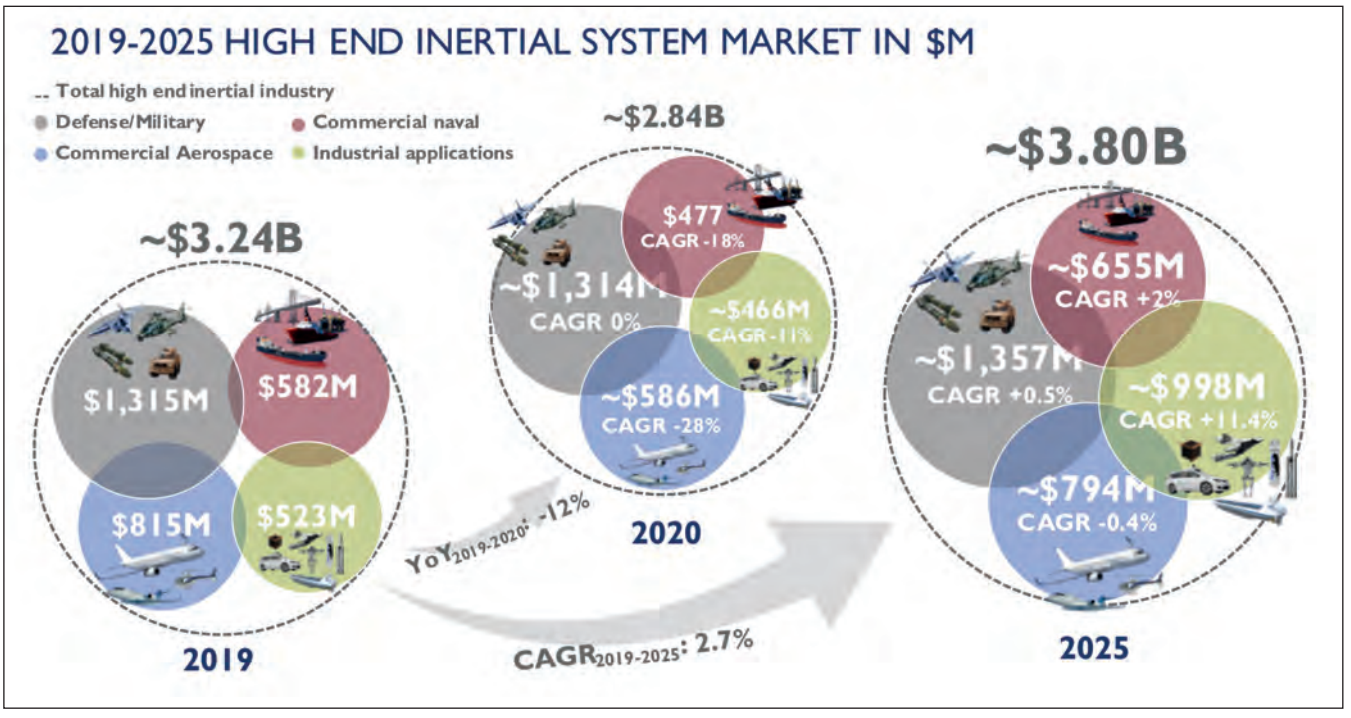


Figure 2: Market forecast for high-end inertial systems by applications for the 2019-2025 period.

sources by Honeywell & TeraXion. RLG is still the legacy technology (and the biggest market) for aerospace and other high-end navigation or strategic applications. Hemispheric Resonator Gyroscope (HRG) was traditionally fabricated by Safran and Northrop Grumman for very high-end and space applications such as satellite guidance.

Now, the technology has potentially experienced a breakthrough on the market, with Safran bringing industrialized manufacturing of the HRG, thus lowering the cost, which is expected to increase the outreach of HRG in the coming years. Finally, MEMS technology is dominating the industrial applications and keeps improving, having the largest impact on the market landscape and on the competition.

Many traditional players try to ride the upcoming MEMS wave, such as Honeywell, Northrop Grumman, Safran, UTC, etc who are already using Si-MEMS technologies. It is not illogical to see a couple of the smaller companies in the domain getting acquired by bigger ones, that need access to specific technology, geographies and clients

While traditionally originating from consumer and other low-end commercial applications, Si-MEMS with a low C-SWAP is continuously improving and pushing FOG out of many industrial and some tactical applications that are considered high-end, at 1-10°/h in-run bias instability performance.

However, Si-MEMS gyros are still immature to expand in other applications that require bias instability below 1°/h. Many traditional players try to ride the upcoming MEMS wave, such as Honeywell, Northrop Grumman, Safran, UTC, etc who are already using Si-MEMS technologies. It is not illogical to see a couple of the smaller companies in the domain getting acquired by bigger ones, that need access to specific technology, geographies and clients. The moment is ripe for bigger companies to buy smaller actors at a good price, that are more flexible in their product and technology development. These strategic decisions could enable the bigger companies have a foot in emerging markets, all the while keeping the strengths in their traditional markets.

High-end inertial sensors are the backbone of new space, autonomous vehicles for commercial or and defense markets (air, land, sea), as well as industrial robots.

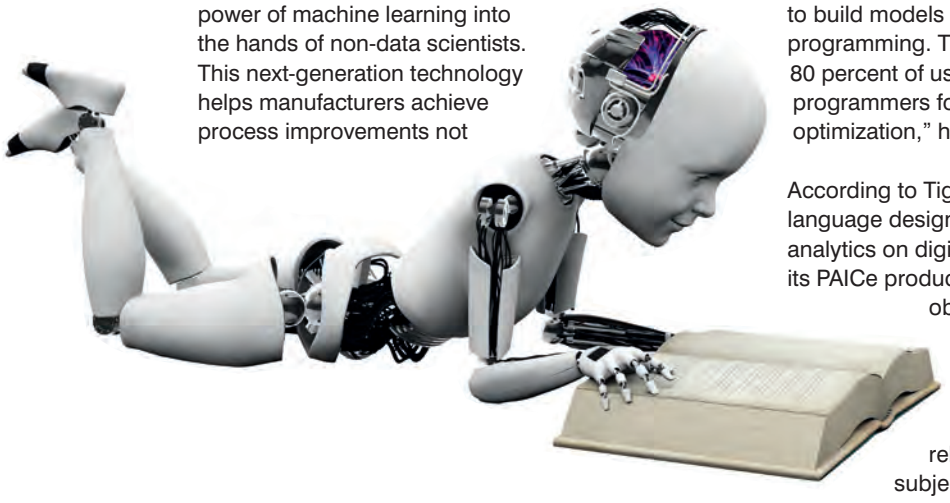
Eventually, one should closely monitor the technology side. MEMS will keep improving and increasing their performances, HRG high-volume manufacturing that could make it spread to many applications and finally photonic integrated FOGs could bring extra value to applications that are dominated by legacy technologies.

Tignis simplifies adding ML to advanced process control manufacturing systems

With the continual buzz around artificial intelligence (AI) and machine learning (ML), one might think it relatively easy to improve manufacturing output by adding a 'bit' of AI/ML to one's IC recipe. But the reality has been far more complicated. Enter the AI process control experts at Tignis who believe they have a new solution that could make ML-driven APC much more accessible and cost-effective.

IMAGINE a small semiconductor manufacturer that wants to add a machine learning-aided application to improve its fabrication process flow. The company is about to discover that besides their process engineer, adding ML capabilities is a multidisciplinary approach with no off-the-shelf solutions that are fast, highly adaptable or easy to implement. According to Tignis, a Seattle-based AI-powered process control company, that paradigm is about to shift.

Tignis announced today its new AI/machine learning analytics tool set that it calls PAICe, which it describes as a solution for companies to add the benefits of AI/ML APC without the substantial investments of time and money that has previously been the norm. Company co-founder and CEO Jon Herlocker told Silicon Semiconductor in a prerelease interview that PAICe is designed to put the power of machine learning into the hands of non-data scientists. This next-generation technology helps manufacturers achieve process improvements not previously possible with today's advanced process control (APC) approaches including the ability to utilize surrogate machine learning models created by Tignis that are more accurate and up to one million times faster than physics-based simulations. This performance enhancement can directly lead to faster production, better quality control and faster time to market.



"In creating PAICe the basic idea is to empower the process engineer. This is the opposite approach that some solutions providers offer today that essentially take a 'magic black box' approach that does what you want, but you have no idea what goes on inside the box and as a customer, you are totally dependent on another company's technology; you give up control. Our approach—using what we call our digital twin query language, or DTQL, is to be able in minutes to build models without even one course in data programming. The basic system is ideal for at least 80 percent of use cases, and we can offer our own programmers for unique situations that need further optimization," he explained.

According to Tignis, their new DTQL is the first language designed specifically to build machine analytics on digital twins. Through DTQL, Tignis says its PAICe product suite significantly removes the obstacles that have prevented engineers from leveraging all the historical data they have collected to help them make better decisions; the new solution enables process and reliability engineers to convert their deep subject matter knowledge into hundreds

of machine learning based predictive models that are easily managed across thousands of diverse physical assets – all without having to become a data-scientist.

The PAICe product suite accelerates the ability to build, validate and deploy machine learning enabled solutions in manufacturing and process industries, with an initial focus on semiconductor manufacturing, oil and gas processing, and energy. It is the latest venture by Jon Herlocker, a serial entrepreneur and deep technologist with a track record of founding and building successful startups, as well as a former VP and CTO at VMware, a $12 billion dollar a year virtual infrastructure management company. Tignis is funded and advised by industry leaders such as software executive Paul Maritz, who is an investor and member of Tignis' board of directors. Maritz was CEO at VMWare, and at Microsoft he was a member of the top executive management team. Harel Kodesh, former CTO of GE Digital, is also an investor.

