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electronica 2022

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NOVEMBER 2022

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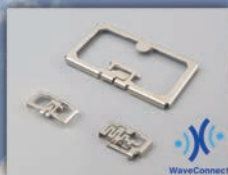
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Leading the future of Automotive through advanced connection technology.



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Antenna
"AN01 Series"



Side View Mirrors
"MX80 Series"



Various ECU
"MX77 Series"



ADAS-ECU
"MA01 Series"



CHAdemo Compliant
"KW1C Series"

Japan Aviation Electronics Industry, Ltd.

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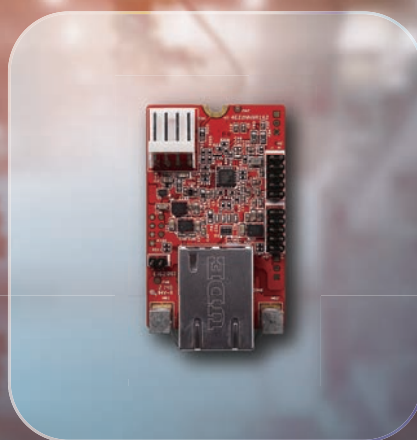
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DDR5 Series

- Data Rate: 4800 MT/s
- Capacity: 8~32 GB
- Pin Number: 288pin
- Operating Temperature: 0°C ~ 95°C(TC)
- 30μ" Gold Finger
- Anti-Sulfuration



InnoAgent

- Remote Power On/Off/Reset
- Programmable Remote control GPIO
- Support Remote UART/RS232 Data Transmission
- Support OT Device without Network Connection
- In-Band Heartbeat Agent to Check Device Alive



InnoOSR

- One-click Recovery
- Rock-bottom Maintenance costs
- Firmware-level Reliability
- No-fuss System Implementation

Empowering The Future of Smart Manufacturing with Innodisk-Powered Edge Solutions

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AI Automation Stirs Industry 4.0 Manufacturing Applications

Automation at its core holds the promise of fully automating manufacturing process; creating a system where every single unit is interconnected. This is the essence of Industry 4.0. By combining cloud computing, the internet of things and AI, these smart factories of the future are seen as the next industrial revolution.

A high degree of device interconnectivity requires a system that can handle many simultaneous operations. Innodisk Corporation can offer industrial-grade components that meet the high demands of the automation industry such as industrial DDR5 memory, InnoOSR (one-click recovery) SSDs, InnoAgent remote band remote management modules, as well as a comprehensive software suite, which includes model zoos, as well as Innodisk's in-house software solutions, such as iCAP (Innodisk Cloud Administration Platform), and iVIT (Innodisk Vision Intelligence Toolkit). iVIT for example, provides a deep learning environment with a "no-coding necessary" user experience to develop AI machine vision



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InnoOSR

- One-click Recovery
- Rock bottom Maintenance costs
- Firmware-level Reliability
- No-fuss System Implementation

solutions. Innodisk estimates that with iVIT's simple three-step development and deployment process, the machine vision learning curve is reduced by over 50 percent.

Absolute Data Integrity

Many automation applications are prone to power supply issues, which in turn poses a threat to data integrity. Innodisk can provide a broad selection of technologies aimed at protecting data in case of abrupt power outages or other power instabilities.

Robustness Prioritized

Factory environments will subject the system to harsh conditions such as heat and mechanical stress, as well as shock and vibration. The company's robust modules are all tested and certified to withstand these stresses while retaining full functionality.

Applications

Among the possible applications for the portfolio are industrial robots, process control units, terminals, and industrial PCs. □



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MEET AND GREET AT OUR SOCIAL RECEPTIONS INCLUDING THE NEW CAREER CONNECTIONS NETWORKING EVENT WEDNESDAY, JANUARY 25!

JAE Sets Milestone in High Speed Vehicle Harnesses

Japan Aviation Electronics Industry, Limited (JAE) released in 2001 the MX25 Series coaxial connector for antennas. It was the company's first mass-produced high-speed transmission connector specialized for automotive application. It had applicable frequency of up to 6GHz, and voltage standing wave ratio (VSWR) of 1.5 max. It was designed to transmit data received by the antenna of an in-vehicle ETC unit. In 2004, JAE released the MX30 connector harness, which transmits differential signals of GVIF*¹ at high speed between car navigation system and monitor.

Drawing on the track record of releasing these products, JAE has developed various connector harnesses that support high-speed transmission, including Universal Serial Bus (USB) and High-Definition Multimedia Interface (HDMI) standards.

Efforts to Achieve Video Transmission

Two main applications of video signal transmission in vehicles are digital output of contents reproduced by an infotainment head unit to a separate monitor and digital

transmission of videos shot by on-board cameras to video processing electronic control unit (ECU). Recently, video signal transmission has been used increasingly to display high-definition digital images on a large screen arranged in the meter panel in front of the driver's seat. These video transmissions use a high-speed serial interface IC called Serializer-Deserializer (SerDes). Transmission of digital signals using SerDes IC is broadly divided into differential transmission and coaxial cable transmission (single-end transmission). Therefore, it is necessary to design circuits, connectors, and electric wires that construct transmission path separately for differential transmission and single-end transmission.

In determining which differential transmission and single-end transmission should be used for a system, it is necessary to consider the balance of the whole system. Parameters to be considered include power consumption, noise characteristics and skew characteristics (the difference in propagation delay time between pairs of differential transmission) of SerDes IC; circuit flexibility and noise countermeasure of printed circuit board; shield performance of connectors; and shield performance, bending performance and weight of electric wires. Fig. 1 shows a measure*² of areas supported by differential transmission and single-end transmission at the present moment. In differential transmission, areas to be supported change in accordance with electric wire structure, such as UTP, STP, STQ and SPP. Each electric wire structure has strength and weakness in terms of shield performance, bending performance, and cost.

After 2020, market requirements for resolution and frame rate of videos used in vehicles have become demanding gradually. Thus, higher signal transmission speeds have made the problems of transmission distance and noise to rise up to the surface. JAE has constructed its product lineup focusing on products for differential transmission that is considered

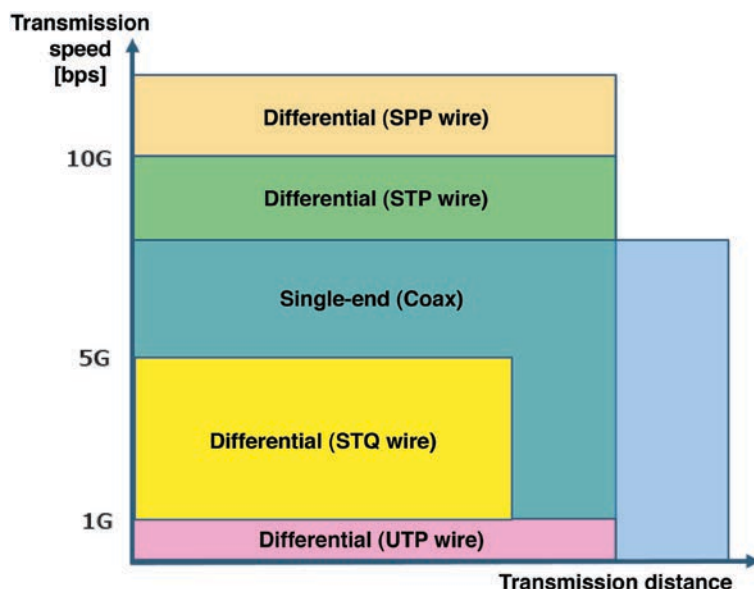
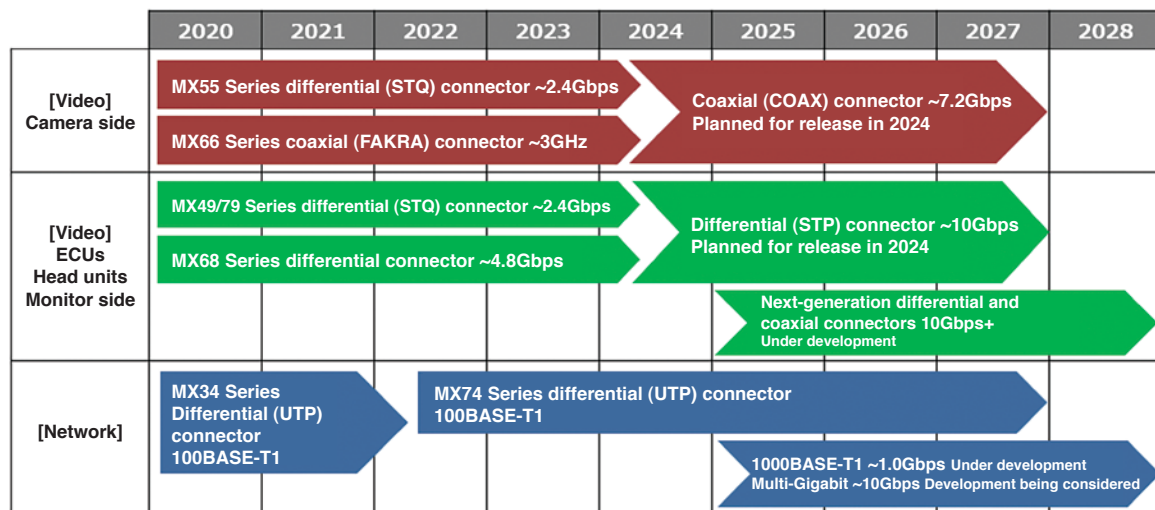


Fig. 1: Areas to be covered by respective transmission methods



* Transmission speed in actual use changes according to ICs used. For more details, please contact JAE.

Fig. 2: Development roadmap

to have strong noise resistance in the high-speed region. In recent years, however, the company has also been developing products that support single-end transmission, as the performance of SerDes ICs for single-end transmission has improved. It also takes into account the balance of the entire system (Fig. 2).

Efforts to Achieve On-Board Networks

With performance enhancement of automated driving and advanced driver-assistance systems (ADAS), the number of electronic devices incorporated in a vehicle, such as on-board cameras, light detection and ranging (LiDAR) systems, accelerometers, and global positioning system (GPS) sensors, has been increasing. To efficiently control data of these devices, faster on-board networks are necessary. Specifically, increased devices in a vehicle and complex on-board networks lead to the increase in the total weight of wire harnesses in the whole vehicle body and hence to the deterioration of fuel economy and electricity costs. Hence, the simplification of on-board network structure is also required.

Against this backdrop, in addition to existing communications protocols, such as CAN, LIN, and FlexRay for on-board networks, the adoption of Ethernet communication, which supports larger data capacities, has been progressing. Ethernet is a communication standard used for local area networks (LAN). It can control multiple devices efficiently. At present, several standards

have been set to meet automotive Ethernet standards. These are 100BASE-T1 (IEEE802.3bw), which supports 100Mbps; 1000BASE-T1 (IEEE802.3bp), which supports 1Gbps; and Multi Gigabit Ethernet (IEEE802.3ch), which supports 2.5Gbps, 5Gbps, and 10Gbps. JAE has been developing products that satisfy transmission standards established by the standard-setting organization, while incorporating specifications required by customers (Fig. 2).

Efforts to Counter Noise

In automotive systems that use high-speed transmission, measures to achieve electromagnetic compatibility (EMC) are indispensable. EMC issue occurs due to

a combination of various factors, including IC, circuit, chassis, connector, electric wire, and harness path. Therefore, when a problem occurs in a system, it is necessary to pursue causes by looking at the entire transmission path. When the main cause cannot be eliminated, such resolution to take measures to eliminate a secondary cause will be needed. JAE has been developing products by matching results of electromagnetic field analysis in the connector design stage and EMC evaluation results obtained in its anechoic chamber (Fig. 3).

IEC62153-4 Series, an IEC international standard, has been established as a test method to evaluate noise shielding performance of communication



Fig. 3: JAE makes use of evaluation results in its anechoic chamber in product development.

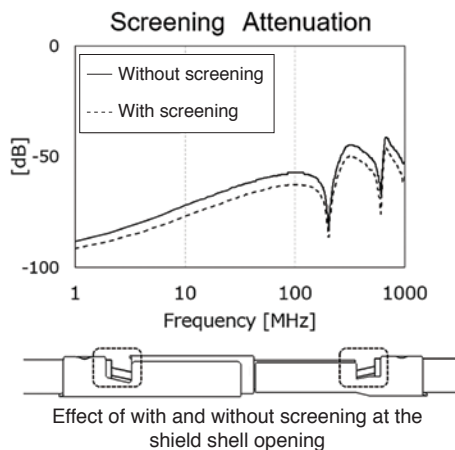


Fig. 4: Electromagnetic field

wires. In it, the triaxial tube-in-tube method (triaxial method) for measuring screening attenuation and coupling attenuation is the specified test method to evaluate noise performance of each constituting part of automotive Ethernet, such as electric wire, connector, and harness. As these parameters allow quantitative confirmation of actual performance of objects to be measured, they are weighed heavily worldwide as evaluation parameters in adopting high-frequency connectors.

JAE has constructed technologies for evaluation using the triaxial method based on both aspects of electromagnetic field analysis (Fig. 4) and actual measurement (Fig. 5). The company feeds back these technologies to product development.

Release of the MX74 Series

JAE started offering the MX74 Series in June 2022 as a connector compliant to 100BASE-T1 (IEEE802.3bw), which is an automotive Ethernet standard. At the same time, the company has put in place a sales system of tools for customers to assemble the connector into a harness. Thus, the company has enabled anybody to produce harnesses compliant with the standard by performing harness assembling according to the procedure manual.

The MX74 Series has performance to ensure satisfactory transmission quality even under severe environment in vehicles. 100BASE-T1(IEEE 802.3bw) specifies only initial characteristics as transmission standard. However, the MX74 Series satisfies transmission standard even after severe environment tests assuming the automotive environment,

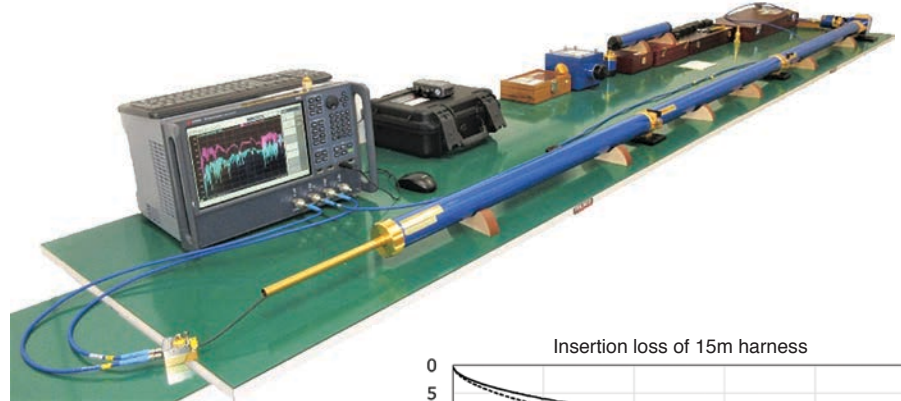


Fig. 5: Actual measurement

including high temperature test, moisture resistant test, thermal shock test, vibration test, and immersion in water (Fig. 6). The MX74 Series comes in the right-angle screening type, straight screening type, and right-angle full SMT type. The two-contact type connectors come in A type and B type, enabling customers to select from them in accordance with their applications (Fig. 7).

Future Prospects

At present, next-generation products of SerDes ICs have been developed actively to meet practical use in the high-speed region (5Gbps to 10Gbps). Meanwhile, with automotive Ethernet, practical use of Multi Gigabit Ethernet is just around the corner. JAE has been developing connectors and harnesses that meet the trend of the time to meet customers' requirements in terms of quality and technology.

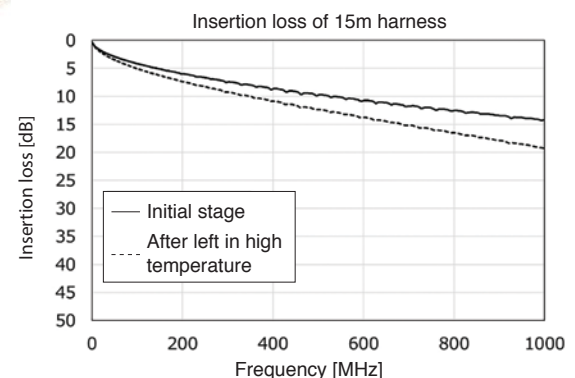


Fig. 6: The MX74 Series satisfies transmission standard even after series of severe environment tests.

Notes:

^{*1}Gigabit Video Interface (GVIF) is a digital interface IC developed by Sony Corporation for video transmission in vehicles.

^{*2}The areas shown in Fig. 1 are considered as a measure as the areas to be covered change in accordance with the performance of components constructing the transmission path.

About This Article:

Japan Aviation Electronics Industry Ltd. provided the contents of the article.

