Product Competitiveness

Medium-term Goals: Create Strong Next-generation Products

With semiconductors and flat panel displays becoming increasingly important as social infrastructure due to the progression of digital transformation and the expanded implementation of information and communication technologies, there is a demand for highly advantageous equipment that responds to diversifying needs. Tokyo Electron creates the best, high-value-added equipment with innovative technology in a timely manner through the development of product marketing and the global promotion of research and development with an eye on future generations. We also continuously strive to reduce the environmental impact of our equipment. By providing technology that contributes to the development of devices with even lower power consumption, we endeavor to preserve the global environment. We contribute to the development of industry and society through innovative technologies and environmental initiatives.

Main activities

Research and development

Research and development for the future, Development system, Shift Left, Product marketing, Collaboration with consortiums and academia, Intellectual property management

Tackling technological innovation

Research and development for next-generation computing, Promoting digital transformation (DX), Support for evolving displays

SDGs initiatives

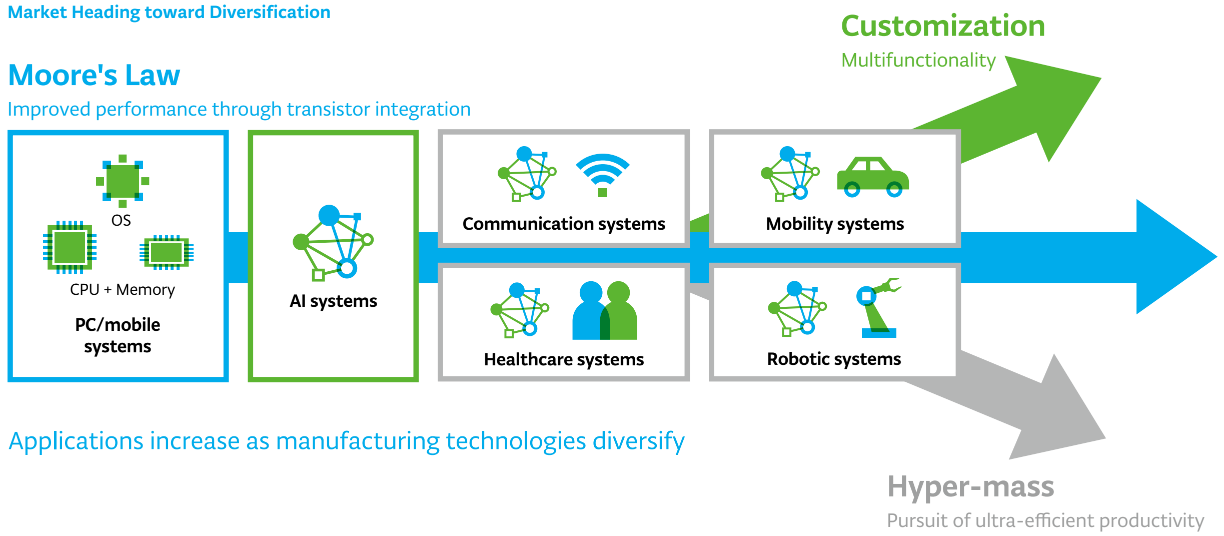
- Create innovative technologies by promoting innovation to help develop a sustainable society
- Contribute to the reduction of environmental impact throughout the company by providing products and services that are conscious of the environment

Research and Development

Research and Development for the Future

Digital technology is becoming an increasingly familiar part of people's lives, such as online education and medical services, remote work, and the emergence of various services utilizing AI. The evolution of IT applications and the diversification of services are expected to continue. As a support for the evolution of such digital technology, semiconductors will become increasingly necessary in the future, and more advanced and diversified technologies will be required for semiconductor manufacturing. At Tokyo Electron, we discuss the role we should play for the future on a daily basis, and are working company-wide on research and development with an eye on future technology markets.

