5. Electronic Devices and Storage

5.1 1 700 V/400 A All-SiC Module

All-SiC module

Courtesy Tokyo Metro Co., Ltd.

2000 series train

VVVF inverter device

1 700 V/400 A all-SiC module

There has been growing demand for smaller, lighter, and more energy-efficient devices for electric railway traction control systems. To meet these requirements, silicon semiconductor power devices have been used for inverter applications. Improving the performance of these power devices has been a primary method for reducing the energy loss of railway traction control systems. However, as silicon devices are approaching the theoretical limit, silicon carbide (SiC), a wide-bandgap semiconductor, is attracting attention as a promising alternative to silicon.

Toshiba Electronic Devices & Storage Corporation has now commercialized a 1 700 V/400 A 2-in-1 all-SiC module that incorporates SiC metal-oxide-semiconductor field-effect transistors (MOSFETs) with a built-in SiC Schottky barrier diode. Composed solely of SiC chips, this SiC module uses SiC MOSFETs as switching devices instead of injection-enhanced gate transistors (IEGTs). This helps to increase the current density, making it possible to reduce the module size, and also increases the switching speed, reducing energy loss.

To obtain the maximum performance from SiC semiconductor devices, a package with reduced parasitic inductance is necessary. Therefore, we have also developed a new package with an optimized internal layout, which provides 40% lower parasitic inductance than the conventional package. In addition, the newly developed package uses a high-strength ceramic substrate as well as bonding and sealing materials with improved thermal fatigue resistance. The newly developed package has exhibited enhanced durability in temperature cycling tests without an increase in thermal resistance. Furthermore, the new SiC module has only half the footprint of the conventional product.

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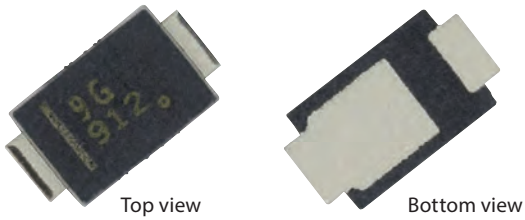
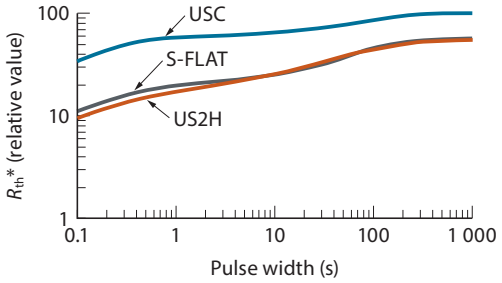
Variable-voltage, variable-frequency (VVVF) inverters using the new SiC module have been employed in the 2000 series trains of the Marunouchi Line operated by Tokyo Metro Subway Co., Ltd., which commenced commercial operation in February 2019. Along with the VVVF inverters, the 2000 series is equipped with totally enclosed permanent magnet synchronous motors (PMSMs) specially designed for inverters and an emergency power supply unit equipped with the SCiB™ lithium-ion rechargeable battery. As a result, power consumption has been reduced by 27% compared with the conventional modified 02 series PMSM vehicles of the Marunouchi Line.

Part of this development effort was conducted under the Development of High-Efficiency Small Power Converter Systems with All-SiC Device project as a demonstration of the Strategic Energy Conservation Technology Innovation Program supported by the New Energy and Industrial Technology Development Organization (NEDO) of Japan.

5.2 Small-Sized Package with High Power Dissipation for Rectifier and Circuit Protection Diodes

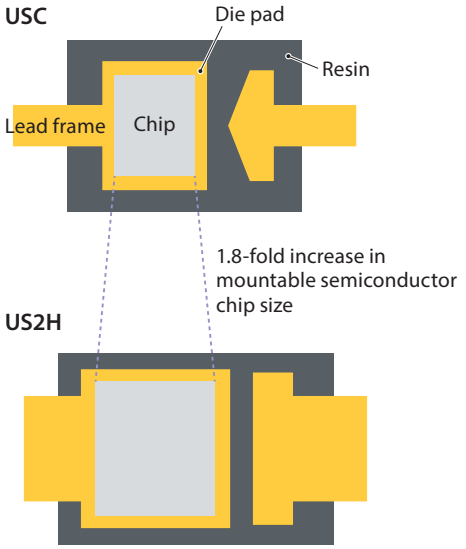


US2H small-sized package with high power dissipation



∗ Normalized with respect to thermal resistance of USC package

Comparison of thermal resistance of US2H and conventional packages



Comparison of internal structure of USC and US2H packages (wiring structure not shown)