No. of contacts Mating key	Pin connectors			Socket connectors
	Right-angle screening type	Straight screening type	Right-angle full SMT type	
Two contacts Key-A				
Two contacts Key-B				
Four contacts Key-A				

Fig. 7: Connector types

FOR AUTOMOBILES

■ Compact Waterproof Automotive In-line Connectors, MX80 Series

Waterproof and dust resistant under IPX7 guidelines

- ISO/JASO/EWCAP/VDA standard 0.64mm tab size
- Terminal Position Assurance (TPA) on pin and socket housing
- USCAR-2 and LV214 Tested
USCAR: United States Council for Automotive Research
- IPX7 ingress protection rated
- Compatible with 2.54mm pitch pin contacts
- Integrated bracket supports chassis fastening vehicle clips



■ Connectors for EV and PHEV Battery Systems, MX77 Series

Compact, low-height and offers smaller diameter wire options with sufficient terminal retention force

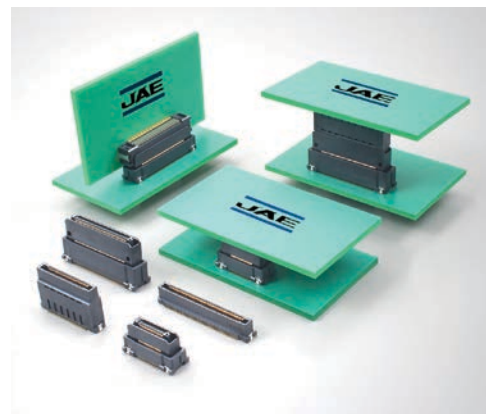
- Ultra compact type 0.4mm tab size (pin width)
- Pin header side insulator uses flame-retardant UL94 V-0 material
- Socket side (cable connection) offers two housing models.
- MX77D FLRY-B 0.35mm² cable is suggested for socket side cavities.
- The pin side are SMT-mounted to save space, and are fixed to the board by soldering the legs to the board using a through-hole reflow process to ensure sufficient strength
- USCAR-2 tested



■ 8Gbps High-speed Transmission, Two-point Contact Floating Board-to-board Connectors, MA01 Series

Automotive Grade, High-speed Transmission, Floating Board-to-board Connector

- Floating tolerance: $\pm 0.5\text{mm}$ in both X and Y directions
- Stacking height tolerance between boards: $\pm 0.5\text{mm}$ in Z-axis direction
- Two-point contact structure ensures high contact reliability
- Low insertion and removal forces achieved by rolled-surface contact point
- Operating Temperature Range: -40°C to $+125^{\circ}\text{C}$
- 8Gbps+ high-speed transmission (10GBASE-KR and PCIe Gen3 equivalent)
- Excellent mating process with large guides for automatic assembly and mating (mating guide: $\pm 1.0\text{mm}$)
- Supports automatic vacuum pick up for mounting
- Allows for multiple connectors to interface between a single set of boards
- Keyed to prevent mis-mating



■ EV charging and discharging connectors, KW1C Series

CHAdeMO-Compliant EV Charging and Discharging Connectors

- Compliant with CHAdeMO specifications Ver.2.0
- Compliant with the EV Charging and Discharging System Guidelines (EVPS-002) Ver.2.1
- CE-Marking (IEC62196-3 Compliant, by certification organization TÜVRheinland)
- Highly reliable design using materials which are tough against various environmental conditions
- Lightweight and highly reliable design



■ Quick charger/Charging and discharging system connector, KW21 Series (Under development)

CCS Type2 Specification-Compliant Connector for Charging and Discharging EVs

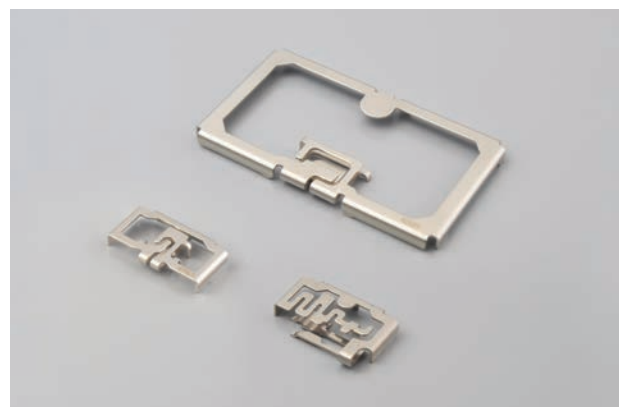
- CE Marking (Planned for IEC62196-3 compliant, certification organization: TÜV Rheinland)
 - High reliability design using materials with high environment resistance
 - Achieves both high-strength and lightweight
 - 40/80A (Under development)
- CCS Type2: Combined Charging System Type 2



■ Compact and high-performance antennas, AN01 Series

Compact and high quality wireless communication antenna

- Compact and high performance: Industry-leading high efficiency despite its size of about 1/10 of the wavelength
- Omnidirectional radiation: Creating radio coverage without dead spots
- Assembly cost reduction: Automatic pick and place mounting compatible surface mount device (SMD)
- Design flexibility: Minimal influence from nearby metallic objects and dielectric materials, fewer restrictions on component placement, ensuring a high degree of design flexibility



Tamura Highlights Strengths in Gate Driver Solutions

Tamura Corporation continues to leverage on its strength as a manufacturing company, with experience spanning almost 100 years. Since its establishment in 1924, the company now has a broad portfolio of sensors, transformers, DC/DC power modules, and gate drivers.

Tamura's business domains encompass electronic components, electronic chemicals and factory automation systems, as well as information equipment. Indeed, Tamura's history for power electronics has been well entrenched. Particularly, the company's lineup of current sensor, gate driver, reactor, among others, have been deeply embedded on wide range of industries, from robots, motor control units, to inverters, uninterruptible power supply (UPS), to name a few.

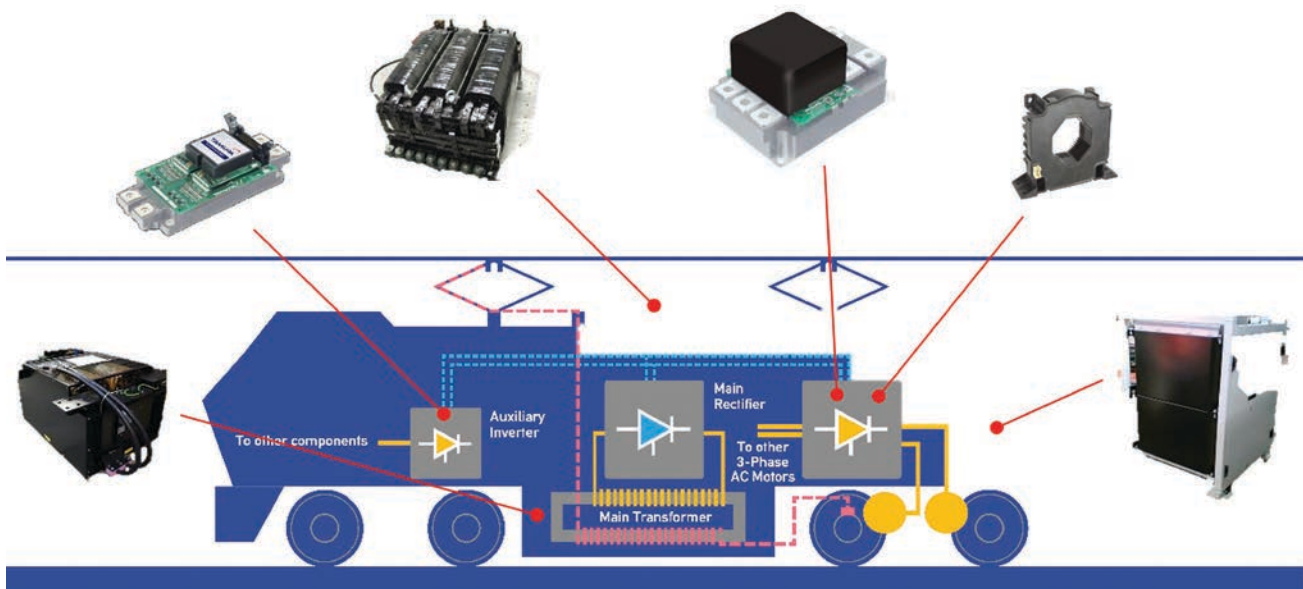
The company offers a rich lineup of gate driver solutions that feature better performance. Particularly, the lineup offers wide input voltage, low stray capacity, high-speed response, and better accuracy.

Tamura's gate driver offers 2-channel isolated circuit module for insulated gate bipolar transistor (IGBT)/silicon carbide (SiC) MOSFET. The gate driver features a DC/DC converter and integrated drive circuit and is designed for robust operation in applications using IGBT/SiC MOSFET.

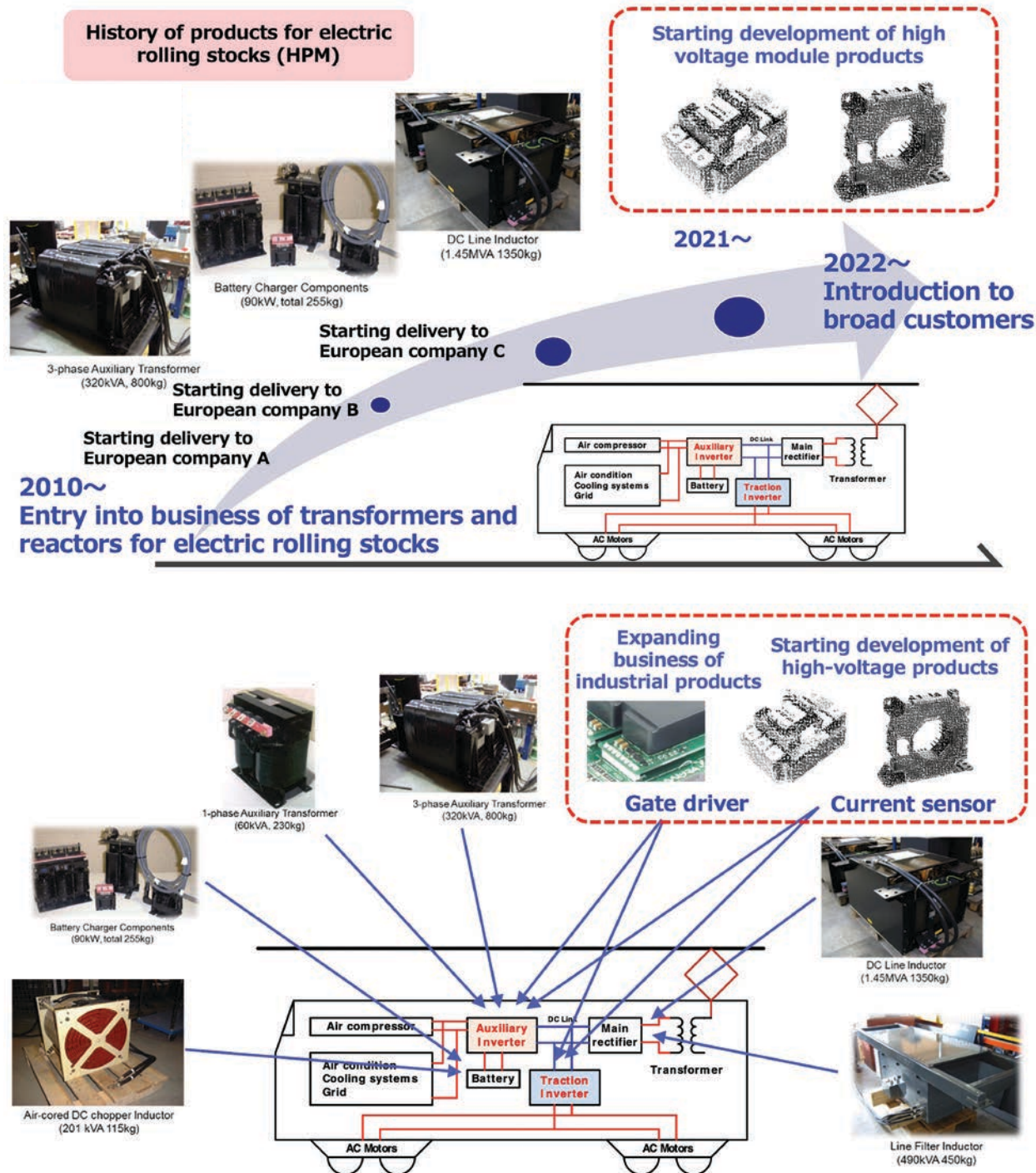
Driver for SiC-MOSFET Modules: Traction Inverter

The gate driver of Tamura is designed for driving SiC power modules with a V_{DS} of 3.3kV installed in rolling stock inverters. It provides a new standard package for the railway market. It can also drive an IGBT power module of the same class by replacing parts.

In addition, a large-capacity DC-DC converter is built-in, making it possible to easily configure parallel drive. As a structural feature, in addition to the conventional type in which the driver board and power module are configured separately, the type that can be mounted directly above the power module is also available, thus simplifying mounting process.



Tamura components for traction



In addition, it is equipped with the short circuit protection function such as DESAT and soft turn off and can be used with confidence.

Driver for SiC MOSFET Module Traction Inverter

The gate driver of Tamura Corpo-

ration is designed to drive SiC power modules with a V_{DS} of 3.3kV installed in rolling stock inverters. It is a new standard package for the railway market. Also, by replacing parts, it can also drive IGBT power modules of the same class. As a structural feature, unlike the conventional design in which the driver

and power module are configured separately, the driver can be mounted directly above the power module, making the implementation very easy. In addition, it is equipped with short-circuit protection functions such as DESAT and soft shutdown and can therefore be used with confidence. □

■ Large-Capacity High-Frequency Isolation Transformer

- This product has achieved miniaturization through high-density winding technology.
- Most importantly, custom design is available according to various requirements of customers.
- Transformers are designed efficiently and optimally using the loss-analysis software developed by Tamura.
- The products will also be made compatible with the safety standards of each country.

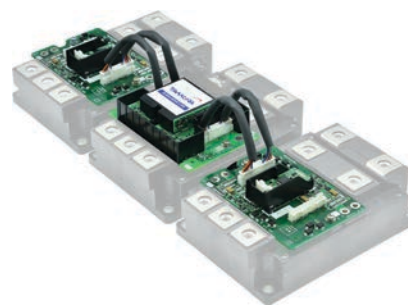


■ LA17P Current Sensor



- This is a general-purpose current sensor for current control of various inverters
- Designed for overcurrent detection of many devices
- Widely used from inverters to various power converters.

■ 2LG Gate Driver



- Tamura's gate driver consists of a 2-channel isolated circuit module for IGBT/SiC MOSFET, with a built-in DC/DC converter and a drive circuit.

■ TNU-CR Reflow Soldering Machine



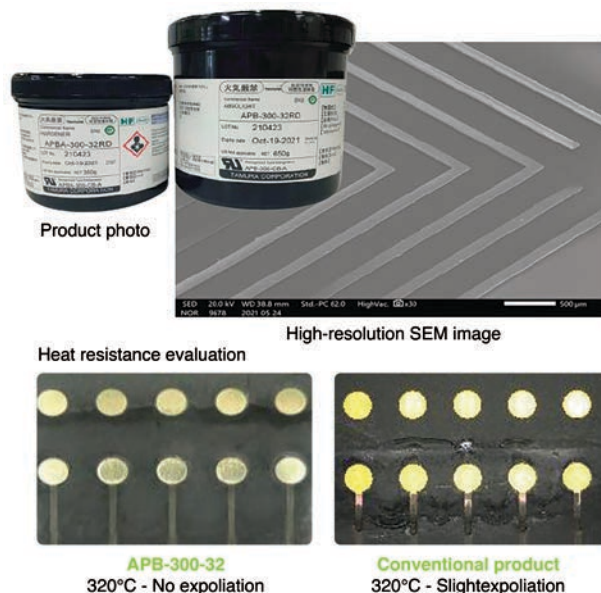
- The unique furnace convection control technology of the company stabilizes the oxygen concentration in the furnace, saves energy, and avoids frequent cleaning requirement.
- In addition, the newly developed double-shell structure has significantly reduced the waiting time for setup changes caused by temperature variations. This will improve productivity and realize further energy savings.

■ Solder Paste: TLF Series and GD Series



- These series provide bonding materials for surface mounting, consisting of mixed solder powder and flux.
- In addition to general products that can be used in a wide range of fields, they include broad lineups including products with high heat resistance solder for automotive use, those for forming micro-bumps for semiconductor PKG, those using recycled tin for supporting environmental regeneration and resource recycling, etc.

■ Solder resist: DSR Series, APB Series, and RPW Series



- Solder resist plays an important role in protecting printed circuit boards from oxidation and in maintaining their insulation.
- In addition to high heat-resistant and highly reliable products for rigid substrates, a wide variety of products are available corresponding to various customer needs, including those for flexible substrates.
- The company will contribute to the realization of a sustainable society with environmentally friendly products free from halogen and products that can reduce production process.

Aqua Plasma Supports Reduction of Oxidized Copper

Samco Inc. focuses on product development with emphasis on environment, health and safety (EHS). The company has been advancing research on water vapor plasma at low pressure, Aqua Plasma®, and product development using the treatment technique. Thus far, the company has introduced reduction effects of oxidized copper and silver using Aqua Plasma®.