"The PAICe product suite puts machine learning in the hands of people that have never been able to use it before," said Herlocker. "This is important because machine learning-based control algorithms not only outperform classic feedback or feedforward advanced process control applications, they continuously learn from new process data, reducing the need to retune controls and improve over time. With the PAICe product suite, many more manufacturers will now be able to take advantage of the benefits of machine learning in modern manufacturing and process control by increasing process quality, throughput and yield." The PAICe product suite enables machine learning for more than just predictive maintenance – it enables it for process optimization and its implementation directly into process control loops. It is able to run machine learning-based simulations one million times faster than legacy physics-based simulations, allowing manufacturers to have real time feedback control in places that were not possible in the past such as real-time optimization. Key features of the suite include:

PAICe Builder, a machine learning analytics tool easy enough for anyone to use. It provides simple connectivity to OSIsoft PI data historian and other data sources, and is available in both downloadable or cloud versions, allowing users to do analytics anywhere.

PAICe Monitor, which allows customers to easily deploy their analytics to private or public cloud infrastructure and thousands of assets with one click (including web APIs to ingest and send data to and from data historians). It offers a scalable cloud infrastructure to build analytics as needed; the Tignis managed infrastructure means customers only pay for the resources they need.

PAICe Maker, which deploys and manages machine learning based control algorithms that improve over time with more data. Machine learning models can compute control variables at speeds up to one million times faster than legacy physics-based simulations, allowing real time computation of control. Hybrid on premise and cloud architecture ensures low latency for control but the best possible model training and learning in the cloud.

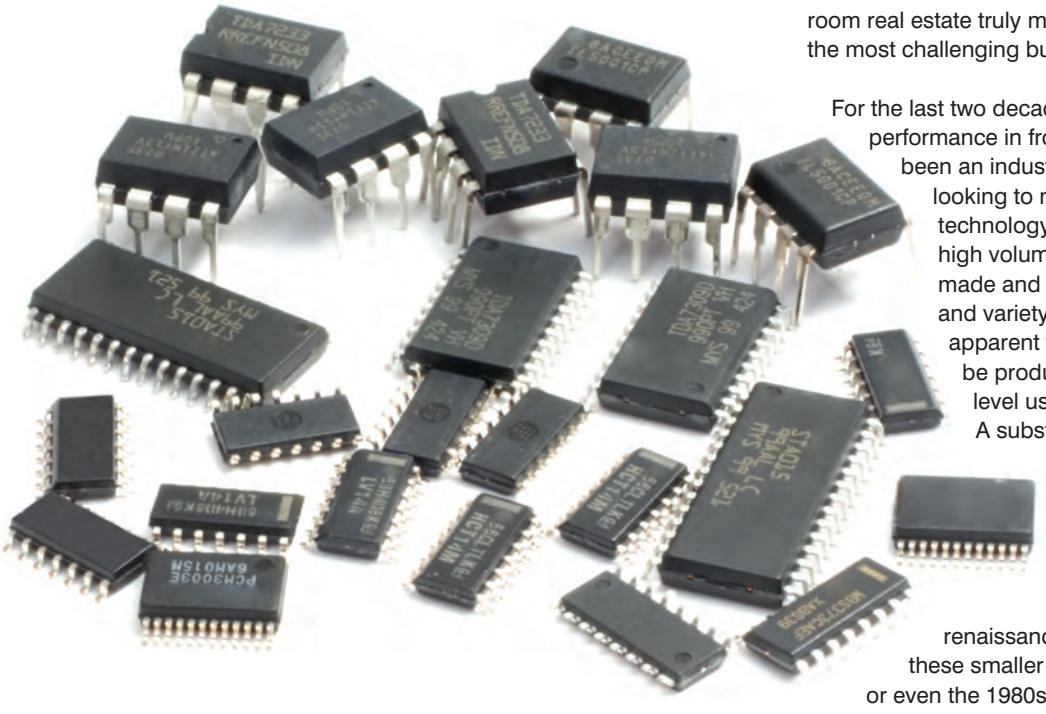
Through the company's extensive beta test program prior to launch, the PAICe product suite is in use by a number industrial clients spanning the oil and gas, semiconductor and energy industries. Some notable users of the product suite include Tokyo Electron (TEL), Synopsys, Etairon, and Optimum Energy. The product suite is now available directly from Tignis; visit www.tignis.com for details.

Advanced MES capabilities can extend semiconductor fab lifetimes

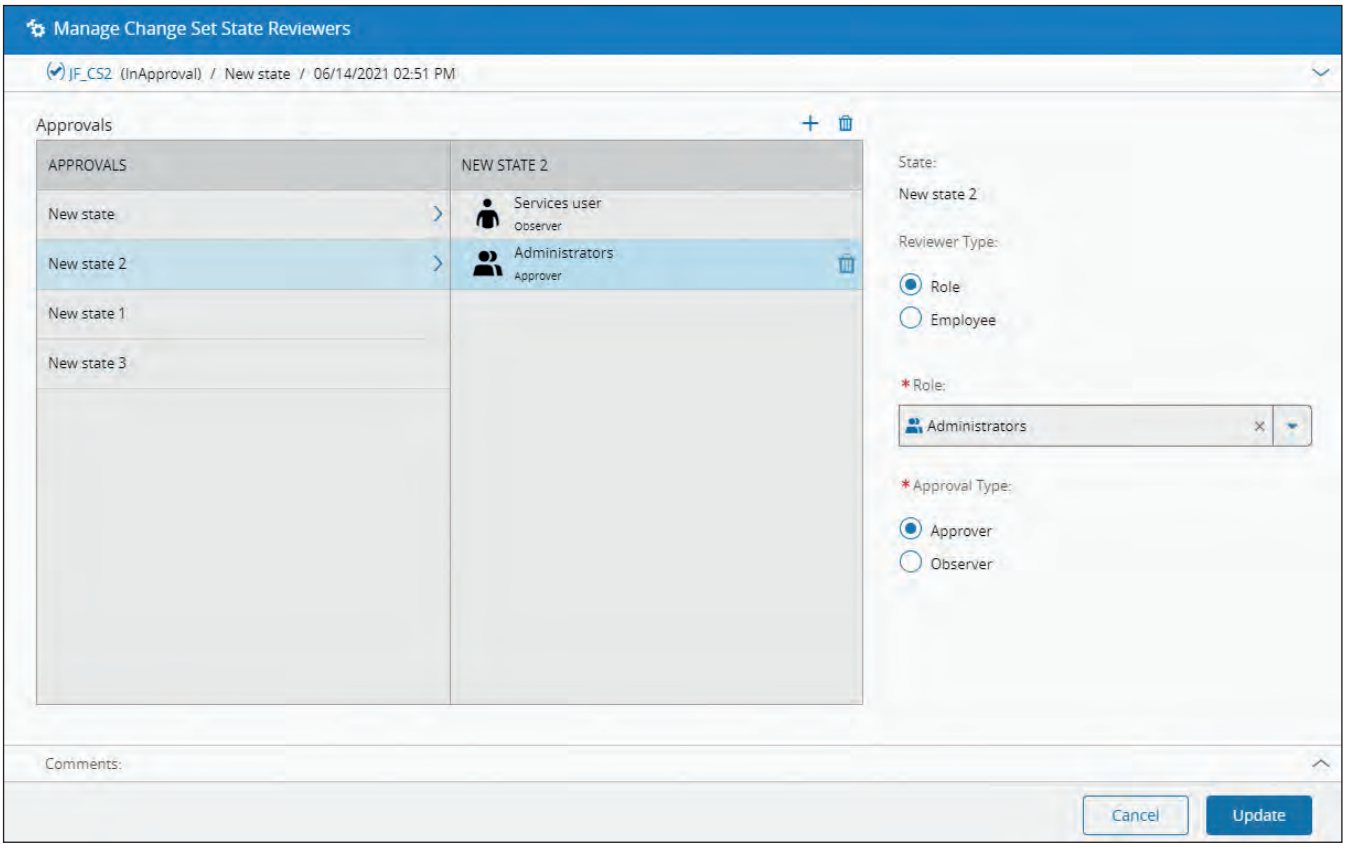
As the current global microelectronics shortage demonstrates, semiconductor manufacturing is not a simple. IC fabs are not created to pivot quickly as much as they are to produce high quality products at low cost. The experts from Critical Manufacturing outline ways advanced manufacturing execution systems (MES) can help fabs maximize output while also extending their serviceable lifetime.

BY CRITICAL MANUFACTURING

SEMICONDUCTOR MANUFACTURING is unquestionably one of the most complex and sensitive manufacturing processes in the world. Creating line widths on silicon wafers down to five nanometers or less with billions of transistors means that even the smallest vibration or misalignment during fabrication will cause issues. Alongside the sophisticated processes required to manufacture, the industry is further challenged with very short product lifecycles involving millions of devices, or, the need for small batches of niche products to be produced over decades. Only a few semiconductor companies in the world can afford to invest in building new, large capacity fabs with the latest equipment and technologies. Incredibly expensive equipment such as extreme ultraviolet (EUV) scanners costing over $125 million each combined with the need for costly clean room real estate truly makes IC manufacturing one of the most challenging business environments.