Market Heading toward Diversification



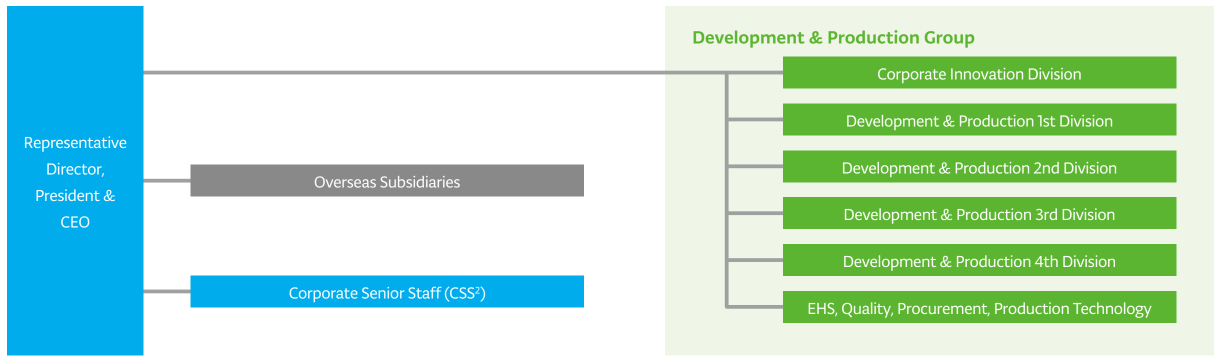
Development System

In the ever-diversifying area of semiconductor production technology, we have built a system to bring high-value-added products into the market in a timely fashion, promoting technology development and technology innovation for the next generations with collaboration between our Development & Production Group and Business Group. We share technology roadmaps spanning multiple generations for the future with our customers, and work with relevant divisions across the company in converting that technology to equipment in anticipation of their needs.

Specifically, the Corporate Innovation Division, which is headed by the Representative Director, President & CEO, along with the development divisions of the manufacturing sites in Japan and the marketing departments of business units, are leading efforts to enhance process integration capabilities based on our wide lineup of semiconductor production equipment and to promote and develop digital transformation[1] using AI technology. In January 2020, we established TEL Manufacturing and Engineering of America to optimize development and manufacturing functions and improve operational efficiency not only in Japan but in the U.S. as well. Since then, the company has been pushing ahead with activities.

Furthermore, with regard to environment, health and safety (EHS), which is becoming increasingly important as societal demands escalate, the EHS Council, which oversees our entire company, is playing a pivotal role in promoting the review and formulation of basic policies. Each of our manufacturing sites in Japan are also actively working to create a development system that is mindful of the environment, health and safety.

1 Digital transformation: Refer to p. 19



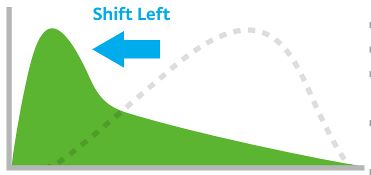
2 CSS: Composed of Vice President and General Managers of Tokyo Electron, Presidents from overseas subsidiaries

Shift Left

We are focused on advancing the Shift Left approach, investing resources (including technology, personnel and money) into the early processes of product development. Together with customers who conduct research with a vision beyond even the next generation and who aim to accelerate the speed of development further, we have created a technology road map, and are engaged in developing the various technologies required for its realization.

In fiscal year 2021, responding to the ongoing customer need for production equipment to take up less space, we succeeded in improving equipment efficiency per unit area by maximizing the use of clean rooms and providing more productive equipment. We also established new goals and strengthened our efforts to meet the environmental demands of customers for equipment.

Through promoting the Shift Left approach, we are endeavoring to understand customer needs at an earlier stage and to strengthen feedback from front-line service engineers, and by reflecting the information obtained through this in the development of technology, we can propose superior products that contribute to maximizing yield for customer devices and capacity utilization of their mass production line equipment. We also promote on-site collaboration for early delivery of evaluation units at customers' plants and research and development laboratories, shortening the period between technology development and the conversion to mass production equipment and maximizing efficiency.