Conventional methods to reduce the oxidized copper include hydrogen reduction and hydrogen plasma reduction. It has been reported that these methods use atomic hydrogen (H) and proton (H⁺) for reduction. However, hydrogen has a wide range of explosion limits of 4 to 75 vol% in the air. Therefore, it needs to be handled with care and safety equipment.

Water vapor excels in terms of EHS with low inflammable property. However, thus far, it has been used as an oxidizing agent, such as thermal oxidation of silicon wafers. Meanwhile, Samco presumed that water vapor would work as a reducing agent because it emits strong atomic H emission in plasma at low

pressure.⁽¹⁾ As a result of the investigation, the company has found that water vapor can be used for the reduction of oxidized metal films as well. This article introduces the results of the latest research wherein the company studied the reduction mechanism of the oxidized copper using Aqua Plasma® and compared with hydrogen plasma.⁽²⁾

Experiment

In this study, copper thin film which was deposited on a silicon wafer by electron beam deposition of copper with 99.99 percent purity was used as a sample. Then, the oxidized copper layer was formed by thermally processing on a hot plate at 250°C for 30 minutes in the ambient air. As a result of X-ray diffraction and X-ray photoelectron spectroscopy (XPS) analyses, the oxidized copper sample was composed mainly of Cu₂O with CuO existing only in the outermost surface (19 nm in the surface layer at the deepest). The depth of oxidized copper layer was identified approximately 600 nm from the results of the depth direction analysis by



Photo 1: AQ-2000 Aqua Plasma® cleaner

the XPS and length measurement of the cross section of the cleaved sample using a scanning electron microscope (SEM).

The surface treatment was performed using Aqua Plasma® Cleaner (Photo 1). The sample was set to room-temperature ground electrodes and treated without applying heat. It was processed by fixing the water vapor flow rate, vacuum pressure and power, and changing treatment time. Hydrogen plasma was processed under the same conditions except for the gas (hydrogen with purity of 99.999%).

Results and Discussion

Fig. 1 shows the thickness of the reduced copper layer measured by SEM observation of the cross section and plotted by treatment time. In addition, the thickness of oxidized and total copper layer

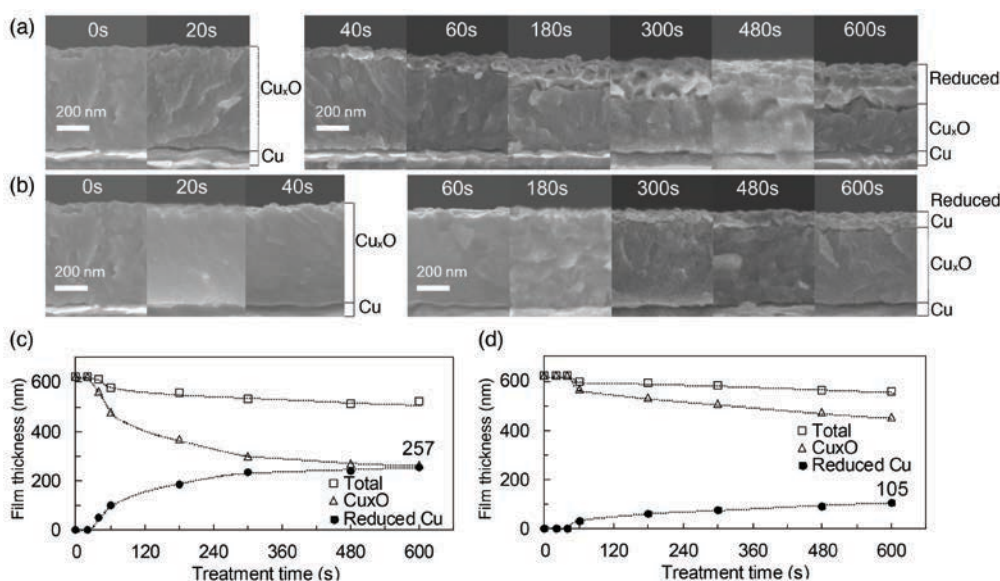


Fig. 1. Cross-section SEM images of oxidized copper film treated with (a) water vapor plasma and (b) hydrogen plasma. Thickness of reduced Cu and Cu₂O ($x = 1$ or 2) film which were measured from (a) and (b) is shown in (c) and (d). Adapted from (2).

was also measured and compared them with the results of hydrogen plasma.

An induction period was observed in which the oxidized copper layer was not reduced until 40 or 60 seconds after the plasma ignition. The depth of the reduced copper layer increased not linearly but along an S-shape curve with respect to the treatment time. This tendency were consistent with characteristics reported in previous studies^(3,4) on hydrogen plasma. The hydrogen plasma in this study also showed the similar tendency of that. These results indicate the oxidized copper in Aqua Plasma[®] can be reduced by H and H⁺ as in the case of hydrogen plasma. For further details of the results and discussion, please refer to reference (2).

In contrast, the depth of the reduction by Aqua Plasma[®] was 257 nm after 600

seconds, which was more than twice that of 105 nm by hydrogen plasma. Therefore, Aqua Plasma[®] enables to shorten the reduction-process time. Samco considers that adsorption of polar molecules with OH to the copper surface contributes to the difference in the reduction rate. The company intends to continue further investigation in this area.

References:

(1) H. Terai, R. Funahashi, T. Hashimoto, and M. Kakuta, "Heterogeneous bonding between cyclo-olefin polymer (COP) and glass-like substrate by newly developed water vapor-assisted plasma, Aqua Plasma Cleaner," *Electr. Eng. Japan*, vol. 205, no. 4, pp. 48–56, 2018.

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About This Article:

Samco, Inc. provided the contents of the article.

TDK Inductors Meet Evolving Automotive PoC Demands

TDK Corporation has commenced mass production of the new MLJ1608WG Series of multilayer inductors. These newly developed compact components are for use in automotive Power over Coax (PoC) implementations.

Far Less Variation in Impedance

The MLJ1608WG Series inductors achieve a maximum impedance of 2500Ω. They also retain impedance levels of 1000Ω over a 300MHz to 2GHz frequency range. While the impedance characteristics of conventional multilayer inductors will vary considerably, depending on the current applied, and cannot secure sufficient impedance, the MLJ1608WG Series offers far less current variation. The series supports high-rated current of 500mA despite compact dimensions of 1.6x0.8x0.8mm (LxWxH). This significantly reduces variation in impedance during current application. The compo-

MLJ1608WG Series inductors

nents can be operated at temperatures of up to 125°C with a current of 400mA.

PoC Adoption in Automotive

With the widespread uptake of advanced driver-assistance systems (ADAS), the performance of automotive cameras has advanced dramatically. Consequently, there are growing demands for higher-speed and larger-capacity interfaces. Automotive camera systems using low-voltage differential signaling (LVDS) transmission

are adopting a PoC approach, which superimposes data and power supply onto a single coaxial cable.

PoC reduces the number of wire harnesses required by transmitting data and supplying power. This contributes to reducing the vehicle's weight and allowing space savings to be realized. Effective filtering is needed to separate data from the power supply in a PoC circuit. This will generally consist of two to four inductors. Inductors used in such filters must have high impedance for AC components from low right through to high frequencies. By achieving impedance values of 1000Ω or higher over a broad range of frequencies, the new MLJ1608WG Series is highly optimized for meeting such requirements.

TDK will continue expanding the product portfolio, addressing the needs for higher-speed and larger-volume transmissions for an even wider variety of automotive applications. □

SiC, GaN Lead Race in Wide-Gap Semiconductor Power Devices

In recent years, the development of wide-gap semiconductor power devices has become active. SiC-MOSFETs and lateral GaN-HEMTs, which surpass the performance of Si power devices, have already been put to practical use. The characteristics and applications of those devices, as well as the current status and issues of vertical GaN devices, Ga_2O_3 and diamond devices aiming for higher performance are presented.

Introduction

With the electrification associated with decarbonization and the expansion of electric energy consumption in recent years, power electronics, which control electric energy, is attracting attention. Especially, higher efficiency of power devices is required, which are key devices that constitute power electronics. Si power devices have been conventionally used, and their performance is still improving today. But the limits of materials are becoming apparent for groundbreaking performance improvements. Therefore, wide-gap semiconductor power devices, such as SiC and GaN, are attracting attention.

The breakdown electric field strength of these wide-gap semiconductors is more than 10 times that of Si, and when compared with the same breakdown voltage, the thickness of the drift layer required to hold the voltage is less than 1/10, and the on-resistance of the device can be reduced. Fig. 1 shows the theoretical limits of the specific on-resistance for the breakdown voltage of the drift layer. Compared to MOSFETs of Si, which are unipolar devices, the on-resistance of SiC and GaN is theoretically 1/1000. Furthermore, Ga_2O_3 and diamond can be expected to have even lower on-resistance.

Therefore, if a wide-gap semiconductor power device can be made, there is a possibility of realizing a power device with an epoch-making low on-resistance (that is, high efficiency). However, to make it a power device, it is necessary to develop various issues. This paper summarizes the current status, issues and applications of wide-gap semiconductor power devices of SiC, GaN, Ga_2O_3 and diamond which are under development.

SiC Power Devices

Among these wide-gap semiconductors, SiC is the most advanced in device development^[1]. Therefore, the switching characteristics of commercially available power devices will be evaluated and the characteristics of SiC-MOSFETs will be clarified. As Si power devices, IGBTs and super junction MOSFETs, which have the same breakdown voltage of 650V and current capacity of 40A as SiC-MOSFETs, were selected, and their switching characteristics were compared in a double pulse test. Table 1 shows the specifications and chip photos of the selected devices. On-resistance is the lowest for Si-IGBT, which is a bipolar transistor, and is the same for SJ-MOSFET and SiC-MOSFET. The biggest difference between the three devices is the chip size. When converted to current density, they are 348A/cm² (IGBT), 120A/cm² (SJ), and 777A/cm² (SiC), indicating that SiC has the highest current density. It is thought that the low on-resistance performance shown in Fig. 1 of SiC was allocated to chip size reduction and cost reduction. In addition, a small chip size leads to a reduction in input capacitance, contributing to an improvement in switching speed. Figure 2 shows the results of the double pulse test. Since the IGBT is bipolar, the turn-off time is long due to tailing of the current, so the turn-off loss is also the largest. On the other hand, the SJ-MOSFET has a long turn-on time due to severe ringing at turn-on, resulting in a large turn-on loss. SiC-MOSFET shows good values

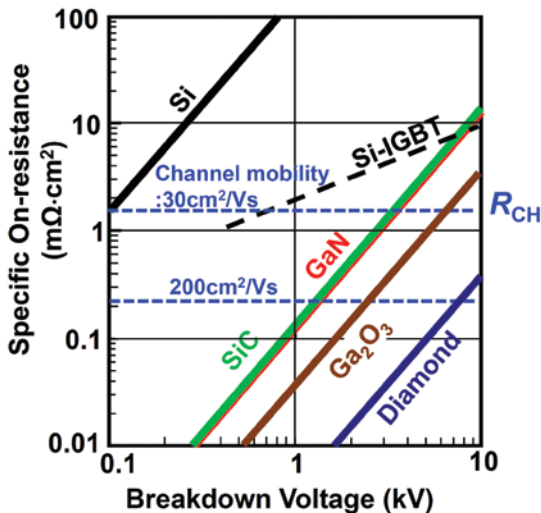

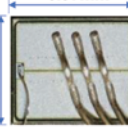



Fig. 1: Relationship between on-resistance and breakdown voltage of Si and wide-gap semiconductors. R_{ch} shows on-resistance of gate channel determined by channel mobility.

Table 1: Device specifications and chip photos comparing switching characteristics

	IGBT	SJ-MOSFET	SiC-MOSFET
Voltage max.	650[V]	650[V]	650[V]
Current max.	40[A]	40[A]	40[A]
On-resistance	43[mΩ]	60[mΩ]	60[mΩ]
Device photo			

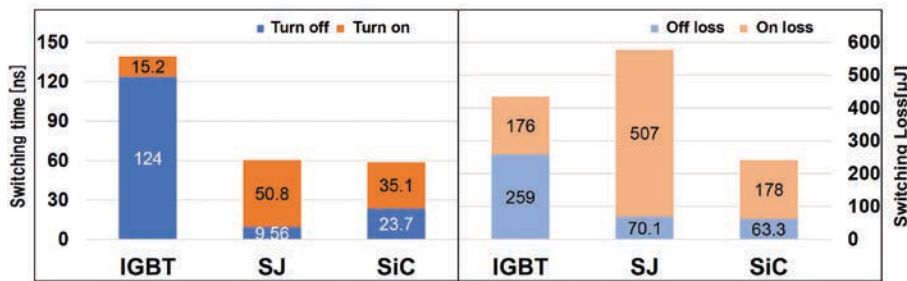


Fig. 2: Comparison of switching time and switching loss for Si-IGBT, super junction Si-MOSFET, and SiC-MOSFET measured with double pulse tester.

for both switching speed and switching loss, showing the highest performance. In addition, devices with 1200V rating also show excellent characteristics, and the adoption of SiC-MOSFETs will likely expand in the future. Future issues for the SiC power device are as follows: 1) further reduction in on-resistance by improving channel mobility; 2) increase in current capacity per chip; 3) improvement in substrate quality and larger diameter; and 4) cost reduction.

GaN Power Devices

GaN power devices have lateral and vertical structures, and the lateral structure is being put to practical use^[2, 3]. On the other hand, the vertical structure is expected to have high performance, but it is still in the development stage and process technology is being developed. Present conditions of both type devices are presented followings.

Lateral GaN power devices

The lateral structure is a structure in which current flows along the surface, and devices rated at 650V, which cannot be achieved with Si, are also available on the market. This is because the lateral structure device has an AlGaIn/GaN heterostructure channel, which can form

a very low resistance channel. In this device, a p-GaN gate structure is adopted as the gate structure to achieve normally-off operation. The structure is shown in Fig. 3. There are two types of gate contacts: ohmic contact and Schottky contact (Fig.3 (a)). Due to these structural differences, different gate drive circuits are employed. The p-GaN gate structure has a feature that the temperature dependence of the threshold voltage is extremely low, but it has a weakness that the threshold voltage is 1 to 2V and cannot take high value over 3V. On the other hand, an another normally-off device is also available. This structure is that the low-voltage Si-MOSFET and the

normally-on AlGaIn/GaN lateral device are connected as shown in Fig. 3 (b) (this connection is called cascode connection) and it can be treated as a normally-off three-terminal device. This structure has the advantage of using a normal MOSFET drive circuit for the gate drive circuit, and since the threshold voltage is determined by the Si-MOSFET, it is possible to have a threshold voltage of 3V or higher. However, since the Si-MOSFET is in series with the circuit, it also has the drawback of increasing the on-resistance. The greatest feature of these lateral structure devices is the capability of high-speed switching. Therefore, the size of the power supply can be reduced, and it is recently used in chargers for PCs and mobile phones. Lateral structure devices are suitable for power applications up to about 10kW, and have many applications including consumer products. GaN lateral power devices are fabricated by hetero-growth on a Si substrate via a buffer layer. Therefore, there is an advantage of cost reduction by increasing the diameter. Sapphire substrates are also used for low power applications. The lateral structure is also suitable for device integration, and the development of higher functionality through integration will be the direction of development in the future.

GaN vertical power devices

Vertical GaN power devices are characterized by low on-resistance under high breakdown voltage similar to SiC-MOSFET. The on-resistance performance of the drift layer calculated from the physical properties is almost the same as that of SiC, as shown in Fig. 1. However, the on-resistance of a power device is determined not only by the

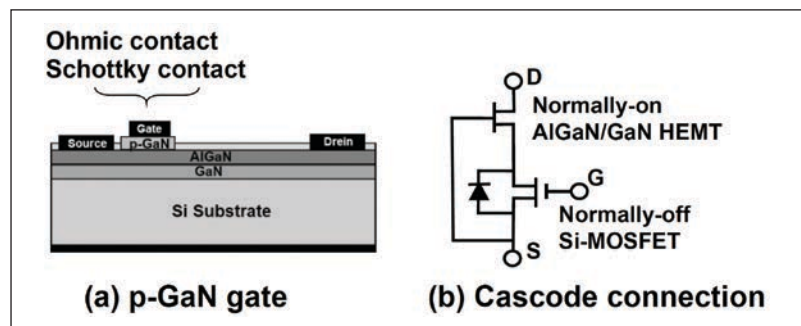


Fig. 3: Device structures of normally-off lateral GaN power devices. (a) P-GaN gate structure device which has ohmic or Schottky gate metal. (b) Cascode connection with Si-MOSFET and normally-on GaN HEMT.