For the last two decades, increasing wafer size and performance in front-end chip processing has been an industry focus, with manufacturers looking to more expensive 300mm wafer technology to meet demands for quality, high volume products. But as chips are made and used in an increasing number and variety of products, it has become apparent that not every chip needs to be produced at the millions of unit's level using the latest technology. A substantial portion of the ICs made today – even those in advanced products – can still be produced, efficiently and profitably, in smaller 150mm and 200mm fabs, which are experiencing a surprising renaissance in recent years. Many of these smaller fabs started life in the 1990s or even the 1980s; a lot of the equipment dates



One hallmark of a good MES designed to support advanced semiconductor manufacturing is a simple interface; ideally the interface should be: intuitive; support multiple production sites; offer multi-lingual options and provide easy navigation.

back to the last century, but still adhere to industry manufacturing standards. This equipment has what some might consider surprising longevity thanks to frequent upgrades, readily available replacement parts and the addition of more sophisticated robots and sensors combined with comprehensive maintenance programmes.

Smart manufacturing is establishing a foothold in the semiconductor industry and Industry 4.0 technologies are breathing new life into aging process tools to make them run even more cost efficiently. By employing modern manufacturing execution systems (MES), the life of aging semiconductor production facilities can be extended, and advanced capabilities can be added to provide a pathway to the future for the industry.

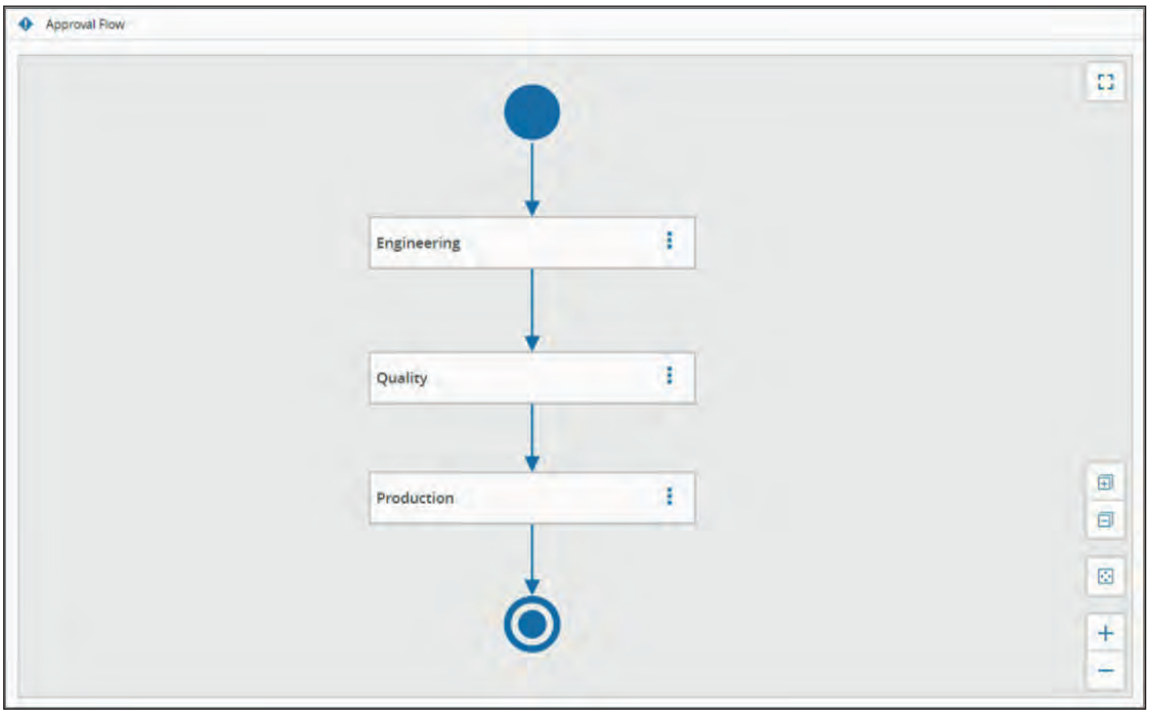
A future-ready MES provides manufacturers with solutions to many challenges. It can add production capacity and throughput by driving efficiency without increasing expensive clean room space. It can enhance production consistency and reduce costly processing errors, reduce time-to-market for new products, and provide solutions to enable the latest, most advanced production steps. Some or all of these benefits may not only be critical for profitability, but may actually be the key to the survival of a company.

Why and which MES

The cost and changing landscape of semiconductor manufacturing needs an MES solution that can adapt for the future. Data is more important than ever and offers manufacturers a way to better monitor and control processes as well as providing deeper insights to help resolve production challenges and support decision making.

As volumes of data continue to increase at a tremendous rate, first and foremost, a future-ready MES needs to incorporate a fully scalable Industrial Internet of Things (IIoT) data platform for ingesting, processing and analyzing the vast volumes of data points that, if contextualized and analyzed correctly, can increase the speed of learning to help drive production efficiency and deliver continuous process improvements.

New fabs and equipment have the capability to be highly automated, but the cost is very high. For older fabs, a modern MES solution presents a way to extend the life of facilities and tools without spending billions of dollars needed to build and equip a new fab. But success requires a highly versatile system that can integrate new IoT devices and legacy equipment to provide full visibility of plant operations. By providing greater control and tighter processing tolerances, the right MES solution can increase production capacity,



In documenting the flow of information and automating such tasks as step change approvals, a simple graphic depiction of hierarchy and process flow (seen here) aids quick comprehension of the task at hand.

efficiency and throughput, presenting significant advantages to producers, especially with the current shortage of chips available in the market.

Older facilities usually have a legacy MES combined with a patchwork of disparate systems that operators have used over the course of years. Long-term operation within a given environment may build confidence, but it is a fact the maintenance of such older systems that consume a great deal of specialized resources since technology upgrades and additional applications have been added over the years.

Because so many resources are focused on keeping an outdated yet familiar system up and running, it is easy to forget that advanced MES now available could substantially improve an organization's capability and profitability. This is especially true for situations where businesses have merged or been acquired; fabs in different locations will often have different MES solutions. This adds an additional maintenance layer to the plant's overhead and inhibits the ability to fully optimize production across multiple sites.

What should older fabs look for from a new MES? One major manufacturer found that bringing disparate systems and processes into a holistic MES solution integrated with ERP delivered substantial benefits. First, it forced them to organize the information and enforce protocols which, in turn, created better understanding and continuous improvement to meet tightening requirements. Having previously used legacy MES technology to guide shop floor processes, the new MES provided much-needed increases in granularity to drive efficiencies. First pass yield increased and cycle times decreased; there was also a beneficial information flow increase, greater visibility into processes and error reduction. Overall, the impact on the bottom line was significant. But perhaps more importantly for the future, the investment made today in a fully scalable MES offers this customer even more ways to reduce costs and increase production capacity through legacy equipment integration and even tighter parameter control while enabling future expansion. Essentially, the customer gained a much more productive present day production environment as well as easier pathways for future expansion.

MES for advanced production scenarios

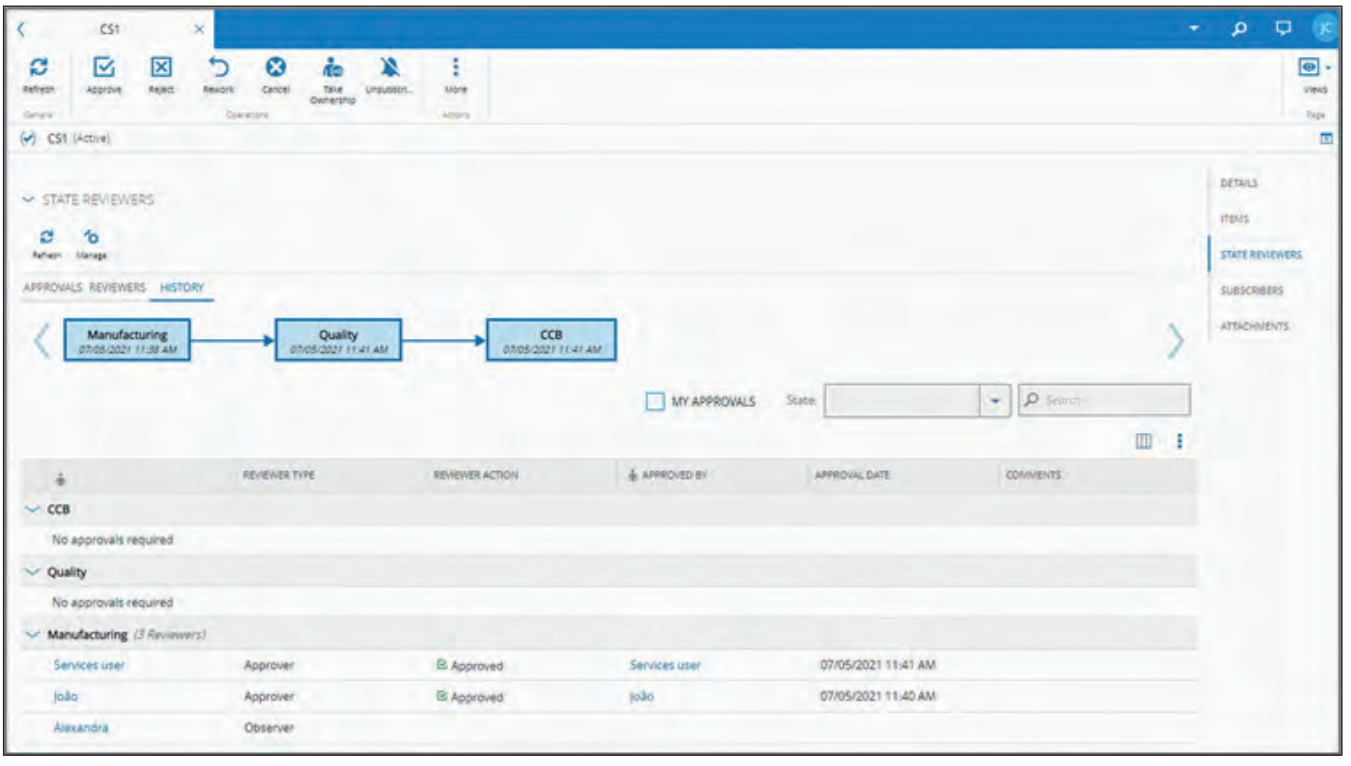
Master data management

Each product in a fab can require the tracking of thousands of pieces of information about process flow, recipes, parameters, reticles, specifications and sampling, to name a few. A modern MES must have the ability to readily maintain and control these huge volumes of data and provide a complete material history for the final product with full change management and versioning control.