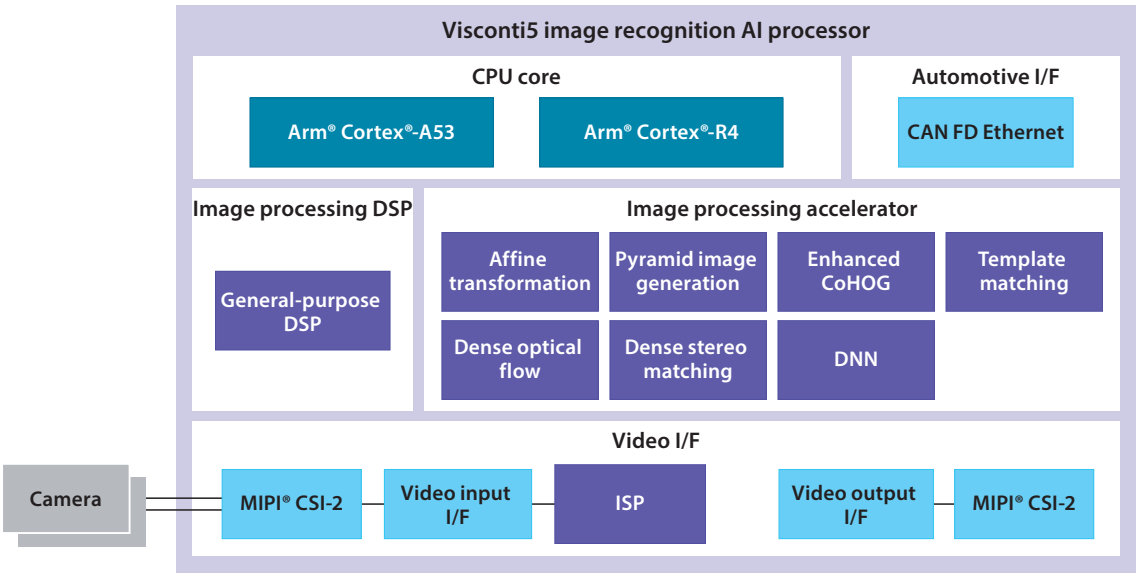
Diodes are widely used for electrical rectification as well as for the protection of electronic and power circuits in PCs, audiovisual equipment, industrial equipment, and other devices. Accompanying the ongoing reduction in the size of electronic equipment and increase in the efficiency of electronic circuits, demand for small diodes with low power loss is growing.

In response, Toshiba Electronic Devices & Storage Corporation has developed the US2H (Ultra Super Mini 2-pin Heat Sink) package with a power dissipation of 1 W, which is equivalent to the SOD-323 package (mounting area: 2.5 × 1.4 mm). When the saturated thermal resistance (R_{th}) is defined as the thermal resistance at a pulse width of 1 000 seconds, the US2H provides 45% lower R_{th} than the conventional USC package.

The US2H is a flat leaded package with wide leads and a lead frame exposed on the bottom side to improve heat dissipation. In addition, it has the same thermal resistance as the S-FLAT package, which is equivalent to the SOD-123 package (mounting area: 3.5 × 1.6 mm), making it suitable for reducing the size of electronic equipment. Furthermore, the US2H incorporates a lead frame with increased die pad size, which provides a chip mounting space 1.8 times that of the conventional USC package.

As a result, we have realized Schottky barrier diodes in the US2H package with low forward voltage and excellent temperature characteristics. At present, Schottky barrier diodes are available with a rated current of 1 to 2 A. We will further expand our product lineup to accommodate a wider range of consumer and industrial applications.

5.3 Visconti5 Series Image Recognition AI Processors



I/F: interface
CAN FD: Controller Area Network with Flexible Data-Rate
DSP: digital signal processor
CoHOG: Toshiba's proprietary Co-occurrence Histograms of Oriented Gradients
CSI: Camera Serial Interface
ISP: image signal processor

Block diagram of front cameras-based advanced driver assistance system (ADAS) using Visconti5 image recognition processor

Demand for further enhancement of advanced driver assistance systems (ADAS) is increasing. For example, the World Forum for Harmonization of Vehicle Regulations (WP.29) has adopted a new United Nations Regulation on Advanced Emergency Braking Systems (AEBS). In Japan, new vehicles will be required to be equipped with AEBS from 2021 onward. In addition, intersection and head-on collision avoidance tests have been added to the 2020 edition of the European New Car Assessment Programme (Euro NCAP), a European vehicle safety performance assessment program.