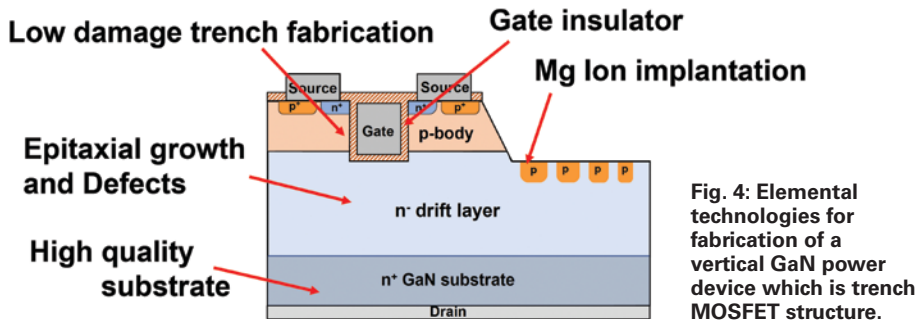


Fig. 4: Elemental technologies for fabrication of a vertical GaN power device which is trench MOSFET structure.

resistance of the drift layer, but also the contribution of the channel resistance of the gate cannot be ignored. The line labeled channel mobility in Fig. 1 indicates the channel resistance determined by channel mobility. So, the on-resistance is limited by the channel mobility. In SiC-MOSFET, the channel mobility is around $30\text{cm}^2/\text{Vs}$, and the on-resistance is determined by the channel resistance below about 3kV. On the other hand, GaN has so far achieved higher channel mobility of about $200\text{cm}^2/\text{Vs}$ for the MOS channel and more than $1000\text{cm}^2/\text{Vs}$ for the HEMT channel. Therefore, GaN has the potential for even lower on-resistance than SiC. This is the motivation for developing vertical GaN power devices. However, at present, it is still in the development stage, and the elemental technologies as shown in Fig. 3 is being developed. In recent years, those elemental technologies have also been solidified, and the development of vertical GaN has shifted to device prototyping and performance verification.

Ga₂O₃ and diamond power device

Ga₂O₃ is wideband gap semiconductor that has been attracting attention in recent years.

The potential for power device is large as shown in Fig.1. Ga₂O₃ crystal has α -type and β -type crystal structure, and α -Ga₂O₃, β -Ga₂O₃ are used for power devices. The β -Ga₂O₃ is the most stable structure. N-type doping and carrier concentration control are possible, however, p-type doping was very difficult, which is a large problem. The merit of Ga₂O₃ is that high-quality single crystal wafers are available. Many types of devices have been tried using Ga₂O₃^[4-7]. However, the performances are not yet excess SiC and GaN devices. Therefore, the development phase of Ga₂O₃ devices is research of elemental technologies for

power devices. Ga₂O₃ still faces many challenges in demonstrating high-performance power devices. Material properties have high potential but the future strongly depends on overcoming two major challenges. The first is a countermeasure against the lack of p-type. The second is the selection of the optimum gate dielectric.

Diamond has the highest thermal conductivity among all substances, and its critical electric field strength is about seven times higher than that of SiC and GaN. Various methods have been developed for the production of diamond substrates since artificial diamond was synthesized by the high-temperature and high-pressure method, but currently microwave plasma CVD (MPCVD) is the mainstream. The n-type and p-type doping are also realized by the MPCVD method, and P (phosphorus) and B (boron) were used for the n-type and p-type dopants, respectively. However, the carrier concentration at room temperature is low because of high activation energies of P and B which are 0.57eV and 0.37eV, respectively. B-doped p-type is widely used for device fabrication because it is easy to grow. The hole mobility of B-doped diamond has been reported to be over $1000\text{cm}^2/\text{Vs}$. SBDs have been fabricated using this epitaxial layer, but they are expected to be used in high-temperature environments because of the high activation energy of B^[8]. In addition, in order to solve this problem in MOSFET and MESFET, the development of devices using two-dimensional hole gas (2DHG) generated on the surface of hydrogen-terminated diamond as a channel is being actively developed^[9,10]. Inversion layer channel MOSFETs have also been developed using hydrogen terminations for source and drain^[11]. In recent years, there have been many reports on the development

of these devices, but their performance does not match the performance of conventional power devices, and the realization of practical devices still takes a lot of time.

Conclusion

Si will still maintain the main position of power devices to the near future, but, the wide gap semiconductor devices have the potential for realizing different world from Si power devices; for example, ultra-low loss power transmission electric motor airplane flying electric car high efficiency renewable energy system, etc. Each material has its own challenges, but the development of wide-gap semiconductor power devices will progress steadily, just as it did with Si.

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About this Article:

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Quantum Computing

Double-Transmon Coupler Lifts Superconducting Quantum Computers

RESEARCHERS AT TOSHIBA HAVE DEVELOPED THE FIRST TUNABLE COUPLER THAT CAN BOTH COMPLETELY TURN OFF COUPLING AND OPERATE TWO QUBIT GATES AT HIGH SPEED FOR TWO-FIXED FREQUENCY TRANSMON QUBITS WITH DIFFERENT FREQUENCIES.

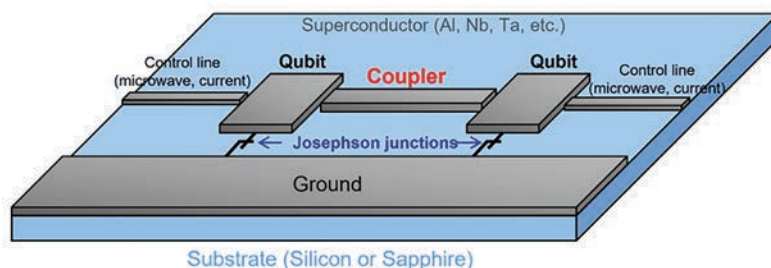


Fig. 1: Conceptual diagram of a superconducting quantum computer

Researchers at Toshiba Corporation have achieved a breakthrough in quantum computer architecture. The architecture features the basic design for a double-transmon coupler that will improve the speed and accuracy of quantum computation in tunable couplers. The coupler is a key device in determining the performance of superconducting quantum computers.

Tunable couplers, in a superconducting quantum computer, link two qubits and perform quantum computations by turning On and Off the coupling between them. Current technology can turn Off the coupling of transmon qubits^{*1} with close frequencies, but this is prone to crosstalk errors that occur on one of the qubits when the other qubit is irradiated with electromagnetic waves for control. In addition, current technology cannot completely turn Off coupling for qubits with significantly different frequencies, resulting in errors due to residual coupling.

Double-Transmon Coupler

Toshiba has recently devised a double-transmon coupler that can completely turn On and Off coupling between qubits with significantly different frequencies. Completely turning On enables high-speed quantum computations with strong coupling, while completely turning Off eliminates residual coupling, which improves quantum computation speeds and accuracy. Simulations with the new technology have shown it realizes two-qubit gates^{*2}, basic operations in quantum computation, with an accuracy of 99.99 percent and a processing time of only 24nsec^{*3}.

Toshiba's double-transmon coupler can be applied to fixed-frequency transmon qubits, realizing high stability and ease of design. It is the first to realize coupling between fixed-frequency transmon qubits with significantly different frequencies that can be completely switched On and Off, and to deliver a high-

speed, accurate two-qubit gate^{*4}.

The technology is expected to advance the realization of higher-performance quantum computers that will contribute in such areas as the achievement of carbon neutrality and the development of new drugs. Details of the technology were published in the United States on September 15 in the *Physical Review Applied*, a journal of the American Physical Society^{*5}.

Development Background

Quantum mechanics describes the invisible world of atoms and molecules using quantum superposition states, allowing a physical system to appear to be in two completely different states simultaneously. Quantum computers make use of this mysterious property to carry out computations that are practically impossible with conventional computers, a capability that has attracted much attention in recent years.

Quantum computers use qubits in quantum superposition states of 0 and 1 to execute computations. Any quantum computation is executed with two basic operations, single-qubit gates and two-qubit gates^{*6}. To realize high-performance quantum computers, fast and accurate gate operations are needed.

The development of quantum computers is being promoted worldwide. This has seen the adoption of multiple approaches, with proposals ranging from the manipulation of single atoms or ions to the use of semiconductors and superconducting circuits. The superconducting circuit approach is now seen as having an advantage in terms of realizing quantum superposition states in large circuits, and in the relative ease of achieving the strong coupling of qubits essential for the high-speed execution of two-qubit gates.

Coupling of qubits is done with a coupler (Fig. 1). Until recently, the mainstay devices have been fixed couplers with

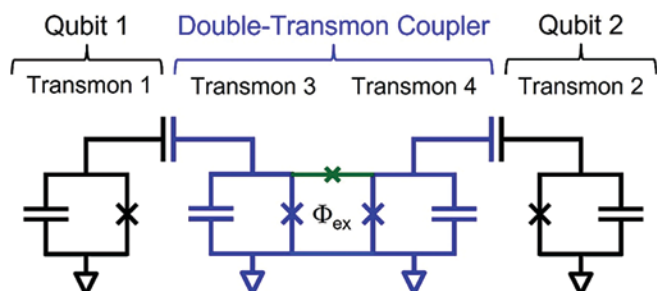


Fig. 2: Circuit diagram of the double transmon coupler, a tunable coupler for superconducting qubits

a constant coupling strength^{*7}, but attention is now turning to tunable couplers, which are seen as offering the adjustable coupling strength necessary to improve performance.

Tunable couplers achieve contradictory requirements: a fast two-qubit gate with strong coupling, along with the ability to reduce errors from residual coupling by switching Off the coupling. Also, it is preferable that the qubit used in computations is a fixed-frequency transmon qubit, which is highly stable, has a simple structure and is easy to fabricate. In addition, the frequency of the two qubits that are coupled should be significantly different, as this reduces crosstalk errors, and is robust against deviations from the design values of qubit frequencies, thereby improving yields in device fabrication. The problem here, however, is that no tunable coupler has yet been able to combine complete off-coupling and fast two-qubit gate operations for two fixed-frequency transmon qubits with significantly different frequencies.

First Tunable Coupler

Toshiba researchers have devised a double-transmon coupler, the world's first tunable coupler that can both completely turn Off coupling and operate the two qubit gates at high speed for two fixed-frequency transmon qubits with significantly different frequencies.

The double transmon coupler comprises two fixed-frequency transmon qubits, shown as transmon 3 and 4 in Fig. 2, along with two other fixed-frequency transmon qubits, transmon 1 and 2 in the figure, used for computation. The double-transmon coupler has one loop, and the three x's on the loop represent two transmon Josephson junctions^{*8} and an additional Josephson junction. The magnetic flux in the loop, Φ_{ex} , can be tuned by an external magnetic field to bring the coupling strength between the qubits on both sides to exactly zero, completely switching Off the coupling (Fig. 3). The coupling strength can also be increased to several tens of megahertz by increasing the magnetic flux, which realizes fast two-qubit gate operations. Simulations have shown gate operations with an accuracy of 99.99 percent are possible, with gate times as short as 24nsec. The coupler is thus expected to contribute to higher-performance quantum computers.

Future Prospects

Toshiba plans to start to prototype and demonstrate the

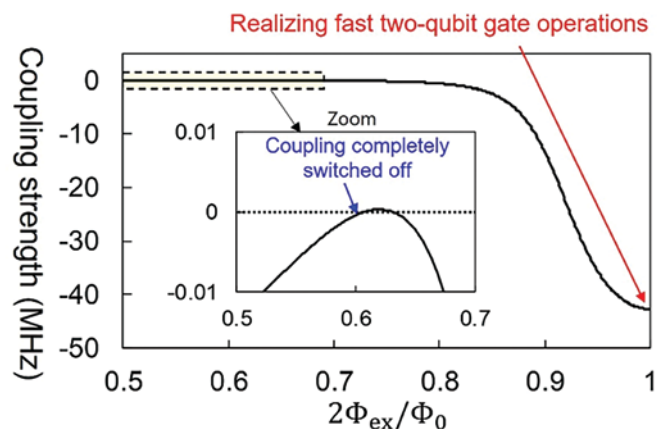


Fig. 3: Magnetic flux dependence of coupling strength in double-transmon couplers

double-transmon coupler this fiscal year. The company aims to make use of its characteristics to achieve the highest-level performance in both speed and accuracy.

References:

^{*1} A transmon qubit is the simplest superconducting qubit. It comprises a Josephson junction (two superconductors joined by a thin insulating film) and a capacitor. It typically has a frequency of several gigahertz. While a fixed-frequency transmon has one Josephson junction, a frequency-tunable transmon has two Josephson junctions.

^{*2} A quantum gate operation performed on two qubits, which can be combined with a single-qubit gate operation performed on one qubit to perform arbitrary quantum computations.

^{*3} Without decoherence. In practice, decoherence, which breaks the quantum superposition state due to the finite coherence time possessed by the qubit, is expected to occur, resulting in reduced fidelity.

^{*4} Toshiba research, as of 16 September 2022. Theoretically demonstrated by numerical simulation. A method to eliminate the residual coupling by irradiating the coupler with electromagnetic waves was reported in a paper published in July 2022 (Z. Ni et al., *Phys. Rev. Lett.* 129, 040502 (2022)), but it has not been reported that this method also realizes fast and highly accurate two-qubit gates.

^{*5} H. Goto. *Physical Review Applied* 18, 034038 (2022) and selected Editors' Suggestion. <https://doi.org/10.1103/PhysRevApplied.18.034038>

^{*6} In universal gate-based quantum computers. In quantum annealing for combinatorial optimization problems, gate operations are not used in quantum computations.

^{*7} For a fixed coupler, coupling is effectively switched On and Off by controlling qubit frequencies. In this case, the qubits need to be frequency-tunable and then the coherence time is relatively short.

^{*8} A Josephson junction. Quantum tunneling causes Cooper pairs in the superconductors to move back and forth across the insulating film, exhibiting quantum phenomena called Josephson effects.

Piezoelectric MEMS Device Innovates Thin Film Applications

OKI Electric Industry Co., Ltd. and KRYSTAL Inc., a Japan-based venture company of single-crystal thin films, have announced a new micro electromechanical systems (MEMS) device developed by leveraging their respective technologies. The two companies have merged OKI's connection technology nurtured in the light emitting diodes and KRYSTAL's thin film technology for the piezoelectric single-crystal thin film*¹ used in the MEMS device. It is expected that various applications will emerge from this new device.

Piezoelectric MEMS are micrometer-level electric machine systems. They are made by integrating sensors, actuators, and electronic circuits, which are piezoelectric element components, on semiconductor silicon substrates, glass substrates, or organic materials.

Piezoelectric thin films have been widely used in the MEMS market. They are incorporated in inkjet printers, gyro sensors, microphones, ultrasonic sensors, and odor sensors. Piezoelectric thin films are being developed for applications to smartphones, wearable devices, mobility, and robotics. However, there are challenges in the development of materials toward achieving miniaturization and lower power consumption.

OKI's Crystal Film Bonding Technology

Crystal film bonding (CFB) is one of OKI's core technologies. It is a technol-

ogy employed to bond different materials using intermolecular forces of materials. OKI's proprietary nano technology is being used for this process without an adhesive. It adopts the same principle as wrap films used for foodstuffs. Moreover, it can bond different kinds of materials on various substrates and structures.

Around year 2000s, OKI successfully used this technology in the mass production of a new device that combined LED and IC. The new device featured high productivity. The company adopted it to bring compact LED print heads to the commercial market.

Single Crystallization Technology

Meanwhile, KRYSTAL is a venture company working on single-crystal thin films leveraging expertise in handling equipment. Based in Yamaguchi Prefecture, Japan, the company has been advancing single crystallization of almost all kinds of materials. The company has a track record of becoming the first in the industry to commercialize a lead zirconate titanate (PZT) single-crystal thin film. It has also succeeded in the single crystallization of various materials, including aluminum nitride, which has been a challenge.

Towards Co-development

Generally, existing thin film materials for MEMS are polycrystalline. However, a problem with MEMS using polycrystalline thin films is that the particles come apart. It is known that uniform particles of single crystallization of thin film materials improves characteristics of materials. However, the formation of thin films on wafers was difficult.

Hence, the two companies focused their attention on the use of the buffer layer between the single-crystallized piezo thin film and the silicon layer, which

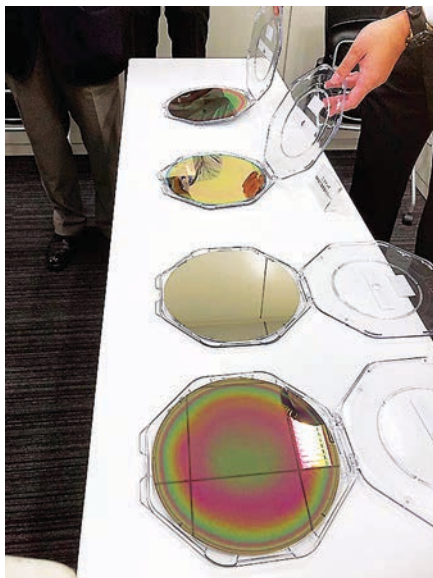


Photo 1: Examples of wafers the two companies have been working on.