It must offer the flexibility to handle common sub-flows with the changes that are made for each layer and provide mechanisms to re-use complete flow blocks while defining appropriate context.

Automatic validation prior to processing

There may be hundreds or even 1,000+ process steps to produce a given semiconductor product, throughout which everything needs to be tracked and checks carried out to ensure there is no misprocessing. Automatic validation prior to processing reduces the risk of errors by validating whether the right product is on the right tool, with the



Typical layout of controls with clear access points; MES tools should always be developed with constant feedback from current and new users.

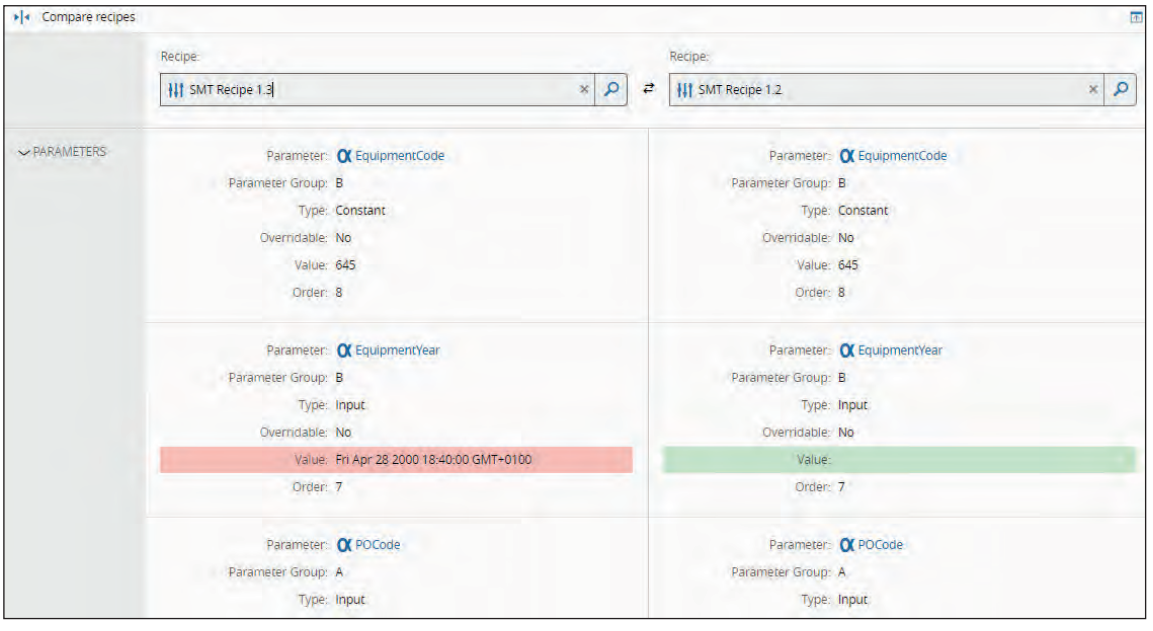
correct recipe and right durable, and the operator has the correct training and authorization.

Multi-chamber tools

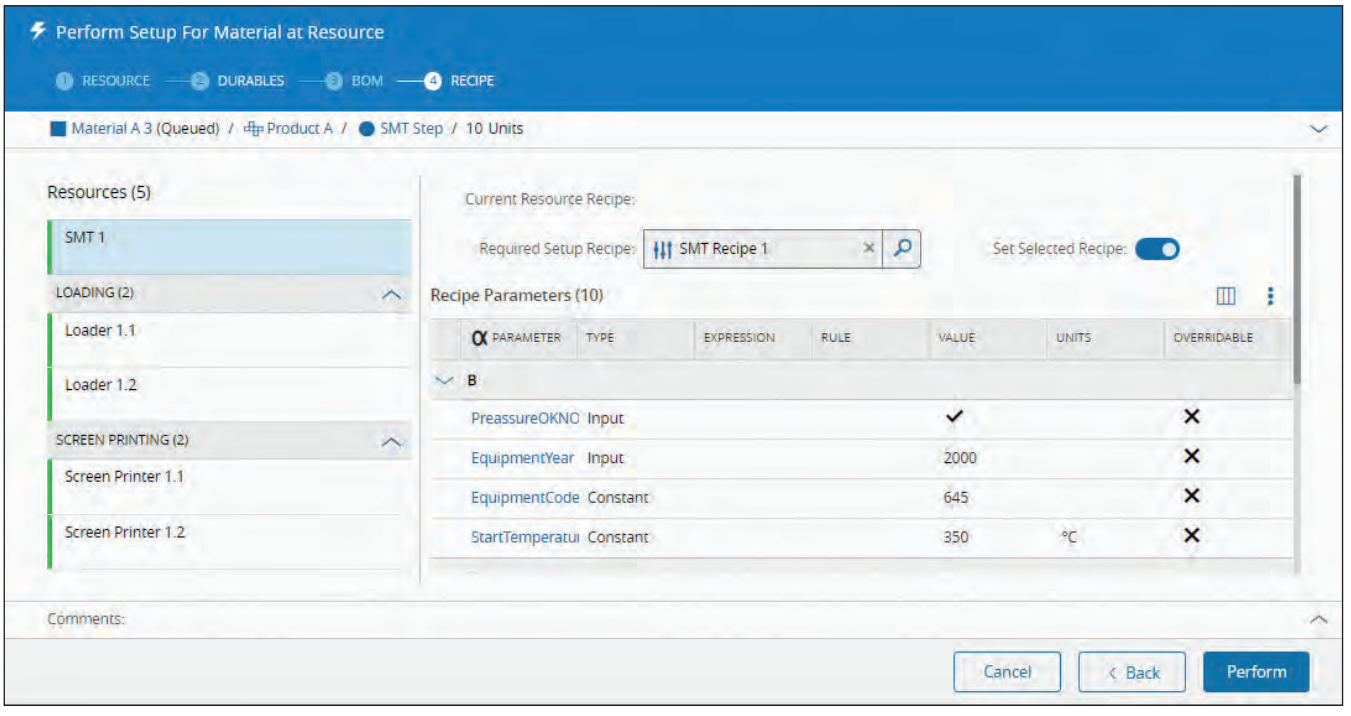
Cluster tools have multiple chambers which can run processes in parallel or sequentially, offering significant efficiencies. Tool vendors typically offer different running modes for maximum efficiency, chamber dedication or some engineering use cases. However, these tools require proper modeling and special control logic in the MES to fully take advantage of the complex capabilities. As an example, if any of the chambers are not working, the MES needs to ascertain whether the machine can still be used for any given product. It also needs to be reflected in KPI calculations such as availability, utilization and OEE.

Experiment management

As many semiconductor products have a short lifecycle, engineering modifications and development products can sometimes account for more than 50% of the wafers in production. This requires efficient



The ability to compare various aspects of a process recipe with those under development is a key benefit any good MES should provide its users.



Recipe management within the MES universe needs to correspond with key reference points as set by production managers and any others the company desires to have access and management privileges.

management of small batches with the ability to adjust process variables and quickly compare results. A Design of Experiments (DoE) module will support processing of experimental wafer groups and allow for the many process variations involved. Integrating this into the MES makes it easy to create experimental runs and execute them together with all other production lots. The inherent tracking and traceability within the MES will further ensure the collection of all necessary data for efficient results evaluation.

Recipe management

Front-end semiconductor processing can involve highly complex recipes; ensuring the right recipe is used for a particular product is crucial. An MES with an integrated recipe management system provides users with the ability to centrally manage recipes and their parameters. Additionally, through equipment integration, upload and download recipes to or from equipment as required can be managed more effectively. Automated recipe management prevents human errors and reduces the need for reworking or scraping wafers.

Front-end semiconductor processing can involve highly complex recipes; ensuring the right recipe is used for a particular product is crucial

Run-to-run

Feedforward and feedback process control is an essential aspect to increasing yield and enhancing quality. An MES can analyze data from the previous batch to determine if any adjustment to recipe parameters is required to consistently maintain tight tolerances. For example, if the results of an etching process are beginning to drift, it may mean that wafers need to remain in the chemical bath for longer, or that the current needs to be increased to achieve the required process results. For complex run-to-run calculations, the MES should be capable of interacting with a dedicated application, such as Matlab.

Reticle management

Alongside tracking wafers, the MES needs to track reticles and probe-cards, ensuring that the correct durable is used while enabling efficient location of any one of the thousands of durables on the shop floor. It must enforce the use of the correct mask at the appropriate processing step and track usage for maintenance purposes. It needs to include data about the mask within the lot history and provide capability to allocate available or even dedicated masks to different process jobs in line with production scheduling.