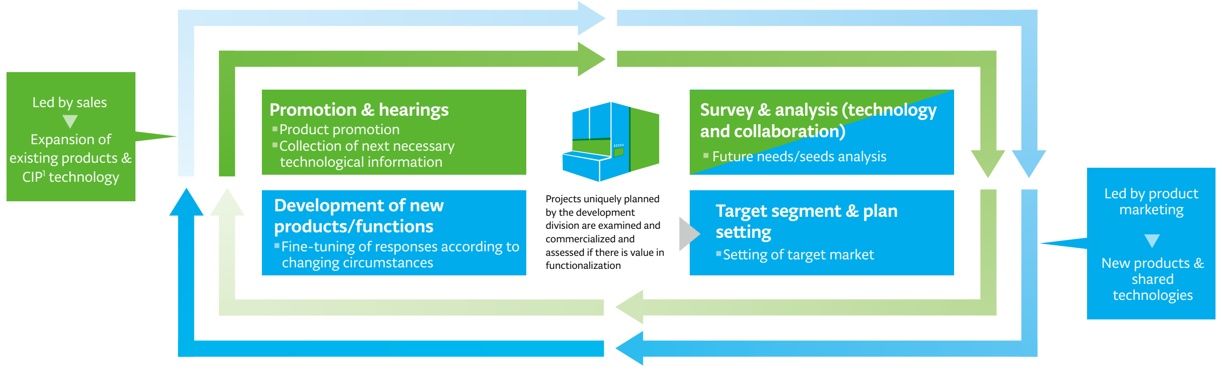
- Joint development of technology roadmaps spanning multiple generations
- Promotion of early engagement
- Maximization of yield for customer devices and equipment operating rate from early stages of mass production, and also reduction of environmental impact
- Promotion of improvement in work efficiency and per person productivity, and further increase in investments into human resources and development
- Increase in equipment efficiency per unit area by achieving higher productivity and using less space

Product Marketing

We are promoting effective product development by having our sales departments and product marketing departments appropriately play their respective roles. Our sales departments are responsible for building relationships of trust with customers and ensuring that products and services are provided through business to the customers they serve. Meanwhile, our product marketing departments plan and manage product strategies that meet the future needs of customers in target markets, such as development planning to increase the value of customer products, services and the examination of value-adding mechanisms. They also consider the commercialization of technology and the addition of functions based on the seeds of our development divisions, and formulate strategies for collaborating with partner companies and consortiums.

Our sales departments and product marketing departments work together in developing product marketing activities that contribute to customers' products by anticipating market needs, and in doing so, help improve our product competitiveness and promote our Shift Left approach.

Involvement in Product Development by Sales Departments and Product Marketing Departments



Collaboration with Consortiums and Academia

We are enhancing our own research and development capabilities through collaboration with international and domestic consortiums which allows us to further our development of leading-edge technologies. Specifically, we are focusing on collaboration in a wide range of areas, from development to market launch of rapidly evolving technologies and applications. This is achieved through participation in a global research hub developing next-generation AI hardware, by cooperating with BRIDG[2], a not-for-profit, public-private partnership located in the U.S. state of Florida, by strengthening collaboration in the field of EUV[3] at imec and by accelerating our research in the front-end and back-end fields[4] at TTCA[5].

We are also working on various collaborations with academia, including major universities in Japan. In particular, we are promoting collaboration in a wide range of fields with the National Institute of Advanced Industrial Science and Technology (AIST)—one of Japan's largest public research institutions—including the MRAM[1]-related research that we have been working on for some time. In the field of semiconductor development, which is becoming increasingly diverse, we will further strengthen our own research and development by leveraging AIST's world-leading research environment and world-class research staff.

1
CIP: Continuous Improvement Program

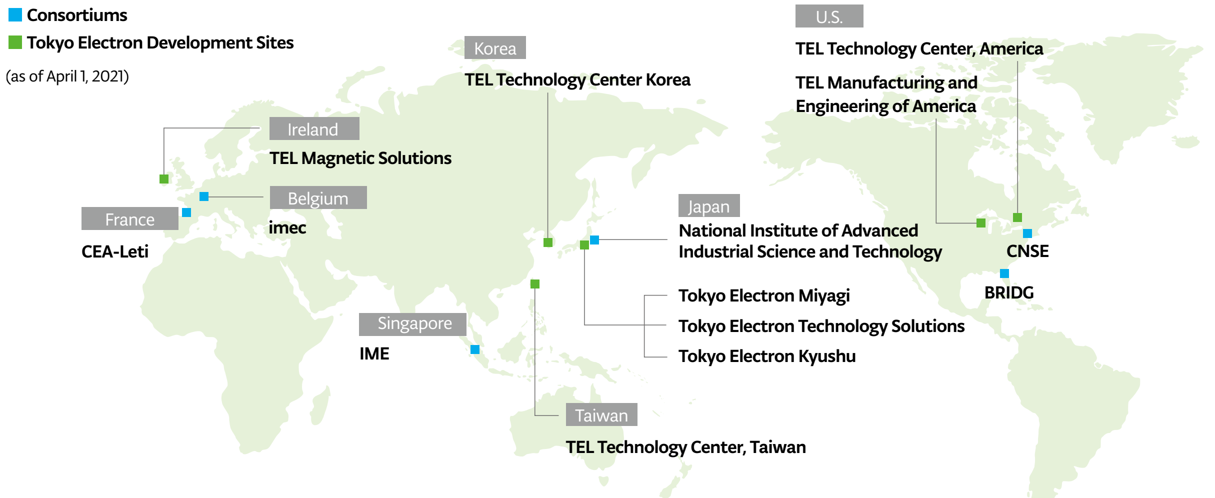
2
BRIDG: BRIDG is a not-for-profit, public-private partnership specializing in advanced system integration, microelectronics fabrication, III-V materials deposition for sensors, optoelectronics and high-speed transistors. BRIDG offers production process technologies, research and development capabilities and 200 mm microelectronics fabrication geared toward system miniaturization, device integration, hardware security and product development key to aerospace/defense and the IoT/AI revolution. Supported by Osceola County, University of Central Florida, Florida High Tech Corridor Council and others, BRIDG provides the physical foundry infrastructure and collaborative process to connect challenges and opportunities with solutions; "Bridging the Innovation Development Gap" making commercialization possible.