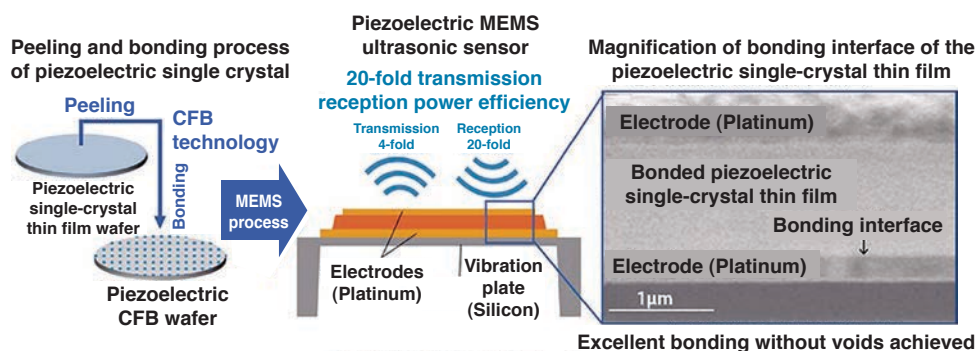


Fig. 1: 20. Bonding process and device structure of piezoelectric single-crystal thin film

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Research Paves Way for Novel Chiplet Integration Technology

A research team headed by Specially Appointed Professor Yoichiro Kurita of Laboratory for Future Interdisciplinary Research of Science and Technology, Institute of Innovative Research at Tokyo Institute of Technology (Tokyo Tech) and a collaborative research company have developed chiplet integration technology^[1] that uses "Pillar-Suspended Bridge (PSB)" technology. This technology meets the requirements for broadband chip-to-chip communication and scalable chiplet integration, which is required for future large-scale chiplet integration, with a minimal configuration and manufacturing process.

It features a silicon bridge interconnection structure via a fine "MicroPillar" for broadband communication between chips and a manufacturing process called "All Chip-last". The structure and the process provide the requirements for chiplet integration in the simplest form. This technology is expected to accelerate the evolution of future semiconductor integrated circuit system technology, replacing miniaturization, which is predicted to slow down.

This research was conducted jointly with Aoi Electronics Co., Ltd. and four other companies ahead of the Chiplet Integration Platform Consortium (described later) established on October 1. Detailed results were presented at the international conference IMAPS 2022, held in Boston, MA, U.S.A. on October 3.

In addition to Tokyo Tech, the Chiplet Integration Platform Consortium is centered on Osaka University (Specially Appointed Professor and Professor Emeritus Katsuaki Suganuma) and Tohoku University (Associate Professor Takafumi Fukushima), and 32 companies are scheduled to participate (as of September 2022). It covers research on chiplet integration platform technology in general, including 3D integration technology and optical integration technology.

Conventional semiconductor integrated circuits (IC chip):
Circuits are connected by on-chip wirings



Chiplet integrated structure:
Connects independently manufactured IC components (chiplets) via a bridge

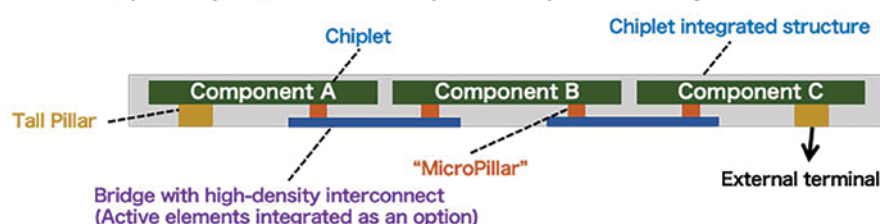


Fig. 1: Comparison between conventional semiconductor integrated circuits and chiplet integrated structures

Development Background

Since their invention in the middle of the 20th century, semiconductor integrated circuits have become the driving force behind the world's digital transformation thanks to Moore's Law, which improves performance, reduces power consumption, and lowers costs through device miniaturization and improved integration. However, in recent years, the size of semiconductor circuits has been miniaturized to several nanometers. Due to the physical limitations imposed by the size of the atoms that make up a semiconductor, industry now recognizes the law's demise.

Meanwhile, chiplet integration technology (Fig. 1) is in the spotlight as a new evolutionary path to scale up integration and improve performance/reduce power consumption in place of miniaturization. This consists of assembling major systems from a collection of integrated circuit chips that are more tightly coupled than in conventional semiconductor packaging technology. Furthermore, this goes beyond the physical/manufacturing technology dimensions of semiconductor wafers and chips and integrates different functions and structures on a

large scale. It is also possible to provide improved performance through heterogeneous integration and integration scalability, which were not achieved with conventional semiconductor integrated circuit technology.

Integration technology using silicon interposers and polymer-based RDL (Redistribution Layer) interposers (also known as RDL-first/Chip-last Fan-Out) has been developed and implemented as a platform technology for chiplet integration, but large-scale integration is limited by wafer size and manufacturing technology. Meanwhile, a technology using locally arranged high-density wiring chips called a silicon bridge is being developed for large-scale integration. However, the complexity of the structure and manufacturing process and the high manufacturing precision required for increased integration present a challenge.

Research Results

In view of the above background and challenges, the research team devised Pillar-Suspended Bridge (PSB) technology as a chiplet integrated structure/process with simplest scheme, and made a proof-of-concept prototype to prove its

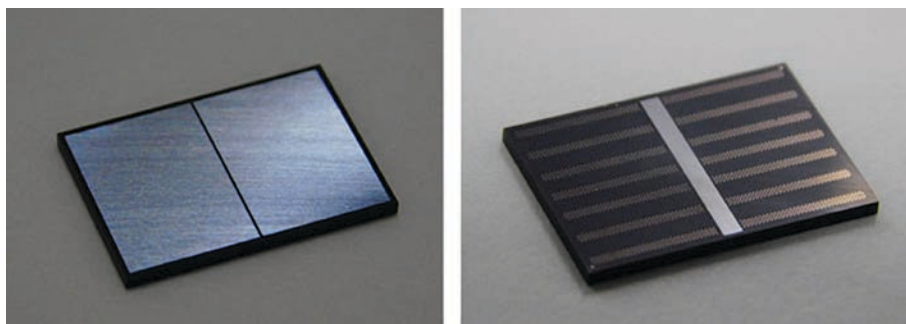


Fig. 2: Appearance of proof-of-concept sample of PSB chiplet integrated structure

feasibility. Figures 1 and 2 show a PSB bridge connection structure. Only a pillar-shaped metal called a "MicroPillar" is interposed at the connection between the chiplet and the silicon bridge. The chiplets are sealed with mold resin together with the bridge, and is connected to an external electrode by a "Tall Pillar" penetrating the mold on the silicon bridge side. This structure makes it possible to improve the inter-chip connection density and electrical properties by minimizing the chiplet/bridge interconnect element, and to improve the high-frequency properties of the external connection wiring and heat dissipation performance. Another advantage it has is that the type of bridge wiring can be selected, there is no yield problem when scaling up integration (Known Good Bridge), and the size and manufacturing units of the integrated module can be expanded to large panels. This structure was created by (1) high bonding accuracy and reducing "die shift" (phenomenon in which the chip moves during mold sealing) during the manufacturing process with the All Chip-last process, and (2) a bonding process with matching linear expansion (Coefficient of Thermal Expansion: CTE).

Thus, the PSB structure has a simple and rational structure for chiplet integration using silicon bridge. By connecting a wiring layer (e.g., RDL Interposer) with a Fan-Out function to this, it is possible to assemble an ideal chiplet integrated package as shown in Figure 3 or a large-scale chiplet integrated system as shown in Figure 4.

Social Impact

While the miniaturization of semiconductor integrated circuits is expected to slow down due to Moore's law, chiplet integration technology will likely be a new evolutionary path for improving system performance. This platform technology is expected to have a large effect on human society in the long term, and the emergence of a huge industry accompanying it. This technology and its component technologies and applications are expected to contribute to these trends.

Future Development

The group plans to increase interconnection density and scale up integration, develop high-performance bridge wiring technology and global wiring integration technology, verify reliability, and verify system applications.

In addition, it will establish the Chiplet Integration Platform Consortium on October 1, 2022 for the purpose of research and development in the value chain from manufacturing technology and element technology to applications and its industrialization, targeting chiplet integration platform technology in general, including this research. Along with Tokyo Tech, the main consortium members are Osaka University (Specially Appointed Professor and Professor Emeritus Katsuki Sukanuma) and Tohoku University (Associate Professor Takafumi Fukushima), and 32 companies are scheduled to participate (as of September 2022). It covers research on chiplet integration platform technology in general, including 3D integration technology and optical integration technology.

Note:

^[1]Chiplet integration technology: Moore's law predicts that the number of components per integrated circuit (chip) will increase exponentially due to transistor miniaturization. From a meta-viewpoint, chiplet integration technology replaces and complements miniaturization in the form of integration of a large number of chips (small chips) to achieve the effect of Moore's law: improved system performance.

About this Article:

The article is an excerpt from the paper *Chiplet Integration by Die-to-Die Pillar-Suspended Bridge* authored by Ichiro Kono, Shinji Wakisaka, Toshiaki Hirota, Takashi Saitou, Ken Ukawa, and Yoichiro Kurita. The paper was presented during the recent 55th International Symposium on Microelectronics (IMAPS 2022) held in Boston, Massachusetts.

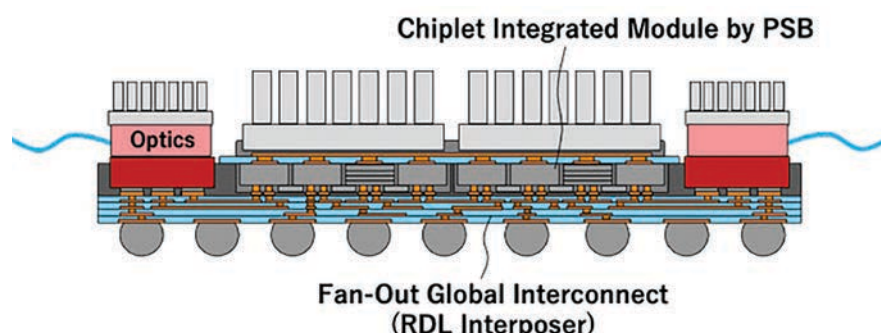


Fig. 3: PSB module external connection structure

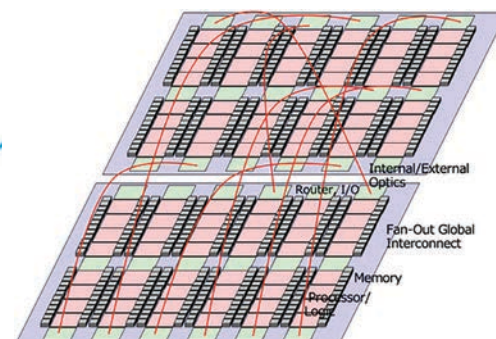


Fig. 4: Image of large-scale chiplet integration

Aluminum Electrolytic Capacitors Gear up to Electrified Vehicles

In recent years, the environment surrounding automobiles has changed dramatically. Amid the enhanced awareness of environmental issues, the shift from internal combustion engine vehicles to electrified vehicles (xEVs) has been rapidly progressing towards decarbonization. Further, the development of automobiles equipped with safety-related technologies and autonomous driving functions for advanced driver-assistance systems (ADAS) designed to enhance safety performance has been accelerating. Moreover, the development of automatic brakes, and image recognition- and sensor-related devices essential to achieve these functions, has also been advancing.

Demands for high-reliability capacitors used for automotive application have been increasing as well. Smaller

capacitors with higher capacities, higher allowable ripple current, and low equivalent series resistance (ESR) have been in high demand.

In automobiles that use internal combustion engine together with electric motors, reduction of the amount of carbon dioxide (CO₂) emissions been progressing. This has been achieved through the adoption of hybrid systems, including 48V power source, and

the electrification of various hydraulic drive systems. In addition, as electronic circuits installed in the engine compartment, which is a high-temperature environment, continue to increase, moves to increase circuit voltage have been advancing to reduce the growing power consumption. Moreover, capacitors that withstand high-temperature environments and have higher rated voltages are being increasingly required.

This article explains latest technological trends of aluminum electrolytic capacitors, conductive polymer hybrid aluminum electrolytic capacitors and conductive polymer aluminum solid electrolytic capacitors for automotive application.

UBH Series ESR Regulated Capacitors

To install electronic circuits in the high-temperature engine compartment, automotive components that withstand high temperatures are highly needed. Automotive components are required to feature miniaturization, higher capacities, lower equivalent series resistance (ESR) and longer life. Nichicon Corporation has met these requirements by offering various series focusing on products with rated temperatures of 105°C and 125°C. Going forward, products that withstand much severe high-temperature environments will be required to cope with the installation of electronic control units (ECUs) in the engine compartment and in the vicinity of the engine. The UBH Series, which withstands 150°C for 1,500 to 2,000 hours, has been developed by Nichicon as ultra-high temperature-resistant products (Photo 1).

In developing the UBH Series, Nichicon has optimized high-capacity, low-resistance, and high-reliability technologies it has refined over the years. The company has adopted electrolytic solution with low specific resistance and low evaporation property and optimized the design of sealing structure to



Photo 1: UBH Series chip-type aluminum electrolytic capacitors

Table 1: Comparison of rated capacitances between existing products and the UBH Series.

Rated voltage (V)	Case size φD×L(mm)	150°C-resistant products		
		Rated capacitance (μF)		
		UBC Series (Existing products)	UBH Series (New products)	Increase rate
25	8×10	100	150	×1.5
	10×10	220	270	×1.2
35	8×10	47	100	×2.1
	10×10	100	180	×1.8

meet the 150°C environment. It has also adopted high-powered electrode foil to expand the effective surface area of the electrode. As a result, the UBH Series has achieved high capacity about twice that of the existing UBC Series, which is guaranteed to operate at 150°C for 1,000 hours. At the same time, it has also achieved high reliability characteristics. Capacitors that withstand 150°C for 1,500 to 2,000 hours are available only from Nichicon. The UBH Series comes in two case sizes: $\phi 8 \times 10L$ and $\phi 10 \times 10L$. They have rated voltages of 25V and 35V and rated capacitances of 100 to 270 μF . As shown in Table 1, the UBH Series has 1.2- to 2.1-fold capacitance of the existing series. Hence, it contributes to miniaturization, weight reduction, lower number of components, and higher performance of devices to be incorporated in the engine compartment.

GYF Series with High Capacitance

Conductive polymer hybrid aluminum electrolytic capacitors adopt two kinds of electrolytes: conductive polymer and electrolytic solution. Thus, they provide aluminum oxide film repairing performance of the electrolytic solution, in addition to low ESR performance and excellent high heat-resistance performance, which are characteristics of conductive polymer. Hence, the GYF Series allows lower ESR, higher allowable ripple current, and longer life compared with aluminum electrolytic capacitors. It also features lower leak current

compared with conductive polymer aluminum solid electrolytic capacitors.

Nichicon released in 2021 the GYE Series, which achieved one-rank higher capacitance compared with the GYA Series guaranteed for 4,000 hours at 125°C. This time, the company has developed the GYF Series with two-rank higher capacitance compared with the GYA Series (Photo 2).

The GYF Series adopts a high-capacitance electrode foil and a thin separator, thereby achieving high capacitance. It maintains reliability equivalent to that of the GYA Series. It guarantees 4,000 hours at 125°C and moisture resistance of 2,000 hours at 85°C85%RH. Table 2 shows the rated capacitances and rated ripple current of the GYF Series and existing products. The GYF Series has achieved higher capacitances for the same sizes. It allows rated allowable ripple current up to 1.44-fold of the GYA Series. Hence, it contributes to the reduction of the number of capacitors, and thus, to weight reduction and downsizing of units. Moreover, the series contributes to designing higher performance circuits.

PCZ, PCH, PCM, PCL Series

Nichicon has been mass producing the PCZ Series conductive polymer aluminum solid electrolytic capacitors guaranteed to operate 2,000 hours at



Photo 2: GYF Series conductive polymer hybrid aluminum electrolytic capacitors

150°C, the highest temperature in the industry, targeting automotive application that requires high reliability to operate even under high-temperature conditions (Photo 3). The company has optimized constituting components, including conductive polymer, improved self-repairing capacity of aluminum oxide film and sealing technology. As a result, the PCZ Series has enabled a rated life of 2,000 hours at 150°C, while maintaining low ESR and high ripple current even in ultra-high temperature areas, in which conductive polymer aluminum solid electrolytic capacitors could not be installed. It is available in dimensions ranging from $\phi 8 \times 7L$ to $\phi 10 \times 12.7L$, and has a rated voltage range of 16 to 63V and rated capacitance range of 12 to 1,000 μF .

Specifically, ECUs for powertrains are more frequently incorporated in engine compartments. Capacitors with heat

Table 2: Comparison of rated capacitance and rated ripple current between the GYF Series and existing products.