Send ahead wafer: Splitting and merging

Sometimes it is required to split a wafer from a cassette to send ahead to test a process. This split, in which a single wafer is processed separately, needs to be tracked but the system also needs to be able to merge the wafer back into the lot afterwards. In some cases, this will not involve a physical split of the wafers. Instead, the whole cassette is moved through the send-ahead path with the MES controlling which slots the equipment needs to process while

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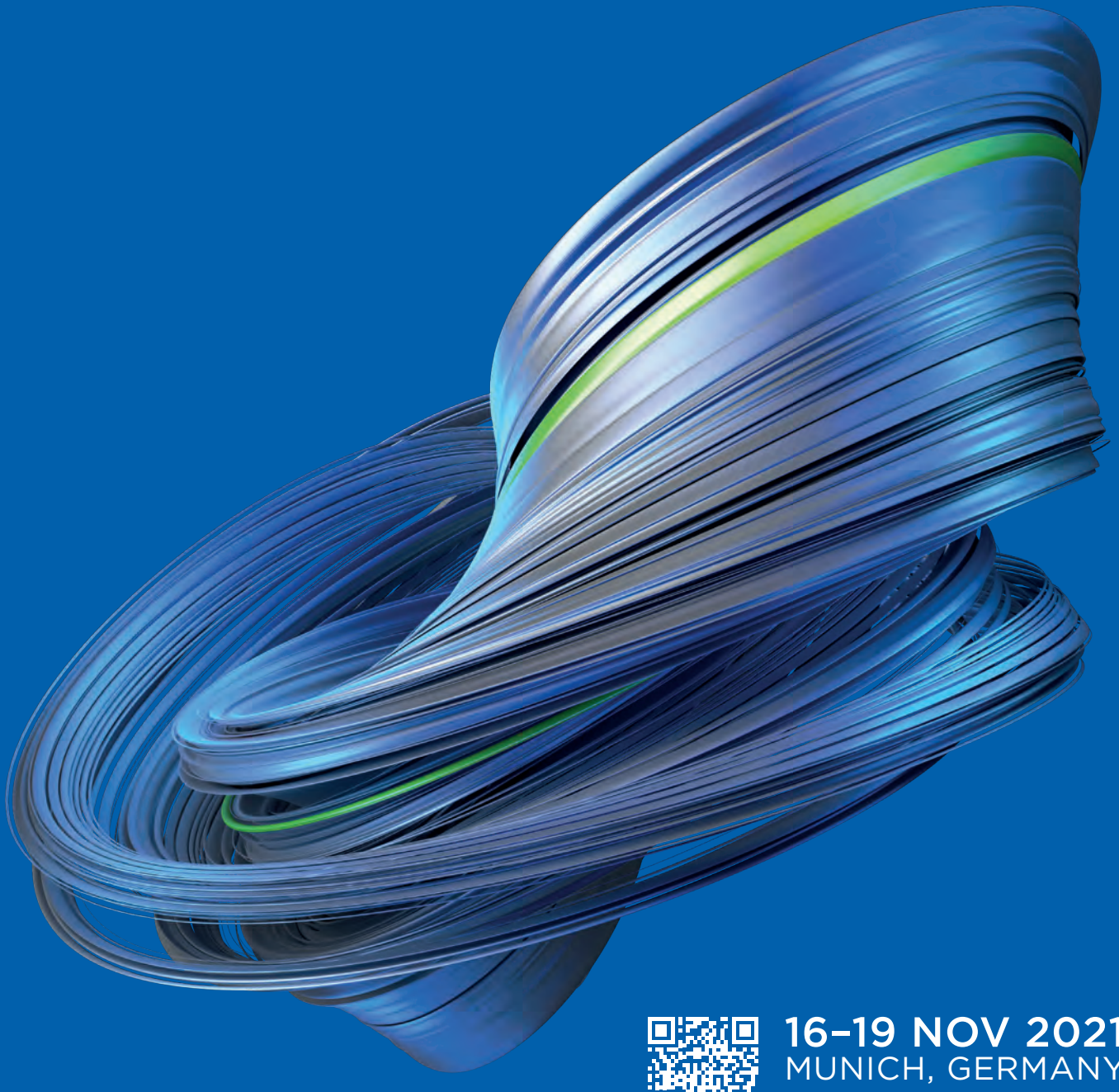

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masking the rest of the wafers. An MES needs to support the creation of a send-ahead run and support the appropriate scenario for the rest of the lot until the success of the process step has been confirmed.

Binning

Although the manner in which wafers that will build microprocessors are manufactured in the same way from one wafer to the next, at the end of processing some chips may perform differently. The most efficient chips can be sold at a higher price. Therefore, it is desirable to grade the chips, which requires the identification of higher and lower performing product. Whether a separate application or part of the MES, binning is a critical production capability.

Container tracking

Whether a cassette, box or FOUP, containers also need to be tracked along with information about their contents. The MES needs to ensure containers are maintained correctly and there is no risk of cross-contamination between processes. It must support the definition of a compatibility matrix between the different contamination classes and automatically increase contamination levels for carriers as they are used. Management of empty containers is important to ensure their timely availability at logistic steps such as lot start, split or transfer.

Time constraints

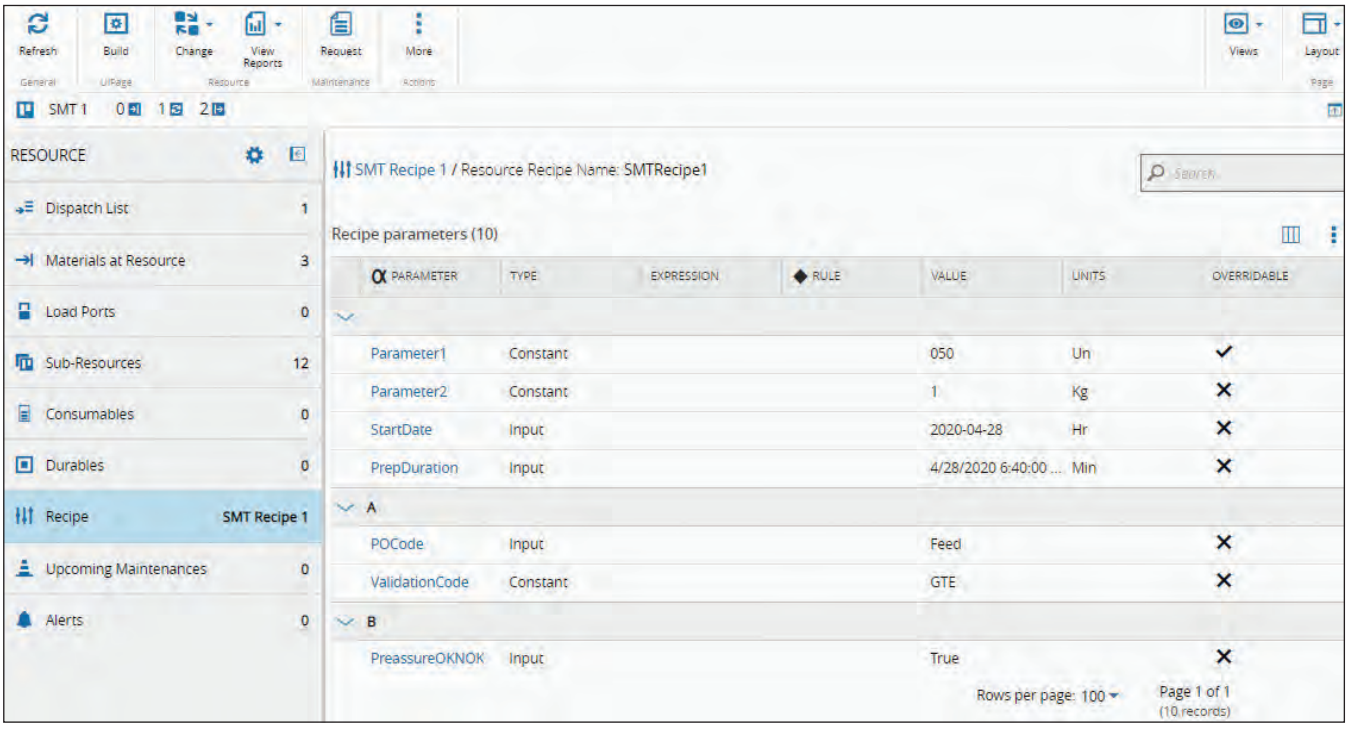
Many front-end manufacturing processes are time sensitive. Also, the time between certain steps very often needs to be monitored as well so that no one step significantly departs from its established tolerance range. The MES must support the definition of process queue time constraints between any process step and ensure all time constraints are adhered to and when they are not, a warning needs to be issued and error rules should come into play if time parameters are violated.

Tool dedication

Busy semiconductor production fabs often need to prioritize certain lots or allocate machines based on their performance on certain product types. A modern MES must support a generic mechanism to set in advance which equipment (chamber, durable, etc.) must be used to process a lot at a particular process step.

Summary

The complexity and variability of front-end semiconductor processing requires a feature-rich but highly flexible MES. A solution should be adaptable to all production scenarios and provide ready scalability to the increasing volumes of data coming from equipment and sensors. With the current high market demand for semiconductors, a modern MES can help older fabs maintain profitable service while extending the life of their tools and operations. It can increase the capabilities of smaller wafer fabs, increase yields, reduce processing errors and increase production speeds. It offers a way to efficiently manage the available data, derive value from it and provide the flexibility to handle adding new sensors, equipment and application modules in the future. An advanced MES is purpose-built for configurability, flexibility and straightforward deployment. Once properly deployed, the MES can reduce overhead costs of managing production systems while extending life of older fabs.



Monitoring process steps and subcomponent modules should be direct with clear access commonalities whether being utilized on the production floor or in management centers.

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How do we protect discoveries without closing the door on innovation and industry growth?

Patents can create more favourable environments for companies to thrive provided they have a suitable IP strategy for their size. In particular, a well-maintained patent portfolio can be a great leveller, allowing small and large players to not only coexist in the market place but also more freely collaborate safe in the knowledge that they will be able to extract fair reward for their contributions.