3
EUV: Extreme Ultraviolet. Refers to ultraviolet radiation (ultraviolet rays) in the wavelength range 1–100 nm.

4
Front-end/Back-end fields: In the fabrication of semiconductor devices, the first half of the upstream process is called "front-end-of-line" (FEOL) processing (substrate) and the second half is called "back-end-of-line" (BEOL) processing (wiring).

5
TTCA: TEL Technology Center, America, LLC. Our research and development center in the U.S.

1
MRAM: Magnetoresistive Random-Access Memory



Initiatives in Japan

Since 2018, we have been conducting a joint research selection program with universities with the aim of discovering and collaborating on advanced element technologies in relation to semiconductors. Over the past three years, 16 topics have been chosen for joint research. Although applicants are free to propose any research topics, we adopt those proposals that match our technological abilities needs and which are expected to help develop our technological and planning capabilities and contribute to the future development of our business areas through the creative perspectives and ideas only possible in academia.

Technical advisors selected from our development divisions and business units (BUs) are in charge of selecting topics, with subsequent joint research activities managed by a secretariat. Technical advisors strive to generate research results by promoting technical assessment with the university, and at the end of the research period, where outcomes are found to be effective, the topics are considered by our BUs for ongoing research.

In addition to promoting the development of a wide range of semiconductor-related technology and devices, we are promoting the selection program in an effort to contribute to the evolution of science and technology and the revitalization of research activities at universities.

Intellectual Property Management

Cumulative number of technology inventors

4,370

Our fundamental tenet for intellectual property (IP) is to protect our intellectual assets and contribute to increasing corporate revenue through the support of our business activity.

In our uniquely evolving industry, we have increased the global investment in research and development, including industry-academia collaborative initiatives that synergistically grow our business. We establish regional IP offices, as well as corporate headquarters, to locate IP personnel at research, development, and production sites worldwide. Those IP personnel assess each project from various angles, including R&D and marketing perspectives, building IP portfolios aligned with technology, and product strategies in an effort to boost competitiveness.

We sustained our worldwide advantage in the IP strength again in calendar year 2020. 1,180 inventions were created in Japan, and 120 were created in other countries. We have maintained a global patent application rate[2] of approximately 70% for the tenth consecutive year and achieved high patent approval rates (85% in Japan and 87% in the United States). The number of joint patent applications in collaboration with partner companies, universities and other research institutes around the world has reached 25, with 13 companies and 8 organizations in the last two years.

To increase IP awareness, we have continuously educated our engineers, who are the foundation of our R&D strategy, and in total, around 4,370 engineers have become inventors. Additionally, because we often handle highly confidential information, including technological information of our customers and collaborative partners, we have also focused on confidential information management education.

2
Global patent application rate: Percentage of inventions filed as a patent application in multiple countries

Tackling Technological Innovation

Research and Development for Next-Generation Computing

Global demand for semiconductors has been increasing in recent years, and the production volume of semiconductors is expected to continue increasing. Under such circumstances, reducing the power consumption of semiconductors has become a major issue. We recognize this issue as an energy supply risk in the market, and are working for a solution.