Case size $\phi D \times L$ (mm)	Rated voltage (V)	GYA Series (Existing products)		GYE Series (One-rank higher capacitances)		GYF Series (Two-rank higher capacitances)	
		Rated capacitance (μF)	Rated ripple current (mArms)	Rated capacitance (μF)	Rated ripple current (mArms)	Rated capacitance (μF)	Rated ripple current (mArms)
$\phi 6.3 \times 5.8L$	25	56	900	82	1100	100	1300
	35	47	900	56	1100	68	1200
$\phi 6.3 \times 7.7L$	25	100	1400	150	1700	180	1800
	35	68	1400	100	1700	120	1700
$\phi 8 \times 10L$	25	220	1600	270	2000	330	2000
	35	150	1600	180	2000	220	2000
$\phi 10 \times 10L$	25	330	2000	470	2800	560	2800
	35	270	2000	330	2800	390	2800



Photo 3: PCZ Series conductive polymer aluminum solid electrolytic capacitors



Photo 4: PCH Series conductive polymer aluminum solid electrolytic capacitors

resistance to operate even under heat soak conditions during stoppage of the cooling fan have been increasingly required. Specifically, they are demanded to feature miniaturization, lower height, and higher withstanding voltage accompanying power saving. To meet these requirements, Nichicon has expanded its lineup of the PCH Series that guarantees operation at 135°C for 4,000 hours for automotive application (Photo 4).

Nichicon has deployed new technologies developed for the PCH Series to capacitors with rated voltages of 16V, 20V, and 80V and a case size of $\phi 6.3$, and has materialized the lineup of 135°C products by optimizing those technologies. With this, the company now can offer products in accordance with applications that require low ESR and high allowable ripple current even under high-temperature environments.

Nichicon has also expanded its lineup of the PCM Series guaranteed for industry-leading 8,000 hours at 125°C in order to meet increasing requirements for longer life from automotive and information and communications applications (Photo 5). The PCM Series comes



Photo 5: PCM Series conductive polymer aluminum solid electrolytic capacitors

in dimensions ranging from $\phi 6.3 \times 6L$ to $\phi 10 \times 12.7L$, and has a rated voltage range of 16 to 80V and rated capacitance of 12 to 1,000 μ F. The company has achieved guaranteed operation for 8,000 hours, twice that of existing products by optimizing various components. Thus, it can provide optimum products for applications that require longer life in high-temperature environments up to 125°C.

To meet requirements of ADAS and infotainment-related devices for longer life at 105°C, Nichicon has expanded ratings of the PCL Series guaranteed for 20,000 hours at 105°C. It is available in case sizes ranging from $\phi 5 \times 6L$ to $10 \times 12.7L$, and has a rated voltage range of 2.5 to 25V, and rated capacitance of 12 to 3,300 μ F.

With these product lineups, Nichicon offers products meeting applications in a wide operation temperature range from 105 to 150°C. The company

promotes low ESR, high ripple current, stable resistance after durability, and long life in high temperatures, which are strengths of conductive polymer aluminum solid electrolytic capacitors. Table 3 shows comparisons of the characteristics of ultra-high-temperature-resistant 150°C Series against different capacitor types.

Prospects for Capacitors

The global market of automotive electric systems is forecast to expand to over ¥42 trillion by 2030. Main markets for the future will be safety-related technologies and autonomous driving functions, including ADAS, autonomous driving systems, and driver monitoring systems. Further, the demand for even smaller and high-performance automotive electronic components is expected to increase. This will necessitate even higher performance capacitors, making it urgent to create capacitors with longer life, higher temperature resistance, and withstand higher current, on top of miniaturization and higher capacitance.

Nichicon intends to advance capacitor development so that it can provide optimum products that meet customers' requirements speedily.

About This Article:

Nichicon Corporation provided the contents of the article.

Table 3: Characteristics of different capacitor types of the same size ($\phi 8 \times 10L$) and the same ratings (25V/150 μ F).

	Aluminum electrolytic capacitors	Conductive polymer hybrid aluminum electrolytic capacitors	Conductive polymer aluminum solid electrolytic capacitors
Series	UBH	GYD	PCZ
ESR (at 20°C/100kHz)	260m Ω	27m Ω	20m Ω
Rated ripple current (at 150°C/100kHz)	80mArms	1400mArms	1800mArms
ESR after endurance test (at 40°C/100kHz)	4500m Ω	54m Ω (at 20°C 100kHz)	40m Ω
Guaranteed operation life	1,500 hours at 150°C	1,000 hours at 150°C	2,000 hours at 150°C

Murata's Unique 24V Battery Modules Power AGVs, AMRs

Murata Manufacturing Co., Ltd. is propelling the sales of 24V battery modules that employ its original FORTELION lithium-ion batteries. Accordingly, the lineup enables the company to meet the demand for battery modules for industrial equipment that require high output power and high safety. These include automated guided vehicles (AGVs), autonomous mobile robots (AMRs), service robots, security robots, and electric forklift trucks.

The FORTELION lithium-ion batteries have a cathode composed of olivine-type lithium ion phosphate. Hence, they are difficult to ignite even if applying a large shock or pressure. They exhibit stable battery function even under high load.

Moreover, the FORTELION lithium-ion batteries achieve more than 10,000 charge-discharge cycles and enable long-term use. Promoting these characteristics of the battery, Murata will first expand sales of the battery modules to industrial equipment manufacturers in Japan and countries in Europe.

In Japan, the company partners with Restar Electronics Corporation, which has been handling its battery-related products for many years. Furthermore, in Europe, the company entered a partnership with a trading company with a strong European market base, putting in place a solid support system from the introduction of products to after-sales service. The company accelerates the cultivation of customers.

High Performance, Highly Reliable

Accordingly, the FORTELION24V battery module is available in two types: all-in-one type equipped with a battery management unit (BMU) (195×132×180mm) and separate type with a separate BMU (259×71×245mm).

Murata started mass production of the all-in-one type in April 2020. In addition, it is the same size as a lead acid battery, facilitating replacement from lead acid batteries. The company has been mass-producing

the separate type since 2018. It is a thin battery module with a thickness of 71mm and suits low-profile AGVs and AMRs.

Normally, AGVs, AMRs, service robots, and electric forklift trucks with power supply system constituting multiple of 24V need to connect two 12V lead acid batteries in series. However, only one all-in-one type 24V battery module is enough.

Particularly, the cathode material of cylindrical olivine-type lithium-ion iron phosphate rechargeable batteries used in the 24V battery modules has an olivine structure wherein phosphorus and oxygen strongly bond. It does not discharge oxygen and the structure does not collapse. Hence, the 24V battery modules are thermally stable and ensure high safety without thermal runaway (ignition) due to overcharge and internal short circuiting.

Even after more than 10,000 charge-discharge cycles, capacity deterioration of the batteries is very slow, allowing long-term use over 15 years. Furthermore, they self-discharge of several percent per year, which is very small compared with lead acid batteries.

It is possible to charge the batteries up to 90 percent of their capacity in about an hour. Thus, they can be charged during the stand-by time of equipment.

Bears Proprietary Processing

Murata has leveraged know-how it has nurtured in the production of batteries for personal computers and mobile phones. Combined with the company's original arithmetic processing technology, the batteries allow users to check the remaining capacity in 1 percent increment and recognize accurate timing for charge.

Furthermore, the batteries are immune to the effects of voltage and enable long-hour use. Unlike nickel-cadmium batteries, they are free from memory effect. To illustrate, this causes the battery's usable time shorter than its actual remaining capacity after repeated shallow charging.

The 24V battery modules have achieved the IP54 dustproof and waterproof level and are usable outdoors. They have also obtained UL2271 certification required for the safety of batteries for light vehicles.

Moreover, they use a cathode using iron as a main component, reducing restrictions of resources. They are cobalt-free and are friendly to environment. □



FORTELION24 battery modules: All-in-one type (right) and separate type (left)

High-Performance Magnetic Slot Wedge for Motors Supports Decarbonization

Hitachi Metals, Ltd. had developed new magnetic slot wedges for motors in an effort to increase the efficiency of motors. It was achieved through the advancement of its original powder metallurgy technology the company has accumulated over many years. Hitachi Metals will strive to achieve lower loss and higher efficiency of motors. The company will leverage the high magnetic permeability and reliability of the newly developed product with a view toward aiding the reduction of society's power consumption and carbon dioxide (CO₂) emissions.

Main Source of Power Consumption

Induction motors are powered by the electromagnetic force of an alternating current. They are extensively used for industrial applications such as pumps and compressors, and in rail rolling stock, among others. Nowadays, individual countries are working to increase the efficiency of induction motors through the Top Runner Program^{*1}.

It is said that motors are responsible for 40 percent of global power consumption. Thus, to reduce power consumption and CO₂ emissions from power

generation, a key issue is increasing the efficiency of motors. There are many different efforts towards this goal.

Increasing Efficiency of Induction Motors

One of the efforts that is drawing attention is focused on magnetic slot wedges. Magnetic slot wedges increase efficiency after installation without changing the structure or size of the motor. Generally, slot wedges for motors prevent coils in core slots from falling off. Slot wedges made of magnetic materials attract magnetic flux^{*2} and increase energy efficiency (Fig. 1). However, existing magnetic slot wedges^{*3} contain iron powder dispersed in resins. This results in poor magnetic permeability^{*4} and failure to sufficiently improve motor efficiency. In addition, the heat resistance of these magnetic slot wedges is so poor that they were not appropriate for high-temperature applications. For these reasons, magnetic slot wedges for motors must be with high strength, magnetic permeability, and heat resistance to withstand the severe conditions inside motors.

High-performance Magnetic Slot Wedges

Hitachi Metals has recently developed a new type of magnetic slot wedge that does not contain any resin. These mag-

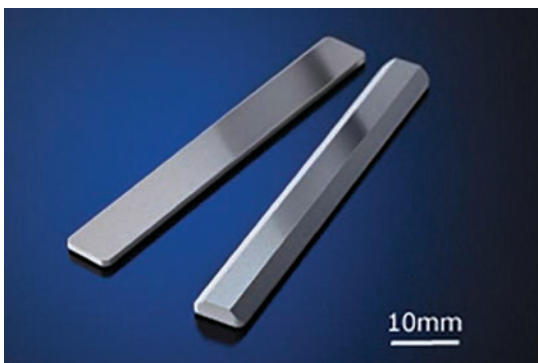


Photo: High-performance magnetic slot wedges

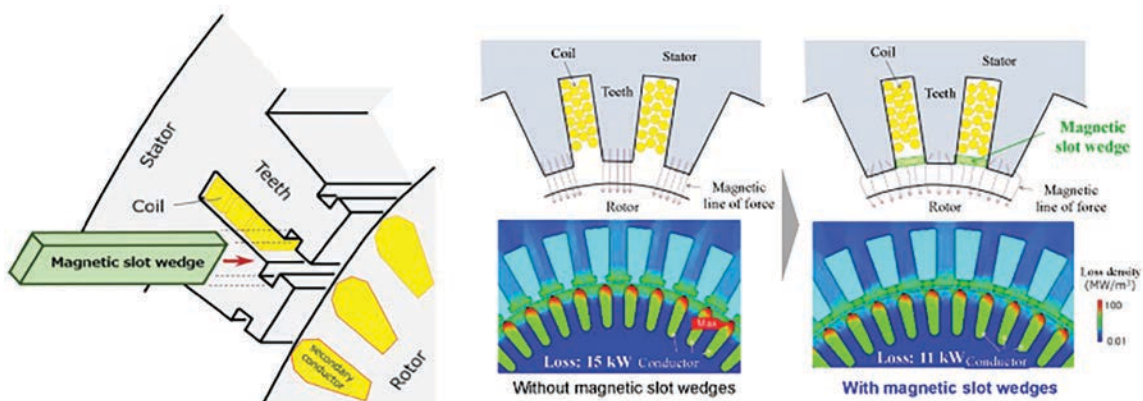


Fig. 1: Reducing loss of induction motors using magnetic slot wedges
 ▶ Compared with the state without wedges, loss (shown in red) is reduced.

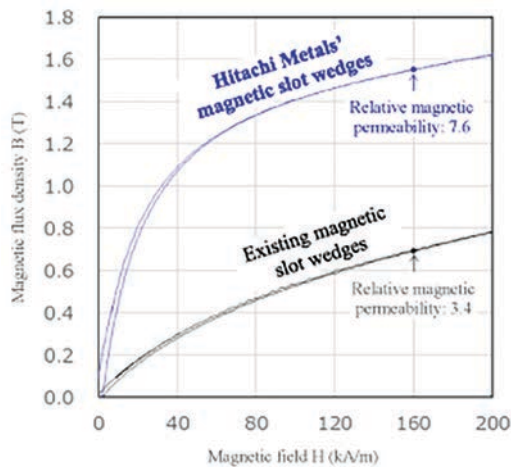


Fig. 2: Magnetic characteristics of Hitachi Metals' magnetic slot wedges. ▶ Magnetic permeability nearly double that of existing wedges.

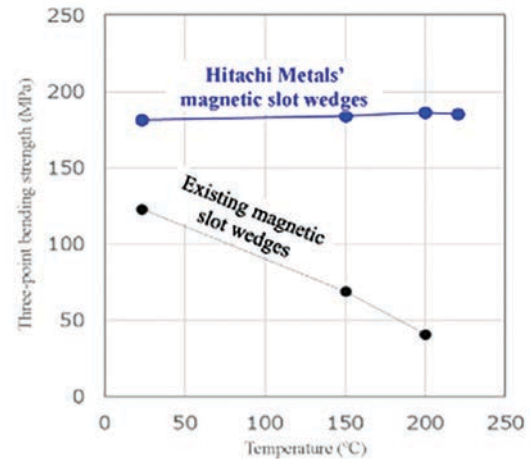


Fig. 3: Dependency of strength on temperature ▶ Strength is higher than existing wedges and it does not fall even at high temperatures.

netic slot wedges are realized using a new technology that bonds magnetic particles. This new technology increases the density of magnetic particles and achieves high magnetic permeability that is about double the level of existing magnetic slot wedges (Fig. 2). The high density leads to high strength that is around 1.5 times the strength of existing ones. Without containing resin, Hitachi Metals' 10mm magnetic slot wedges exhibit outstanding heat resistance enabling the wedges to maintain their strength in high temperature conditions (Fig. 3). The new magnetic slot wedges suppress eddy-current loss^{*5} that occurs in them because their electric resistance is higher than existing ones. In addition, they are expected to help improve motor cooling efficiency since they have higher thermal conductivity than existing ones. A computer simulation suggests that the new magnetic slot wedges sized 0.5mm or larger increases the efficiency of the general 3.7-kW four-pole motors used in pumps, compressors, and other devices by around 1 percent compared with motors without magnetic slot wedges or about 0.5 percent compared with motors with existing magnetic slot wedges (Fig. 4). Hitachi Metals' magnetic slot wedges are characterized by their high magnetic permeability, strength, and heat resistance. Therefore, they can be used in motors in different sizes and for different applications where magnetic slot wedges were not conventionally used.

On the occasion of this development, Hitachi Metals will promote the products as a solution for increasing motor

efficiency to global customers engaging in motor development. As a high-performance materials company that supports a sustainable society, the company will endeavor to achieve carbon neutrality.

Endnotes:

^{*1}*Top Runner Program: A program launched to ensure both consumer satisfaction and energy efficiency measures in a manner based on the method by which a goal of exceeding the level of the most energy efficient device is set when the standard value is formulated.*

In Japan, the program is used for automobiles and home electric appliances, for example.

^{*2}*Magnetic flux: A group of magnetic lines of force that represent the force applied at different points in the magnetic field. Electric field intensity and direction at a particular point are represented as a bunch of lines.*

^{*3}*Existing magnetic slot wedges: The specifications had been researched, investigated, and evaluated by Hitachi Metals Ltd.*

^{*4}*Magnetic permeability: An indicator of how easily the magnetic flux passes through a magnetic material. This article uses values calculated by dividing the magnetic flux density at a magnetic field of 160 kA/m by the magnetic field.*

^{*5}*Eddy-current loss: Loss resulting from heating due to loops of electric current inside a metal or other substance with low electric resistance after an alternating current magnetic field is applied.*

^{*6}*InnoTrans: The world's largest international trade show specializing in railway technologies, which is held in Berlin, Germany every two years (in even calendar years). URL: <https://www.innotrans.de/en/>*

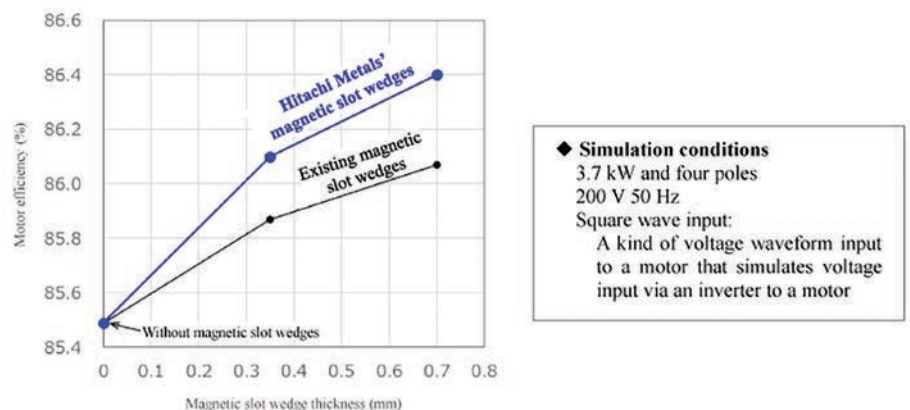


Fig. 4: Comparison of efficiency of a 3.7-kW induction motor ▶ Efficiency is higher than the motor with existing wedges.