BY PETE SADLER, PARTNER, ALEX COPE, ASSOCIATE AND ANDY ATTFIELD, ASSOCIATE AT REDDIE & GROSE – a firm of patent, trade mark and design attorneys

INTELLECTUAL PROPERTY (IP) disputes, particularly those involving patents, have attracted headlines in recent years – most notably surrounding the "smartphone patent wars" exemplified by the Apple v Samsung patent litigation saga.

When reading these headlines, it is easy to be left with the impression that patents are leveraged to stifle the innovation of competitors. Indeed, it is true that patents can be used to exclude third parties from entering the market by copying existing ideas. This is because a patent, by definition, provides inventors with a monopoly that excludes others from using the patented invention for a limited period of time. However, digging deeper beyond the headlines reveals that the reality is much more nuanced.

Patents are essential for incentivising investment in research and development (R&D). They provide a tangible record of those bringing new ideas to market and preventing competitors from getting a free ride. Without this protection, companies cannot maximise their growth and leverage their own innovations in the best possible way. Patents also actively encourage innovation by providing companies with the motivation to avoid the threat of legal proceedings by innovating around existing patent rights.

In this article, we will outline how both large and small companies can reap the rewards of an effective IP strategy to improve their position in the market and maximise the benefit of their R&D investments.

Patents overlap and create balance

The bar to getting a patent granted is not as high as many people think. An invention does not need to be ground-breaking, or open up an entirely new field of technology, to be patentable. Indeed, the vast majority of patents are granted for small, incremental improvements to existing technology.

The ability to protect their developments, even relatively small ones, means companies can confidently invest in new research knowing that they will be in a strong position to capitalise on any resulting inventions. This is because they are protected from competitors, who do not have to recoup the R&D costs associated with creating an invention, seeing their new technology when it is brought to market, copying it, and undercutting them on price.

By having a strong patent portfolio, a company is in a better position to invest more heavily in R&D to develop their technology further. This is because their products can command a higher price in the market due to their technological superiority, and thanks to the patent protection, their market position will also be more secure. In this way, the patent system rewards and promotes innovation.

Furthermore, despite providing the proprietor with a temporary monopoly, patents can also encourage cooperation. This is because the protection provided by a patent usually goes beyond the exact way that the patent proprietor may be using their invention to cover the principle behind the invention. When a number of companies are operating in a similar area of technology, they will often each have a collection of overlapping patent rights. This encourages, and sometimes necessitates, cross-licensing agreements between competitors as each may require the right to adopt the others' invention in order to make and sell their own product. Such an arrangement enables technical improvements from different companies to be used in the same product, benefitting the consumer.

On the other hand, without the protection and relative stability provided by patents, companies would be much more hesitant to cooperate and share their developments. This is because, with a patent, the patent proprietor retains control over the invention and can specify how their competitor can use it. Without a patent protecting the invention, however, once disclosed then a competitor can use it in any way they want, and without providing any compensation in return. In such a scenario, the risk associated with cooperation for a company would be much greater, whilst the reward would also be lower.

Patents are good for large and small players

It is often thought that patents are particularly beneficial for large companies – that they are used, and sometimes abused, by these companies to secure market dominance with respect to certain new products (drugs and medicines, for example). This can be the case, particularly in certain industries such as pharmaceuticals.

However, this use of patents does not necessarily stifle innovation. Such use is typical in industries in which new innovations require a huge amount of investment and time to produce. It is often the case that only large companies with deep enough pockets can finance such expensive projects over a timeframe that spans multiple years. If these companies then had no mechanism to recoup this investment, we would expect to see a drop in innovation in these areas of technology. Patents provide precisely the incentive needed for high investment innovation by allowing the company a fixed term monopoly over their innovation in order to recover the costs.

Further, large companies can benefit from patents in any area of technology that requires collaboration with other entities. The benefit can be especially apparent if the collaborative project is investment intensive and has a long timescale. Patents allow each company involved in the collaboration to commit to the project as a viable business strategy as they can recover


Alex Cope


Andy Attfield


Pete Sadler

the costs via cross-licensing. Take the telecoms industry as an example. Standard setting exercises involve huge amounts of time and effort on the part of the participants. The benefits for consumers are huge, such as functioning 4G and 5G networks and smartphones, and are made possible because (among other reasons) the participants are able to protect their innovations and seek cross-licenses from other participants to ensure that they are free to operate in the market.

Of course, large market actors can abuse their position and use patents in ways that are at cross-purposes to innovation. However, such cases, although often high profile, involving expensive litigation, are typically exceptions that can be addressed by judicial intervention or targeted government policy. These exceptions do not reflect the norm and should not be taken as a wholesale reflection on how patents affect innovation. Indeed, examples such as smartphones interoperating with networks worldwide are testament to the patent system working as intended.

What is more, the benefits of patents do not just accrue to large companies with deep pockets. An intelligent patent portfolio can also be highly beneficial to SMEs. Indeed, a study last year published by the European Patent Office (EPO) and the EU Intellectual Property Office (EUIPO) found that SMEs that apply for patents have a greater probability of experiencing high growth than SMEs that do not. One reason is that a good IP strategy can help SMEs attract funding and investment. Investors often use granted patents as a signal for the value of the underlying product, and as evidence that the SME in question is commercially astute and has properly considered its IP.

Another is that IP rights can help an SME protect their market position, especially against larger actors in the market. It gives them a "seat at the table" so to speak, and a foundation from which they can enter into negotiations with companies that may not otherwise take them seriously. Just look at industry leaders Arm for example. Arm started off in 1990 in a barn in Cambridge and by 1998 were a billion-dollar company. They decided on an IP business model, licensing their processor designs to many semiconductor companies. Their IP allowed them to partner with their customers in a way that would have been much more difficult without a robust IP portfolio to protect their interests.

Thus, IP rights may open up new opportunities for business collaboration by, for example, entering into mutually beneficial agreements with other parties through cross-licensing of complimentary IP assets. In short, IP rights such as patents are flexible assets that can usefully be used by SMEs or larger companies as part of a wider business strategy.

Conclusion

Patents can create more favourable environments for companies to thrive provided they have a suitable IP strategy for their size. In particular, a well-maintained patent portfolio can be a great leveller, allowing small and large players to not only coexist in the market place but also more freely collaborate safe in the knowledge that they will be able to extract fair reward for their contributions.

However, to extract maximum benefit from a patent portfolio it doesn't just end with protecting your own technology. It is important to know whether your competitors have patents covering your technology and vice versa. An overlap in protection with competitors helps a company to maintain market position, putting them in a stronger position to continue to innovate and grow.

To extract maximum benefit from a patent portfolio it doesn't just end with protecting your own technology. It is important to know whether your competitors have patents covering your technology and vice versa

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Outsourced SAM testing provides a cost-effective solution for testing and failure analysis

Ultrasonic-based Scanning Acoustic Microscopy (SAM) has long been the method of choice for quality testing and failure analysis of silicon ingots, wafers, integrated circuits, MEMS, and other electronic packages. Ultrasound can locate voids and disbonds between material layers better than other non-destructive methods because sound waves can look inside the layers to detect the thinnest of air gaps and delaminations down to a hundredth of a micron.

BY LISA LOGAN, SAM APPLICATIONS MANAGER, AT PVA TEPLA

INCREASINGLY, manufacturers in the industrial, aerospace and medical sectors are turning to SAM technology to ensure good adhesion and mechanical integrity of devices by examining their internal structures, interfaces, and surfaces. Because potential defects can occur in different layers, more advanced equipment is required to inspect each simultaneously.

Many are choosing to outsource SAM services rather than do this quality testing in-house. Outsourcing offers manufacturers key advantages, including capital cost savings on SAM systems, access to specialized expertise in image management and analysis, and the ability to diagnose and isolate material defects. "Customers typically come to us for SAM testing to address one of three needs," says Lisa Logan, SAM Applications Manager, at Sunnyvale, California-based PVA TePla America provides contract services and sales for both PVA TePla Analytical and OKOS, both of which design and manufacture advanced Scanning Acoustic Microscopes. "As part of product R&D, an engineering team may be evaluating welds, bonds, or the effectiveness of an adhesive. When a product is in production, we may be asked to scan trays of parts for quality assurance testing. We may also use SAM testing to investigate why a particular part failed."

"Often, when customers come to us, they don't know what problem they have. If it is relatively easy to solve, investing the time and expense in bringing a SAM system in-house is unnecessary," she adds.

Contracting SAM services can also be a better match for one-time projects.

"The customer's project may be finite," said Logan. "They may only need to scan 10,000 parts, and then the project is done. It is much more cost-effective to outsource the work in this case."

"Convenience is a big factor, too," adds Logan. "It is just simpler to give parts to a trusted partner to evaluate. Our customers often give us a part to analyze when they can't isolate the issue and ask us to use our expertise to determine the problem for them."

Problem solving

Newark, California-based California Brazing uses SAM testing to validate and verify processes required by its customers and comply with American Welding Society specifications for brazing of materials such as aluminum, stainless steel, and copper. Metals are joined together in the brazing process by melting and flowing a filler material into a joint without melting the workpieces.

"Brazing specifications define accepted quality requirements for analyzing internal discontinuities using non-destructive testing," said Jeff Ager, General Manager of California Brazing.

"In our experience, ultrasound [SAM] gives us the highest resolution images, and they are also easier to interpret than with x-ray technology."

"We use the SAM technology to validate and verify that our processes are always in spec. This testing happens initially on a new build of a part, particularly for our aerospace and defense customers, because of their unique requirements. These parts can be all sizes - anywhere from 1 inch by 1 inch to as large as 30 by 30 inches."

He added, "when we have potential brazing failures to investigate, we first go to Lisa and her team at PVA TePla for testing to pinpoint exactly where it occurred. If necessary, we follow-up with destructive testing too, but only after we've identified the precise location of the failure using SAM."