Modern computing is not necessarily optimized for power efficiency. The mainstream solution to this problem these days is to optimize the architecture, placing memory devices closer to logic devices (arithmetic circuits), resulting in a considerable reduction in power consumption. One of the technologies that make this "optimization of architecture" possible is 3D system integration. Also called "heterogeneous integration[1]", 3D system integration technology is one that combines and packages different materials such as silicon and non-silicon elements, CPUs[2] and DRAMs[3]. Specific combinations applying this technology are expected to reduce power consumption to between 1/100th and 1/1000th of conventional architecture.

Furthermore, the development of resistive analog neuro devices[4] and nonvolatile resistive random access memory[5] that simulate the human brain is essential to the evolution of AI technology, and our film deposition technology is contributing to this.

Realizing next-generation computing requires the development of AI chipsets with even faster processing and greater energy efficiency. By taking maximum advantage of a wide range of technologies and various techniques, we are working to create high-value-added products that meet the next-generation need of bringing computers closer to the human brain. To this end, we are expanding further the technological areas in which we can contribute, such as developing new materials and boosting the performance of chipsets through 3D system integration, and we are rolling out initiatives aimed at optimizing the power efficiency of semiconductors and realizing next-generation computing.

1 Heterogeneous Integration: Packaging that unites different kinds of chips

2 CPU: Central Processing Unit. A semiconductor chip that serves as the brain of a computer.

3 DRAM: Dynamic Random Access Memory. A type of semiconductor memory used in the main storage unit of a computer or as a large-capacity working memory of other electronic devices.

4 Resistive Analog Neuro Device: Electronic devices capable of continuously changing resistance

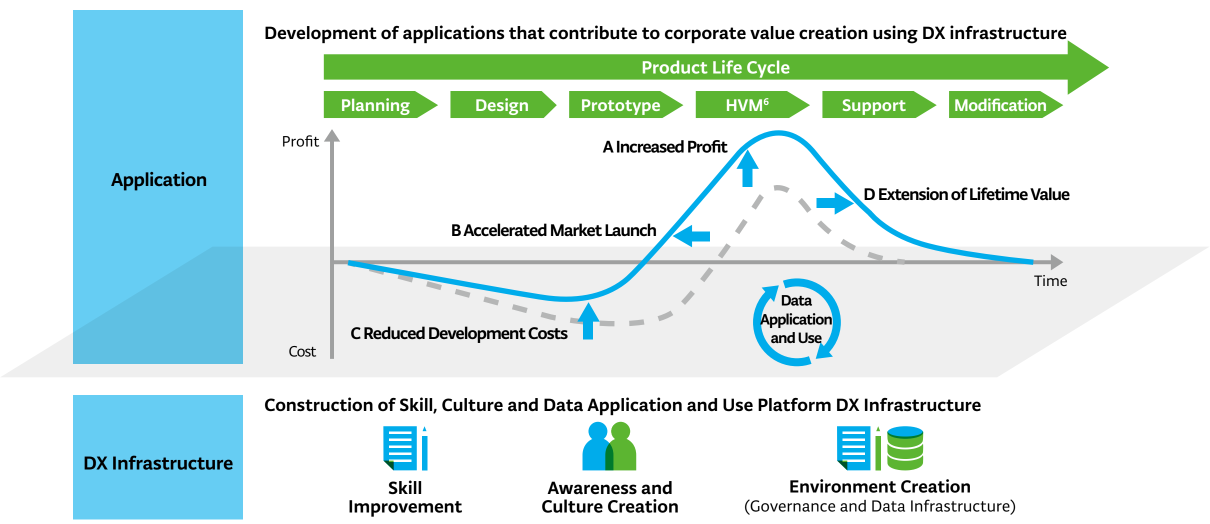
5 Nonvolatile Resistive Random Access memory: Random access Memory that uses nonvolatile resistive memory elements

Promoting Digital Transformation (DX)

DX promotion, which is making waves across the global industrial world, is also becoming more prominent in the semiconductor and flat panel display (FPD) production equipment industries. Having positioned DX as an important part of the solution to the demand for further miniaturization and multi-layering, in January 2021, we formulated the TEL DX Vision of "a global company where all employees drive enterprise value creation sustainably through activities such as value addition and efficiency improvements by leveraging digital technology". The two key objectives of this are to contribute to customers' value creation in a range of settings from development to mass production and to raise capital efficiency in a range of settings from the product planning stage to maintenance. We will achieve these two objectives by resolving high-level problems via a cycle of monitoring, analysis and prediction, control and autonomy.