On-Vehicle Night Vision System Integrates White-IR Light

Kyocera Corporation has developed the first on-vehicle night vision system to equip headlights that integrate white light and near infrared (IR) light (white-IR light). The night vision system recognizes objects, which can become risk factors, at high accuracy even in low-visibility environments, such as night-time, rain and fog. Additionally, it supports safe driving. Further, it integrates an original artificial intelligence (AI) learning data generation technology, thus enhances efficiency. Overall, the system offers significant cost reduction and high performance.

Significance of Risk Detection

There are many fatal traffic accidents in areas where risk detection is difficult, such as during night-time and in fog. It is reported that the fatal accident rate of traffic accidents occurring at night-time is 2.5-fold of traffic accidents occurring during day-time. Moreover, the rate of fatal traffic accidents occurring in foggy environments is 3.3-fold that of the whole traffic accidents. More advanced detection functions are sought not only to reduce accidents, but also to achieve autonomous driving.

To detect risk factors, individual sensors for different applications are incorporated. However, their detection performance is not sufficient, and enhancement of functions has been a challenge. At the same time, there are also requirements to reduce the number of sensors incorporated in a vehicle.

High Accuracy Detection of Objects

Kyocera Corporation has developed a system that enables high-accuracy detection of objects during driving. The system photographs objects illuminated by integrated headlights with optical axes of white light and near-infrared light matched, using an RGB-IR sensor (visible light and near IR sensor) incorporated in a vehicle. Based on the image data, the system detects objects using the company's original fusion recognition AI technology.

As the optical axes of the white light and near IR light are the same, differences in the ways of irradiation with light do not develop, and changes due to aging are less likely to occur. Thus, the system enables the display of recognition results with higher accuracy.

The Kyocera Group has developed the integrated headlights by incorporating its originally developed gallium



Photo 1: The on-vehicle night vision system technology



Photo 2: Demonstration of the on-vehicle night vision system technology

nitride (GaN)-based white light laser that features high brightness, high efficiency, and compact package. The system can change light distribution in accordance with people and objects, such as white light in the headlights for low beam and near IR light for high beam. Thus, it enables sensing while suppressing dizziness. In addition, the integration of lights enables space-saving of headlights and provides freedom to vehicle design.

Furthermore, the RGB-IR sensor adopts a fusion recognition AI technology originally developed at Kyocera's Advanced Technology Research Center in Japan. The AI technology has enabled judgements by combining regions with high reliability out of both recognition results. It is done through visible light image and recognition results using near IR light image. In other words, it "picks

the best of the two" rather than simply adding recognition results using visible light image and recognition results using near IR light image.

Thus, the system detects pedestrians and vehicles with high accuracy even in low-visibility environments. It detects risk factors and notify the driver.

Furthermore, the system has also improved data generation efficiency. Conventional methods needed the collection of a huge amount of learning data of near IR light, requiring time and cost. In the method developed this time, Kyocera has established AI technology for learning data generation. It automatically generates an image for learning near IR light from the image for learning visible light. Thus, the system achieves both significant learning cost reduction and high-accuracy recognition.

Eyes Autonomous Driving

Initially, Kyocera eyes a system to display information in the display at the driver's seat. The company also expects linkage with an autonomous driving system, and capability to enable the driver to check the detected image without moving his/her line of sight.

In 2020, the global market for on-board night vision systems was about US\$2.2 billion. It is forecast to grow at 16.5 percent or higher by 2027. Kyocera plans to basically complete the system by 2025, and introduce to market in 2027, while watching group companies' moves for commercialization.

The system developed this time will likely be used in other fields as well. According to Kyocera, it aims to establish the system as an on-board system. □

Piezoelectric MEMS...

Continued from page 23

enables peeling. Initially, they were unsure if this process will go well. However, the companies were able to precisely mount a thin film on a wafer. Using an ultrasonic sensor as a demonstration device, the companies confirmed the improvement of sensitivity to 20 times.

Promising Applications

For the time being, the two companies are targeting biometric authentication of smartphones as application of the new piezoelectric MEMS thin film. Using ultrasonic waves provides stability with resistance to sweat and dirt. Furthermore, the film allows MEMS to be arranged on the back side of the display, contributing to more efficient use of space.

Vein authentication as an application is promising. Specifically, fingerprint authentication is susceptible to a certain level of error. Moreover, fingerprints can be faked using gelatin or other material to break authentication. Meanwhile, vein authentication increases security. Compared with fingerprint authentication, which remains at the skin surface, ultrasonic waves must reach inside the skin. The new MEMS device will likely enable that.

This time, the companies have demonstrated bonding to silicon on insulator (SOI) wafer^{*2}. The new device can be applied to glass substrates and organic material substrates as well. It does not limit the device structure and greatly expands application areas of piezoelectric single-crystal thin films.

Moreover, as it can selectively peel/bond only the necessary part of single-crystal thin films, it is possible to peel

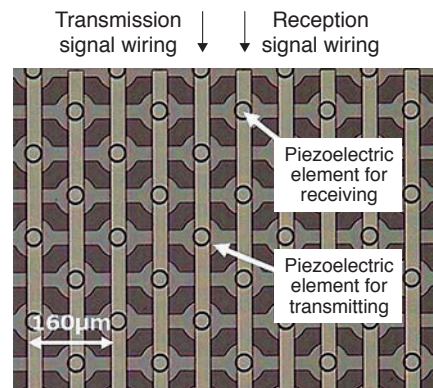


Fig. 2: Micrograph of the prototype piezoelectric MEMS ultra-sonic sensor array.

necessary thin films multiple times from the same wafer. Thus, it can contribute to the effective use of resources and reduction of environmental loads and manufacturing costs.

Keywords:

^{*1} *Piezoelectric single-crystal thin film: Thin-film layer that determines characteristics of MEMS devices, such as sensors and actuators. In general devices, polycrystalline thin films are used.*

^{*2} *Silicon on insulator (SOI) wafer: Silicon wafer with a structure in which a silicon single-crystal layer is formed on a silicon oxide film. It is used in a wide range of fields from high-speed LSIs, low-consumption LSIs, power devices, to MEMS.*

Electrostatic User Interface to Improve Next-Generation Vehicle Interior

Japan Aviation Electronics Industry, Ltd. (JAE) has developed a technology to achieve non-contact operation, touch operation, and pressure-sensitive operation with a single film sensor as a next-generation user interface (UI) for vehicle interiors.

With the evolution of Connected, Autonomous, Shared, and Electric (CASE) trends in automobiles, JAE is aiming to apply this technology as UI in vehicle interiors. In this area, higher quality entertainment is required for next-generation interior components, such as armrests and door trims.

The automotive market is undergoing a once-in-a-century transformation, and vehicle interiors are evolving according to innovations resulting from CASE

trends. In particular, as automated driving and connected technologies advance, displays are becoming larger and more curved to meet the demand for unprecedented high quality of entertainment. Also, for UI, multi-modal (interface style combining multiple methods) operations such as voice and gesture operations are required, in addition to touch operation. To meet this need, infrared sensors and piezoelectric elements have been proposed in addition to electrostatic sensors. For its case, JAE has recently developed a technology that enables touch, non-contact, and pressure-sensitive operation with a single electrostatic film sensor.

Next-Generation User Interface

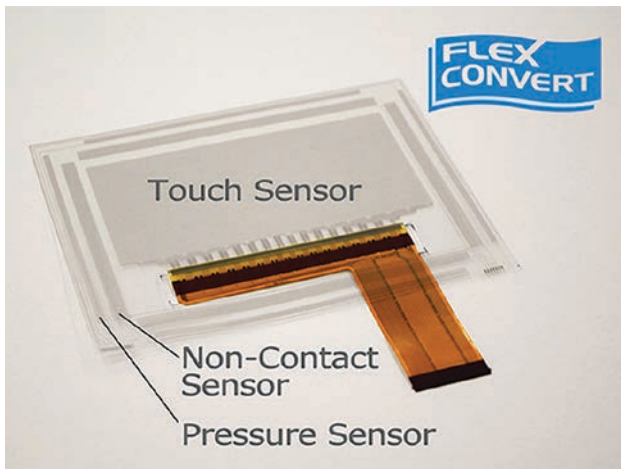
This technology makes full use of the company's capacitive sensor technology and original printing technology cultivated in the touch panel business. These technologies enable non-contact operation (gesture operation), touch operation (light touch) and pressure-sensitive operation (push operation) with a single film sensor.

The sensor pattern is made of metal mesh, which makes it possible to achieve high sensitivity characteristics. This enables highly sensitive and light touch operation and proximity detection at a distance of approximately 150mm. Moreover, it also enables gesture operation at approximately 100mm and step-less pressure detection. Because the pattern is achieved using only capacitive sensors, it facilitates development of interior equipment. Specifically, the sensors produced by the printing method are highly flexible, enabling them to follow the complex shapes of armrests and door trims, thus contributing to greater flexibility in design and installation location.

When combined with a stealth printed panel, a next-generation, high design quality UI can be created. This can be made possible by displaying a switch screen on the panel when necessary, through gesture operation, and by enabling control of the equipment through touch operation.

Leverage on Domestic Production

JAE started mass production of capacitive touch panels in 2012, and have been developing, manufacturing, and selling UI for automotive applications. Since the beginning, the company has consistently focused on domestic production, delivering products to its customers with stable quality from automated production lines at the Akishima Plant in Akishima City, Tokyo Japan. The company will leverage strength of domestic production to expand into a wide range of markets, including industrial equipment and the smart home domain, in addition to the automotive market. □



Flex Convert electrostatic film sensor



Rendering of a next generation vehicle interior

Decarbonization Achieves Sustainable Smart Factories

IN THIS ARTICLE, NOMURA RESEARCH INSTITUTE (NRI) DWELLS ON THE ROLE OF CARBON FOOTPRINT MANAGEMENT TO ACHIEVE ENVIRONMENT-FRIENDLY SMART FACTORIES AND ENHANCE COMPETITIVENESS.

Amid the growing global trends to reduce carbon emissions, more companies are becoming more transparent of the carbon footprints of their products. In addition, several countries have also employed political pressures to implement stricter disclosure of carbon footprints of specific products.

For example, countries in Europe, as well as in Japan, continue to pass laws for more transparent disclosures of carbon footprints among battery manufacturers. For one, companies such as BASF recently said it has been keenly calculating the carbon footprints of their respective products.

Carbon Footprints Disclosure

Currently, disclosure of carbon footprints has been an important issue in the industry. However, what will happen as a result of disclosure? Likely, companies will have to compete in terms of carbon footprint disclosure. For example, when there are two products with the same performance, a product with lower carbon footprint will likely get patronage.

In fact, carbon footprints of batteries for electric vehicles (EVs) will become basis for industry certifications. Furthermore, Taskforce on Nature-related Financial Disclosures (TNFD) currently

under consideration will require improvements of companies' efforts from the viewpoint of biodiversity. Companies will be required to evaluate and improve not only carbon footprints but also the use of water resources and other resources.

Effects on Factories, Supply Chains

If product carbon footprint disclosures progress, managements of factories and supply chains will likely change as well. For that reason, it will become necessary for companies to enhance productivity not only in terms of manufacturing costs but also carbon neutrality. Eventually, an index like Return on Carbon Footprint (RoCF) will become prevalent in factories, aside from Return on Invested Capital (ROIC).

To improve RoCF, factories need to reduce carbon footprints, but also to contribute in terms of emissions credits and revenue enhancement, such as tax breaks. Furthermore, there is a high possibility that contribution of the entire supply chain will be evaluated, in addition to contribution of the company itself. Changes in supply chain management (SCM) are necessary. In the medium to long term, RoCF will incorporate a wide range of sustainability indexes, such as measures for biodiversity, in addition to carbon footprints.

Necessary Three Steps

Looking at examples at non-manufacturing industries as well, changes are occurring in three steps. First, is the disclosure of carbon footprints. Main initiatives in this stage are the calculation by specific consumption with quantity using already available information technology (IT) services. In addition, the determination of allocation rule for the common part.

Next, is the improvement of carbon footprints using energies and materials with low specific consumption, such as renewable

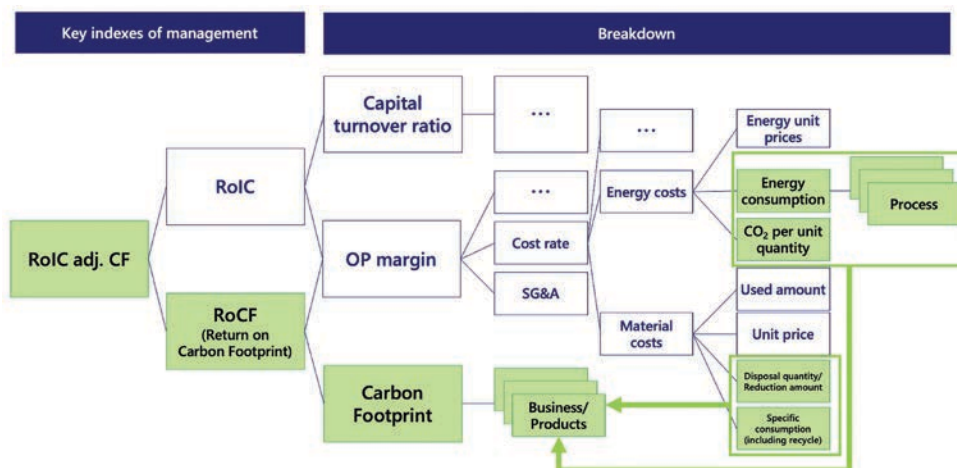


Fig. 1: RoCF

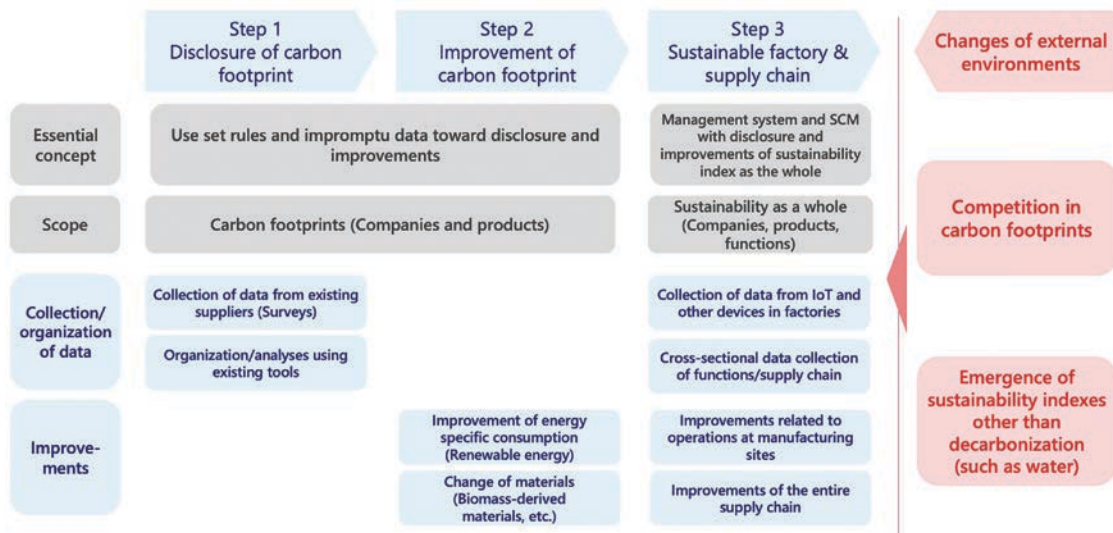


Fig. 2: Advancement toward sustainable management

energy. Here, investments for the use of biomaterials and the shift to renewable energy and development activities are necessary. In many cases, it is necessary to carry out steps 1 and 2 simultaneously. These are already underway in various industries. Today, these activities are common practice already.

Meanwhile, step 3 dwells on originality and improvement of specific consumption. This involves suppliers using data inside the factory.

For example, AEON CO., LTD., a Japanese retail company, is beginning to construct a system to calculate the amount of greenhouse gas emissions of its entire supply chain, including several hundred thousand suppliers. Walmart, also a retail company, has begun to implement a program to provide financing to its customers that implement environment-friendly programs in collaboration with HSBC and CDP.

These efforts have already been taken in the downstream of the manufacturing industry, and these moves will spread to the manufacturing industry in not-so-distant future.

In Step 3, a foundation to analyze data obtained from sensors and internet of things (IoT) devices in factories based on sustainability is necessary. Many companies accumulate data in SCM, procurement management, distributed control systems (DCS), and manufacturing execution system (MES). However, from sustainability viewpoint, their design is not merely about carbon footprint disclosure.