Under these circumstances, Toshiba Electric Devices & Storage Corporation has developed the Visconti5 series of image recognition artificial intelligence (AI) processors (TMPV7708XBG and TMPV7706XBG) incorporating deep-neural-network (DNN)(*1) hardware intellectual property (IP) suitable for realizing ADAS and automated driving functions.

The DNN hardware IP embedded in the Visconti5 series uses the results of deep learning to recognize a variety of objects with higher accuracy than conventional pattern recognition and machine learning, making it possible to realize an ADAS with enhanced functionality. The embedded functions of the Visconti5 series also include a high-density stereo matching function that improves the accuracy of distance measurement using a stereo camera and a high-density optical flow function, which improves the performance of moving object detection.

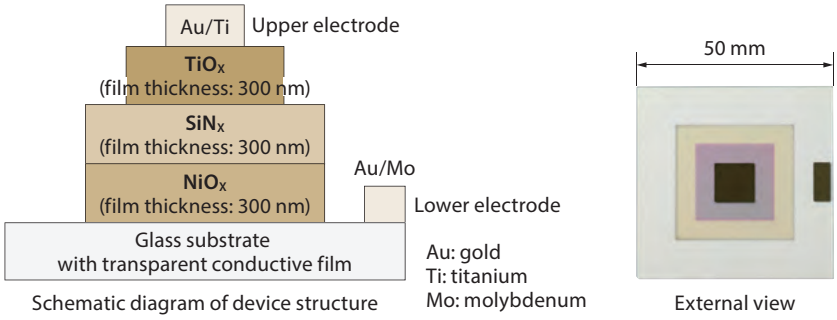
Furthermore, the performance of the central processing unit (CPU) and various image processing accelerators has been enhanced and the operating frequency has also been increased by shrinking the semiconductor process geometries.

Consequently, the Visconti5 series provides image processing performance that is nine to 10 times(*2) that of our conventional series, allowing it to execute various image recognition algorithms at high speed with low power consumption.

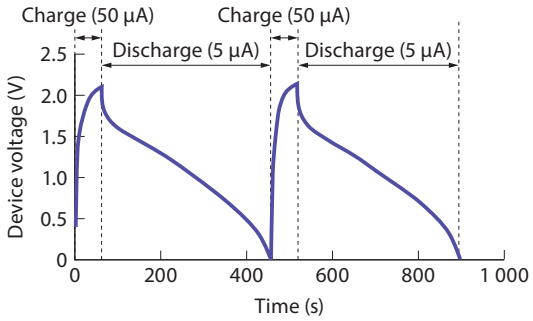
(*1) Artificial neural network algorithms based on the neural circuits of the human brain

(*2) As of March 2020 in comparison with an existing product of the Visconti4 series (TMPV7608XBG) (as researched by Toshiba Electronic Devices & Storage Corporation)

5.4 Fabrication of All-Solid-State Electricity Storage Device Using Semiconductor Thin Films



All-solid-state electricity storage device using semiconductor thin films



Time dependence of device voltage during constant-current charge-discharge cycles

Battery manufacturers are actively developing all-solid-state lithium (Li)-ion batteries to improve safety and energy density. All-solid-state batteries are characterized by the use of an inorganic solid electrolyte instead of a flammable organic electrolyte. However, since the movement of Li ions is required during the charge-discharge reaction, problems concerning the diffusion rate of Li ions and the depletion of Li resources must be solved to realize all-solid-state batteries.

Toshiba Materials Co., Ltd. has developed an all-solid-state energy storage device that uses electron-hole carriers instead of Li ions. We fabricated a semiconductor solid-state electricity storage device with a layered structure consisting of n-type titanium oxide (TiO_X), insulating silicon nitride (SiN_X), and p-type nickel oxide (NiO_X) thin films. The characteristics of this structure were evaluated through charge-discharge measurements. The evaluation results clearly indicated the characteristics of a rechargeable storage device. Furthermore, this structure provided a carrier accumulation capacity more than 5 000 times that of a parallel plate capacitor.

At present, we are elucidating the charge-discharge mechanism and improving the capacity and durability of the all-solid-state electricity storage device to achieve its practical application.

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