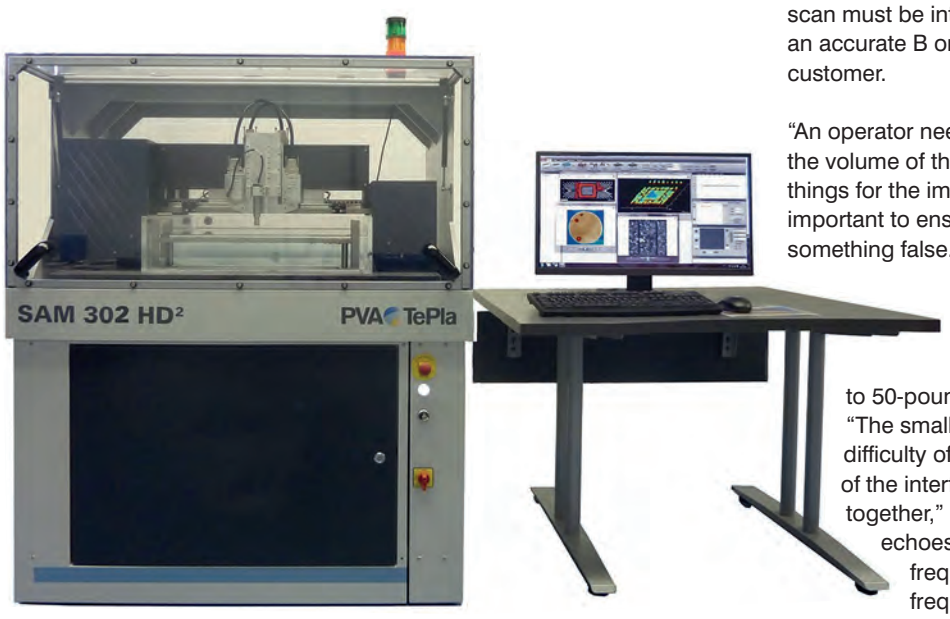
Superior non-destructive testing

SAM uses the interaction of acoustic waves with the elastic properties of a specimen to image the interior of an opaque material. A transducer, the heart of a SAM system, directs focused sound at a small point on a target object. The sound hitting the object is either scattered, absorbed, reflected (scattered at 180 degrees), or transmitted (scattered at 0 degrees). By detecting the direction of scattered pulses and the "time of flight", the presence of a boundary or object can be determined as well as its distance.

To produce an image using SAM, samples are scanned point by point and line by line. Scanning modes range from single-layer views to tray scans and cross-sections. Multi-layer scans can include up to 50 independent layers.

The resolution of the microscopic image depends on the acoustic frequency, material properties, and aperture of the transducer. Transducers perform such a critical role that manufacturers like PVA TePla design and manufacture an extensive range of different transducers used in their contracted testing services. The frequency of the ultrasonic signals can be increased to the GHz range, which makes it possible to detect defects in the sub-micron range.

At PVA, their contract testing services are performed only on equipment the company manufactures, namely the 300, 302 HD2, 500, and 501 HD2 scanners. These scanners provide scanning ranges from 200 μm x 200 μm to 500 mm x 500 mm using transducers up to 400 MHz. PVA's proprietary transducers deliver high image resolution to



evaluate the integrity of each part. Given the critical role it plays, in-depth knowledge of the advanced software features available is another considerable benefit.

"SAM testing houses that purchase equipment may only be familiar with some of the features of the software," says Logan. "As the manufacturer, we have to understand all the features and can even request customizations if needed."

A matter of interpretation

The quality of the equipment and knowledge of its use is only one factor in SAM testing. Operating a SAM system requires a trained technician and, even more importantly, experience configuring the equipment and interpreting the scans. Setting up the scans and interpreting the images is similar to a radiologist reading MRI scans of a medical patient.

"Imagine if you got an MRI," said Logan. "Wouldn't you want your doctor to have the clearest image possible to make the best medical decision? When you realize that an undetected flaw can have a catastrophic impact on a part, it's the same for quality testing too."

SAM system experts know how to work with three different imaging modes, A, B, and C. The A mode is an X, Y, or Z point and provides information on all the echoes occurring inside of a part. These echoes provide valuable insight into material analysis, time-of-flight imaging, amplitude, and polarity. The A scan must be interpreted appropriately to produce an accurate B or C scan, which is shared with the customer.

"An operator needs to interpret, focus and change the volume of the A scan as well as adjust certain things for the image to be accurate," said Logan. "It is important to ensure that the image does not convey something false."

According to Logan, PVA TePla typically tests products ranging from the smallest electronic components to 50-pound aluminum parts. "The smallest and thinnest parts increase the difficulty of interpretation because the echoes of the interface become really tiny and close together," said Logan. "It causes an overlap of echoes, and you end up having to adjust the frequencies used. As you go higher up in frequency, it is more difficult to manage the transducers."

According to California Brazing's Ager, "we have thought about bringing ultrasonic testing in-house, but to be able to do it well, we need someone who can read the images and help interpret them. It is not easy to find people who have that depth of experience." "We have a very good working relationship with PVA TePla," said Ager. "As a result, there is very little interaction needed because she's so familiar with our process and the types of products we manufacture. I think that's the biggest advantage – a deep understanding of our process."

"We typically get our results from PVA TePla in a few days, said Ager. "We might have a conversation about focusing further on a particular area or a certain level, after which Lisa would go back and focus on that."

Finding your SAM partner

When selecting a SAM partner to outsource quality testing and failure analysis, manufacturers should consider how well the SAM equipment matches their testing needs and the breadth and depth of experience of the testing team.

In-depth knowledge of the SAM equipment is critical to optimize image resolution. The ideal situation is having factory-level experience in the manufacturing of acoustic microscopes and their software development. With a strong SAM outsourced partner, manufacturers effectively add a powerful resource to resolve their quality testing and failure analysis challenges.

The quality of the equipment and knowledge of its use is only one factor in SAM testing. Operating a SAM system requires a trained technician and, even more importantly, experience configuring the equipment and interpreting the scans

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Today's digital transformation demands better bulk gas delivery

Today's digital transformations are happening faster than ever. And as technology evolves, so should the systems and solutions that support it.

DIGITAL DEVICES and smart tech are driving rapid growth in the semiconductor industry, with the 300mm silicon wafer market expected to reach $10.570 billion by the end of 2027, growing at a compound annual growth rate of 5.1% over the next five years. Further, the current semiconductor shortage has led to an even greater demand for these materials and put more pressure on fabs to increase output.

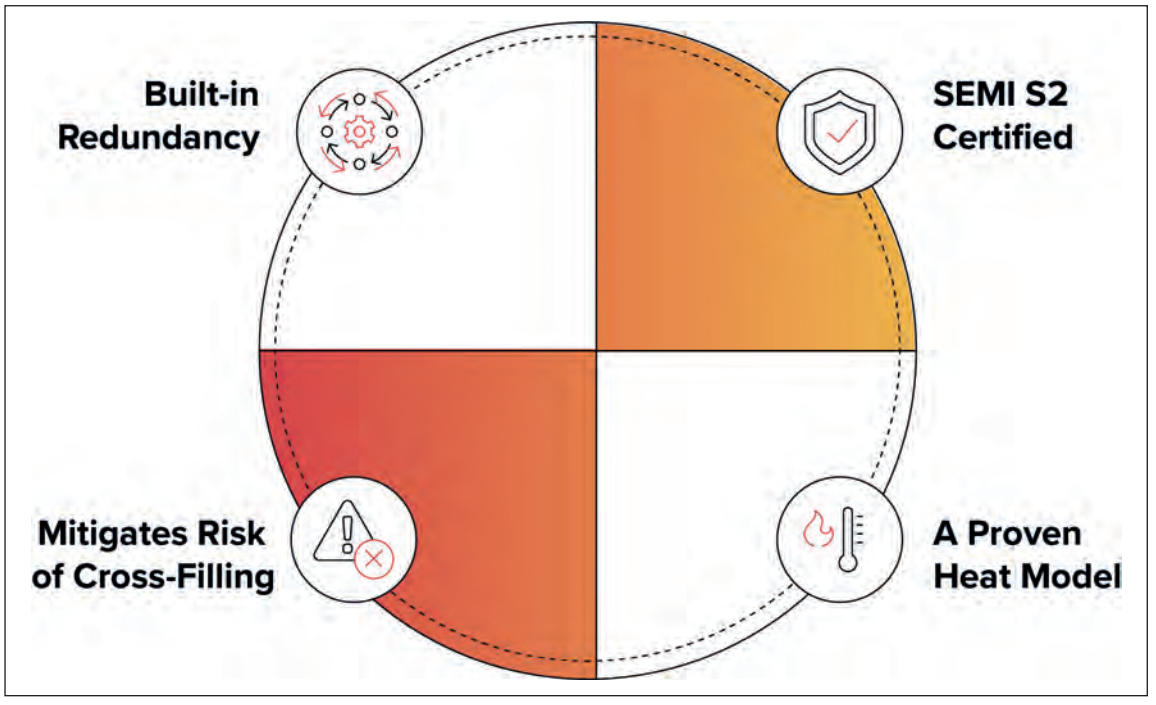
Semiconductors are built and shaped using largely gas materials. Gases have the ability to create chemical reactions at the molecular level, helping to shape a semiconductor's electrical conducting properties to allow or prevent the movement of electrons. But in order to ensure the semiconductor is configured to properly regulate electron movement, these gases must be precisely dispensed at every stage of its engineering process to incite the right reactions.