Role of Automation

Hence, it is necessary to fix excess and deficiency of data from the viewpoint of decarbonization and sustainability factories. It is also necessary to introduce an operating process that analyzes those data regularly and lead to the improvement of operation. In addition, a mechanism to deploy those standard operations to different factories, businesses, and suppliers is also necessary.

In terms of the disclosure of CO₂ emissions, even leading companies with sales of over ¥1 trillion are using a different system for each factory. In many cases, the purpose of the data their data are not for the disclosure of CO₂ emissions. For that reason, they are managing to prepare data by cutting and pasting various data sources.

Reduction of carbon footprints leads to competitiveness. Nonetheless, using much manhour for grasping the reduction of carbon footprints is like putting the cart before the horse. For example, the measurement of original specific consumption is very important for competitiveness from the viewpoint of decarbonization. However, Japanese companies are using considerable manhour to update their original specific consumption. Hence, an automation mechanism to solve these problems is necessary.

From the viewpoint of involving suppliers, discussions on data linkage bases, such as GAIA-X11, have already been advancing. However, data linkage loses its effectiveness unless individual companies are grasping data on CO₂ emissions

and environmental loads correctly. Hence, it is necessary that individual companies introduce efficient and competitive mechanisms and deploy them to their suppliers.

The decarbonization trend forces companies to increase investments and costs. Nonetheless, changes in business and system to lead them to competitiveness will become key elements in the next-generation smart factories.

Right now, considerations are necessary.

IGAIA-X is a framework that is targeting the construction of a data infrastructure integrating communication infrastructure, equipment; collection and usage of industrial and individual data; and digital platform existing in Europe.

What Is Carbon Footprint?

A carbon footprint is the total greenhouse gas emissions arising in the entire lifecycle of goods and services from the procurement of materials, production and distribution to disposal and recycling converted into carbon dioxide.

The birthplace of carbon footprint is England. The British government created a standard for carbon footprint called PAS 2050, and multiple companies started demonstration experiments. In 2007, carbon footprint labels were applied to potato chips, smoothies, and shampoos for the first time in the world.

Then, the idea of carbon footprint spread to the United States, Japan, Korea, and countries in Europe and Asia, including Thailand. These countries begun to create original carbon footprint standards. Amid the situation, discussions on the necessity of a unified standard for trading started. In 2013, an international technical specification, ISO/TS14067, was issued.

About This Article:

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3D Printing Rises to Change Manufacturing Landscape

IN THIS ARTICLE, NOMURA RESEARCH INSTITUTE INVESTIGATES THE EVOLUTION OF THREE-DIMENSIONAL (3D) PRINTING AND HOW IT HAS GAINED TRACTION OF LATE TO BRING INNOVATIONS IN MANUFACTURING.

Since 1990, three-dimensional (3D) printers have been attracting attention as a technology that would transform the manufacturing industry. Particularly, 3D printing produces three-dimensional solid molded objects based on 3D CAD data.

Previously, production of prototypes and small-lot production of finished products adopt 3D printing method. This was due to the slow takt time of equipment and high materials costs.

In this article, Nomura Research Institute tracks the evolution of 3D printing. NRI also discusses how 3D printing has gained traction of late to bring innovations in manufacturing.

Adoption Gains Speed

Recently, however, use of 3D printings in wider situations have grown. There are two main factors for the renewed attention on 3D printing.

First, the COVID-19 pandemic has helped increase needs for flexible manufacturing methods. Closure of factories and the stoppage of logistics due to the pandemic caused existing supply chains to become dysfunctional. For that reason, attempts have been made to produce face shield masks with priority and high degree of urgency, and components for medical equipment, such as artificial

respirators, using 3D printers.

Ordinarily, manufacturers avoid the use of costly 3D printers. However, amid the pandemic, the flexible manufacturing method of 3D printers to enable production has attracted attention. Most especially, of products that require CAD data. 3D printing have been attracting renewed attention also from the viewpoint of the improvement of resilience of manufacturing function.

Second, technological development of 3D printers has enabled production in larger lots. In general, production lot size of products using 3D printers is smaller compared with conventional production methods. For example, it takes about 45 hours to produce one brake caliper, a metal component for vehicles, using a 3D printer. For this reason, the use of 3D printers for mass production components is difficult.

However, recently, equipment manufacturers have been developing multi-laser equipment and expanding the printing volume of equipment. Through these efforts, manufacturing speed and manufacturing lots per shot have been increased.

In fact, some manufacturers are targeting to improve takt time to one-third of existing equipment by 2030. Thus, equipment manufacturers have been advancing technological development to achieve mass production of products using 3DPs.

Gains Confidence

Meanwhile, software with improved functions also contributes to increased size of manufacturing lot per shot. Normally, to mass-produce products using 3D printers, the equipment needs to produce greater number of products at one time. Software with improved functions has also improved the accuracy to recommend maximum production lot size per shot. This is also contributing to the solution of above-mentioned issues.

Because of above-mentioned factors, 3DPs have begun to come into

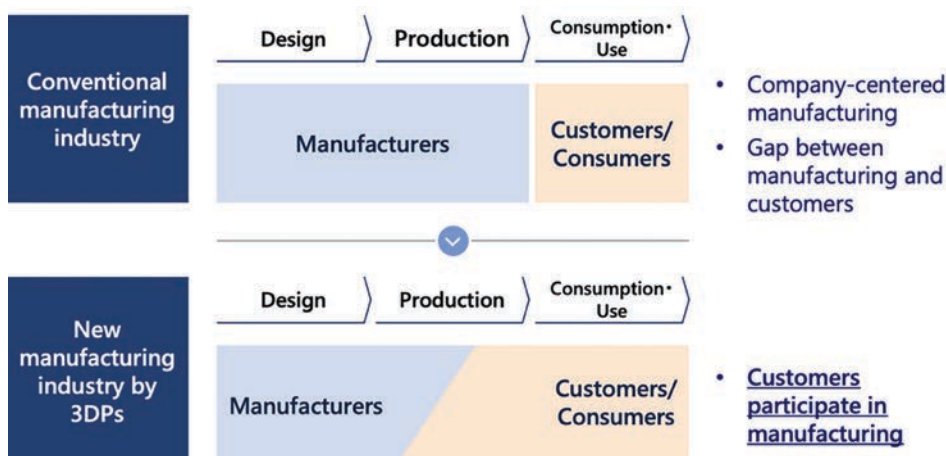


Fig. 1: Transformation of manufacturing because of 3D printers

limelight again. For example, in Mar. 2022, Ford Motor Company, an original equipment manufacturer (OEM) of automobiles, incorporated 3D printers in its production line. For that reason, the company successfully operated the production line without human intervention. Hence, confidence on 3D printers have grown despite previous skepticism.

Prospects of Manufacturing Using 3D Printers

As described above, situations where 3DPs are used will expand as a result of the improvements of functions. Moreover, they will not stop as mere new tools for manufacturing but will have two development potentials to fundamentally change manufacturing itself.

First is to simplify the manufacturing process. This is possible by the improvement of software functions. At present, players with contracted manufacturing function, such as 3D Systems, Inc., Stratasys Ltd., and Materialise NV, are providing software along with equipment. They are developing software that better reflects users' requirements by reflecting knowledge they obtain. This is because service bureaus conduct contracted manufacturing to their software. They deploy developed software to customers and analyze and accumulate success and failure patterns for each laminated structure on the cloud.

By doing so, they are recommending manufacturing methods that are more likely to succeed to software functions. For example, they are targeting manufacturing using 3D printers wherein software recommends optimum materials, lami-

nating temperature, optimum lamination route, and the position of support material for each laminating structure even if users of 3DPs do not have sufficient manufacturing knowhow. Improved software for 3DPs will likely help further simplify the manufacturing process.

Next, the wide use of 3DPs in manufacturing floors will have ripple effects to consumers. This is the achievement of a world that satisfies customers' mass-customization needs, which is the second development potential. For example, Ford Motor has released open-source 3D CAD data of accessories for vehicle interior parts. Particularly, the set of CAD files include those for cup holders, mobile phone mounts and game console mounts.

Ford also provides Ford Integrated Tether System (FITS). Using the system enables customers to customize design and colors rather than simply outputting existing interior components. Customers can bring data outputted using the system to 3DP service bureaus to produce customized products. These initiatives have a factor to meet consumers' diversifying needs. Further, they also help business operators reduce inventory costs. In particular, the aftermarket of the automotive industry is huge. OEMs and components suppliers are still stocking components, design drawings, and metal molds of already discontinued models as inventories, thus facing increasing inventory costs. The release of open-source 3D CAD data will free OEMs and components suppliers from stocking after-sales components. Thus, open-sourcing has an advantage for

companies to suppress costs, and hence, the trend of open-sourcing will likely accelerate.

Elaborate Pursuit of Customer Needs

Conventionally, the manufacturing industry has adopted a business operator-centered model wherein companies mass-produce products based on market needs that they presume and provide products to consumers at prices as inexpensive as possible. However, 3DPs lower the hurdle for customized products. Hence, it is highly likely that their business model changes to a new one, wherein manufacturers create bases of products and users themselves customize the products to their own likings. In the world where customers participate in manufacturing, manufacturers are required to differentiate themselves in the broadness of customization range and elaborate recommends for customization using software and data, rather than conventional competition by products alone. Thus, 3D printers provide a potential to fundamentally change the axis of competition.

Certainly, 3D printers still have issues such as high materials costs and slow takt time of equipment. Nonetheless, when they solve these issues and enjoy wide use, they will have a potential to cause fundamental changes to the manufacturing industry.

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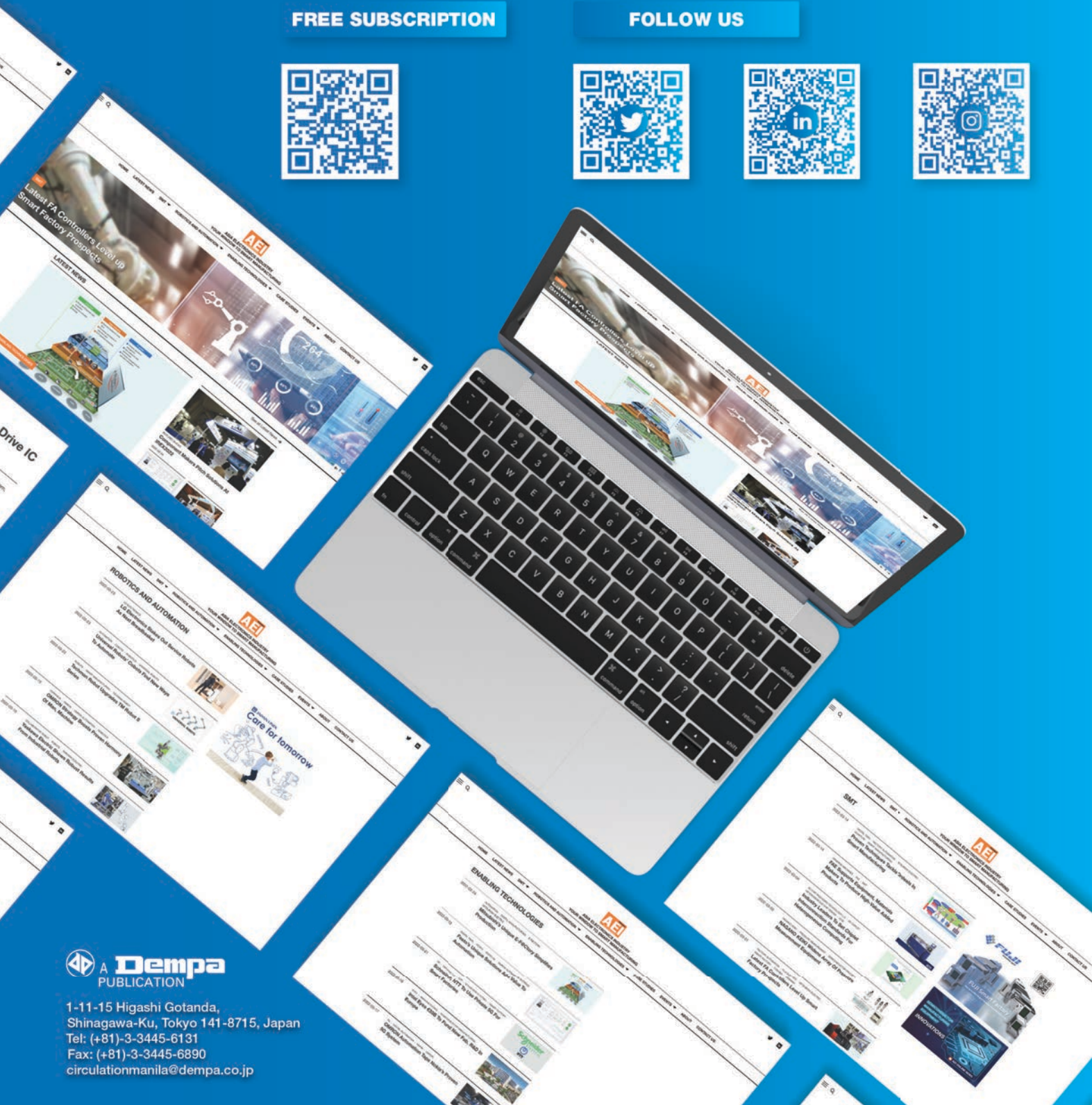
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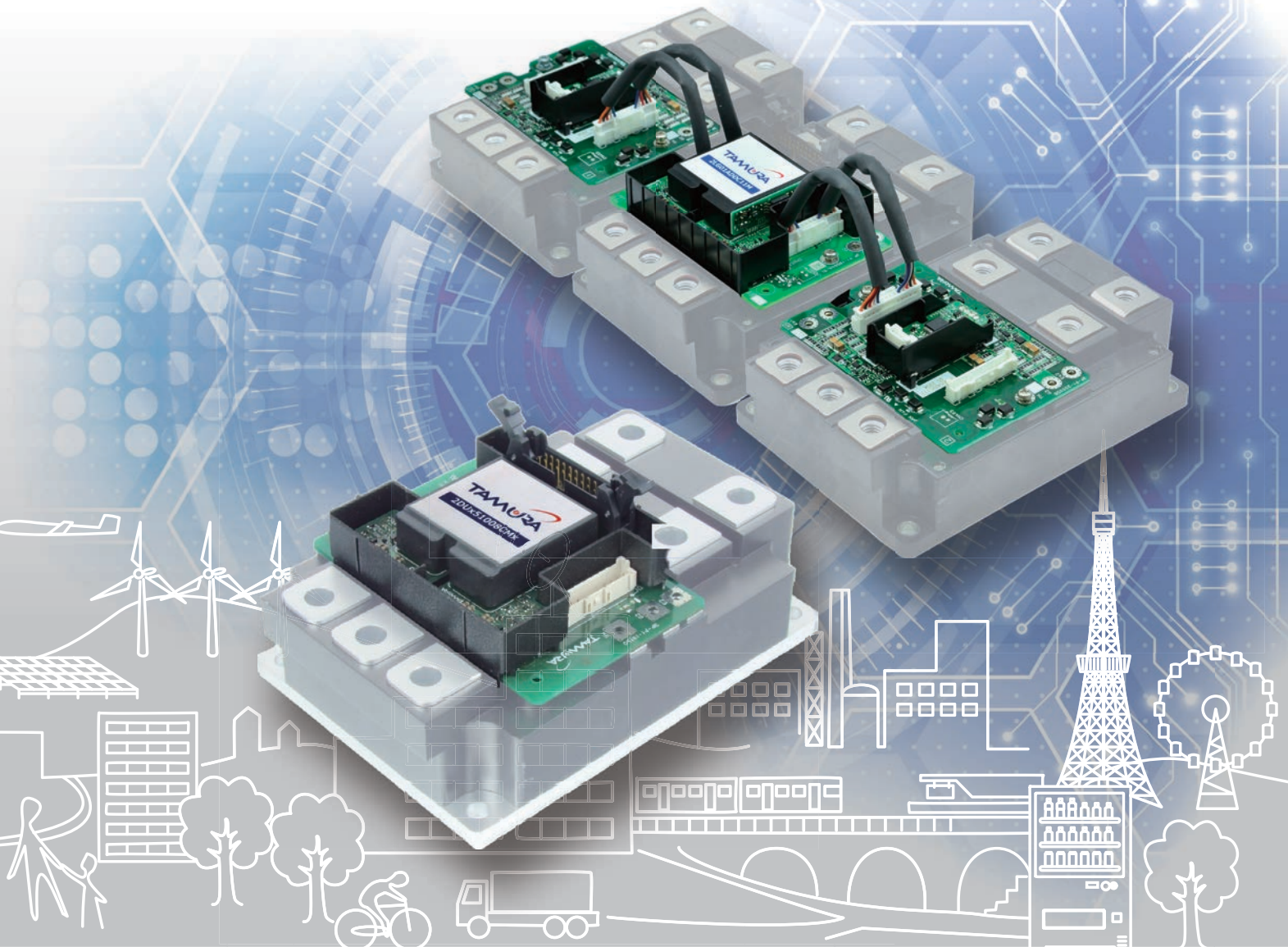


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