6 HVM: High Volume Manufacturing

Image of DX Usage



We are also proceeding with the practical application of TELeMetrics™, which remotely connects our company with our customers' manufacturing site, thereby enabling remote maintenance, as well as remote support for equipment using AR[7] smart glasses and material searches utilizing AI.

7 AR: Augmented Reality. Wearing smart glasses to link with the real world and obtain an augmented reality output based on information about objects in the real world.

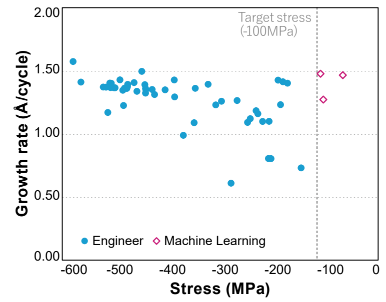
Furthermore, we are also systematically recruiting and training human resources to utilize data science[1] in our business. In November 2020, we relocated our Sapporo office, a software development site, and established TEL Digital Design Square as our home base for DX activities. In addition to installing leading-edge facilities and adopting a hot-desking system to develop software technology, we will put effort into recruiting and training data scientists, data analysts and other human resources necessary for DX to utilize data science in our business.


TEL Digital Design Square

Based on the belief that utilizing digital technology can contribute to everything from accelerating the speed of development, improving productivity and quality and enhancing business efficiency to reforming workstyles, we are working on greater DX promotion.

■ Example Initiative

In the adjustment of film stress[2] (target value: -100 to 0 MPa) using plasma-enhanced atomic layer deposition (PE-ALD[3]), we used AI-based machine learning to consolidate and analyze past test data and optimize the process in order to overcome the inability of the previous method to achieve film stress requirements using engineers. As a result, we were able to not only resolve this issue but also contribute to reducing wafer consumption. By making use of AI as a member of the team without being bound to conventional thinking and practices, engineers will be able to perform work with high added value.



Comparison of process exploration results of a film stress (target value: -100 to 0 MPa) using a 300 mm plasma-enhanced atomic layer deposition (PE-ALD) system, conducted by a human engineer and machine learning respectively.

1 Data science: The approach of using data to extract new scientific and socially beneficial knowledge

2 Film stress: Stress caused by different rates of expansion, etc. between the thin film and substrate

3 PE-ALD: Plasma Enhanced Atomic Layer Deposition. Atomic layer deposition (ALD) is a thin-film deposition technology that uses continuous vapor-phase chemical reactions. PE-ALD is a method of applying plasma to activate a reaction on the substrate.

Support for Evolving Displays

With the evolution of communications technology such as IoT and 5G, further performance improvements are also expected for displays that project all kinds of information into the real world. In addition to higher image quality and lower power consumption, there is also a growing need for built-in sensors and greater flexibility of design. Organic Light Emitting Diode (OLED) displays, which are used widely in smartphones and televisions, are expected to expand to a wide range of applications, including IT and automotive, because of their high image quality and design qualities. Foldable displays, in particular, are predicted to further expand the potential of information devices. Along with the growing demand for such high-performance displays, control technology for defective modes and stable performance are becoming more important than ever for FPD production equipment. Furthermore, as the number of manufacturing processes increases, so too does the need to use energy and materials more efficiently in order to successfully reduce environmental impact.

Our product lineup includes the Impressio™ and the Betelex™ FPD etch/ash systems, the Exceliner™ FPD coater/developer and the Elius™ inkjet printing system for manufacturing OLED displays. Impressio and Betelex use PICP™[4], a plasma module with improved energy efficiency, reducing power consumption by up to 20%, and achieving precise processing and stability in mass production. We have also released PICP™ Pro, a new plasma module for high-definition displays which achieves both yield improvements and mass production stability by reducing the generation of particles. The Exceliner, equipped with our original Air Floating Coater, permits higher throughput while maintaining excellent film uniformity and saving chemical costs. The Elius inkjet printing system can significantly reduce the amount of OLED materials used in the manufacturing process compared to conventional vapor deposition methods, and is also suited to production on large substrates. We are proceeding with development and sales of the Elius series ahead of the imminent era of large, high-definition OLED.

We will continue contributing to the further development of diverse display products, tackling effective technological innovation based on market needs such as improving productivity and yield and using energy and materials more efficiently.

4 PICP™: Original plasma module developed by Tokyo Electron which produces extremely uniform high-density plasma on panel substrates