Bulk gas delivery systems that support higher flow rates can solve today's need to increase output – but they have engineering hurdles that must be overcome. In particular, there are unique thermodynamic challenges when handling larger flows, and under-equipped delivery solutions can result in serious compromises to safety and reliability.

Bulk Gas Delivery Systems' Benefits and Challenges

There are many benefits of bulk gas delivery systems, including longer run times, less potential risk, and better production uptime. However, bulk gas systems have a few challenges, especially in regards to heating and size. To safely reach higher flow rates, gases must be properly heated to maintain a consistent temperature. Complications can take place when adding a system to existing infrastructure, as bulk gas delivery equipment can be large, making it difficult to position bulk systems close to the source.

To take advantage of the benefits of a bulk gas delivery system, engineers must critically evaluate its available features to ensure they gain the output benefits of a bulk system – without compromising on safety and performance.



➤ There are four key areas to consider in order to ensure your bulk gas delivery system is up to the challenge of today's industry demands.

Let's explore four key areas to consider to ensure your bulk gas delivery system is up to the challenge.

- **Determine if the System is SEMI S2 Certified**
  The bulk gas delivery system should be SEMI S2 compliant - upholding the standards set by SEMI for the safety and design of equipment. For bulk gas delivery equipment, this means that systems should comply with requirements for hazard alert labels, safety interlock systems, emergency shutdown, hazardous energy isolation, seismic protection, and more. AES' SEMI-GAS® Megaturion™ Bulk Gas Delivery equipment is SEMI S2 compliant and built for the high-volume handling and delivery of hazardous gases like NH3, HCl, AsH3, and SiH4.

- **Confirm that the System Has a Proven Heat Model**
  When fabricating wafers, gas flow rates can vary from 100 LPM to over 700 LPM. Due to this range of flow rates, weights, and pressures, the bulk gas delivery system's heating design must account for a wide range of conditions to maintain consistent temperatures. To ensure the heating model does not fall short, it's critical to confirm that it can be applied at varying flow rates and that system alarms can be adjusted to meet process-dependent thresholds.

- **Maintain the System's Built-in Redundancy**
  Uptime is critical for today's fabs, and complete redundancy ensures that bulk gas delivery systems mitigate failures. But this redundancy should not be limited to gas cabinets alone. An ideal solution will have multiple controllers on a cabinet, so the system is not reliant on a single control technology. These controllers can operate independently and also interface together with controllers on other systems to orchestrate processes efficiently. AES' SEMI-GAS GigaGuard™ controllers offer intuitive, safe, and precise ultra high purity gas system control, with continuous monitoring and easy management of gas delivery systems.

- **Ensure the System Mitigates the Risk of Cross-Filling**
  In a multi-cylinder bulk gas delivery system, cross-filling happens when cylinders empty at different rates. If this occurs, gas from a fuller cylinder can flow into a drained vessel, which risks cross-contamination. It's critical to ensure gases drain evenly, and to do so, a system's software must account for heat flux variations and modify blanket set points to maintain consistent draw across multiple cylinders.

Maintain Bulk Gas Performance with the Right Partner

Today's fabs remain under intense pressure to maintain efficiency and optimize output – no small task during the current semiconductor shortage that has drastically increased demands. Having the right partner in place is crucial to maintaining success throughout this challenging time.

By implementing a S2 compliant UHP gas delivery system, semiconductor leaders are assured that their systems are ensuring safe, high-performance delivery.

To learn more about how the right bulk gas delivery system empowers semiconductor fabs to increase output, visit www.appliedenergysystems.com

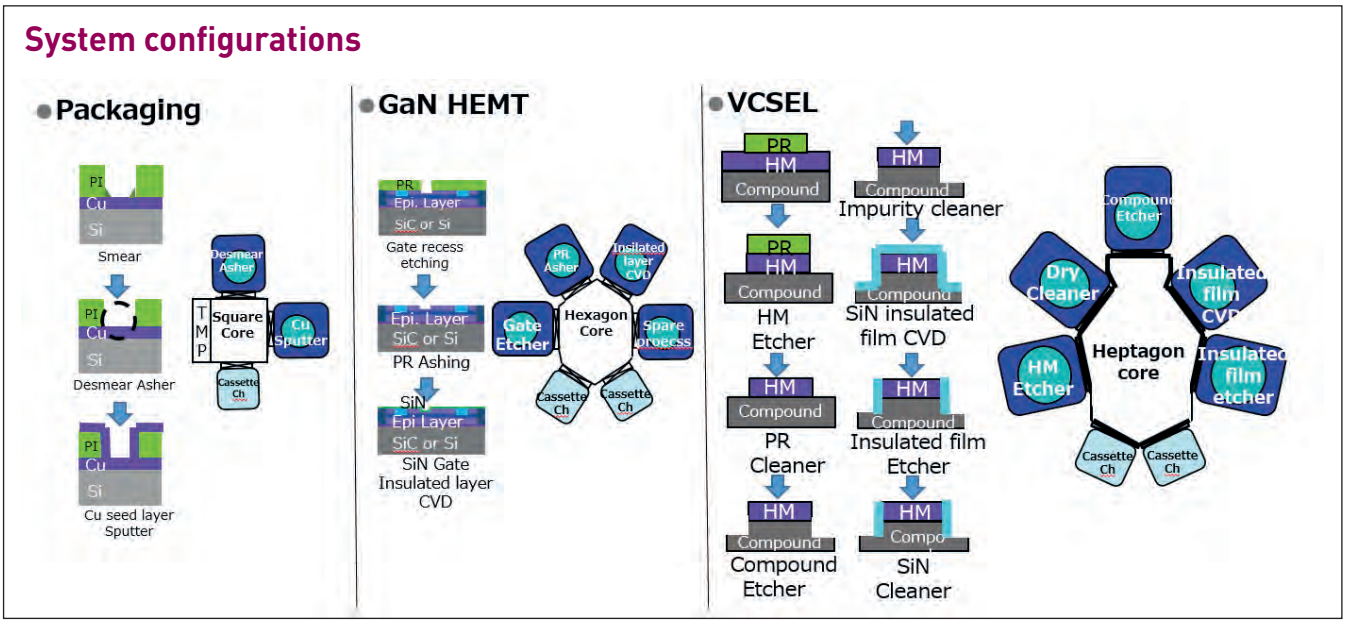
ULVAC uGmni Cluster System for Advanced Microelectronics

The ULVAC uGmni, all-in-one tool provides different process modules such as sputtering, etching and others on the same transfer core. The system uses the same operation panel between different modules making the system easier to use. Common parts used throughout the process modules greatly reducing spare parts requirements. This improves efficiency and reduces the cost for manufacturing advanced electronics.

ULVAC's new uGmni is available in three platforms: SQUARE, HEXAGON and HEPTAGON core options. Each core can equip two, four or up to five process modules, respectively. Flexible module options based on process requirements permit customers to mix and match chambers to best suit their application.

- Sputter (uGmni -200S), Etcher (uGmni -200E), Asher (uGmni -200A) & PE-CVD (uGmni -200C) modules
- Common Core software shared by all platforms
- Straight forward field upgrades add capacity as required

System configurations



uGmni can be configured with the transfer core and process modules best suited for the users application

- Spare parts commonality reduces CoO

Applications

Power device	Seed & Metal layer Sputtering
MEMS senso	PZT Sputtering & Etching
Opt. device	VCSEL Etching
Packaging	Descum Ashing
Communication	Insulated film PE-CVD and Etching

ULVAC

About ULVAC Europe

ULVAC GmbH was established in 1987 as the European subsidiary of ULVAC, Inc. Headquartered in Munich, Germany. From Munich, our sales and service team serve the EMEA region. ULVAC provides a very broad portfolio of manufacturing equipment for the vacuum, materials, and thin film industries.

ULVAC's solutions diversely incorporate equipment, materials, analysis, and services for semiconductors, MEMS, flat panel displays, electronic components, PCB, TFB and other vacuum equipment.

ULVAC offers state-of-art products and technologies for semiconductor and related processes.

To support MEMS, power devices, and NVM fabrication, ULVAC offers equipment for sputtering, evaporation, plasma etch, ashing, ion implanting, oxidation/POA/nitridization, and activation annealing for both R&D, pilot line, as well as high volume manufacturing.

A complete line of vacuum components is also offered which includes vacuum pumps of all types, helium leak detectors, UHV systems and gauges, RGA's and thermal analysis instrumentation.

At ULVAC we pursue leadership in vacuum technology to realize innovation for our customers.

Contact ULVAC today, and discover how we can work for you.
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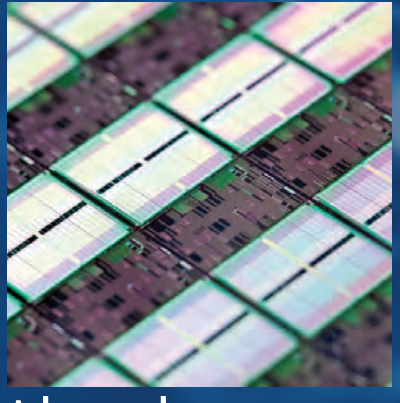
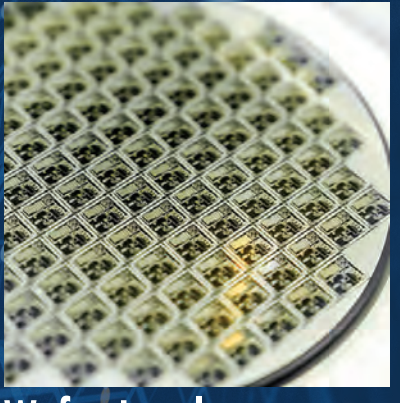


Advanced Lithography

Smart Devices and PE Foundry



Wafer-Level Packaging

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