Fundamental and Advanced Technologies

Fundamental Technology
Advanced Technology

Outlook

Fuji Electric is working on developing competitive components that are excellent in creating customer value and solutions using the components. At the same time, we are energetically committed to research and development of fundamental technology that supports product development and advanced technology that can differentiate our products for those of competitors.

In material technology, we have developed simulation technology for predicting the progress of corrosion of geothermal turbines with a multi-phase field method. The technology uniformly deals with ion diffusion in corrosive liquids and metal melting, and it supports various corrosive environments and corrosion modes. We will apply this technology to product design in the future.

We are proceeding with the development of silicon carbide (SiC) devices aiming at overwhelming differentiation and power electronics equipment using SiC devices. We are promoting research by using leading analytic technology and computational science to clarify the mechanism to achieve SiC devices with low resistance and high reliability. In addition, we have made the relation between discharge voltage and electric field distribution of insulation surface into a mathematical expression by using discharge theory. Combining the mathematical expression with a simulation of the chip's internal structure, we developed breakdown voltage prediction technology for accurately predicting breakdown voltage (difference with the measured value within 5%) and optimized the insulating structure of SiC devices.

To maximize the performance of a SiC-MOSFET (metal-oxide-semiconductor field-effect transistor), we have developed unique active gate drive technology to achieve both high-speed switching operation and surge voltage suppression. Surge voltage jumping was reduced by about 20% with this technology.

As thermal energy technology, we developed advanced technology aiming at effective use of unused low-temperature exhaust, and we are applying the technology to products. We have developed the technology to achieve two-stage compression with the same compressor and are now developing a 150°C high-temperature steam generator that can operate efficiently. In addition, we have succeeded in developing adsorbent employing a new concept and it has overwhelming adsorption performance. We are now developing an adsorption freezing machine using this adsorbent.

We also established laser display technology with high visibility and the ability to project focus-free images that are in focus regardless of the distance with and the angle of the projection plane. This breakthrough technology can achieve both safety and visibility by utilizing visual effects. We will work to have it implemented in digital signage in the fields of factory automation and food distribution.

As system technology, we developed crane control technology that can resist disturbance such as wind and requires no adjustment of control parameters with respect to fluctuations of the suspended load weight and rope length. Robust control for reinforcing the existing controls can reduce the introduction cost.

The Internet of Things (IoT) is attracting attention as a solution for creating customer value. We are expanding the solution using various field devices and a sophisticated, characteristic analytic technology with the key phrase "Small, Quick Start & Spiral-Up." We developed an IoT platform having a communication function and security function of a cloud and an edge controller, as well as the service interfaces for easily constructing services based on general-purpose cloud technology. We are going to start operating the IoT platform in FY2018.

We also developed device authentication technology for IoT systems that prevents the connection of unauthorized devices. IoT devices mutually authenticate with the cloud before transmitting data and transmit a token (license) with the data to the cloud when transmitting data.

To meet the rising demand for abnormality diagnosis technology for equipment, we developed diagnostic visualization technology that determines the diagnosability of an abnormality using the acquired data in one-tenth of the time of the conventional type. We have also developed non-linear diagnosis technology to diagnose complicated object that had been difficult with the conventional technology.

We aim to apply deep learning technology, which allows accurate inference, to an industrial field. To this end, we are developing deep learning technology that enables automatic learning and inference basis explanation via automatic parameter learning with model structure optimization and inference basis explanation with input and output relation quantification.

We are developing a method that optimizes purposes in a large-scale calculation to reduce the number of prototypes. We established a multi-purpose optimization method for temperature and noise of power electronics equipment by automating 3D-CAD shapes and analysis settings with respect to a parametric design factors, and we verified the improved performance. We will promote the product development by front loading.

Fuji Electric will strive to develop advanced technology that contributes to innovating electric and thermal energy and environmental technology. We are also improving the fundamental technology that supports product development. Thus, we will continue providing components and solutions that allow excellent differentiation of products and create customer value.

Fundamental Technology

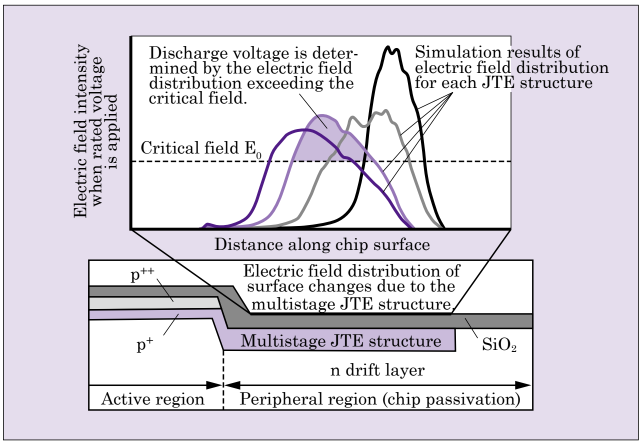
1 Optimization of Surface Insulation Design of Semiconductor Chip Based on Discharge Theory

Fuji Electric has established design technology for preventing the breakdown of surface insulation in the peripheral region (chip passivation) of SiC semiconductor chips.

In the conventional chip design process, the breakdown voltage was calculated from the carrier density and mobility of the inner junction termination extension (JTE) structure of a peripheral region. Meanwhile, an estimation based on the maximum electric field was used for the surface structure part. To improve the power density of a chip, it was necessary to maintain the breakdown voltage with a shorter insulation width; however, it had been difficult to accurately determine the insulation breakdown of the surface.

We have made the relation between the discharge voltage and the electric field distribution of the surface into a mathematical expression applying the discharge theory of a gas space. With the mathematical expression, we developed technology for predicting the breakdown voltage of chip surface from the simulation result of the JTE structure at a high accuracy of 5% or less compared with the measured value.

Fig.1 Passivation schematic diagram of SiC chip and its electric field distribution



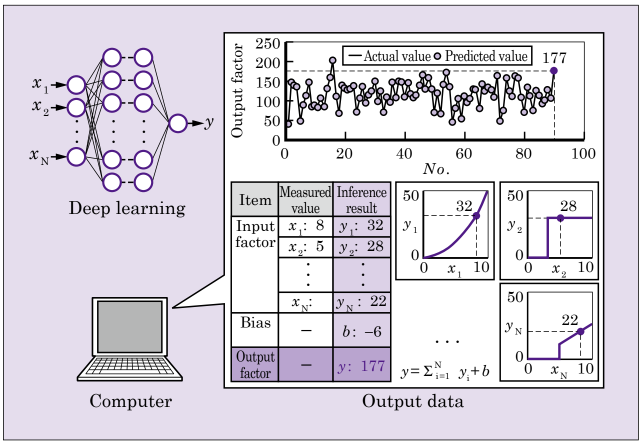
2 Deep Learning Technology That Allows Automatic Learning and Inference Basis Explanation

Deep learning is attracting attention in the image processing field as technology that allows accurate inference (classification and regression). However, deep learning requires manual parameters and maintenance tuning, and it is difficult to interpret the inference results. Therefore, deep learning had been only applied to limited applications in the industrial field, which require long-term operation and reliability. Fuji Electric has been developing deep learning technology that allows automatic learning and inference basis explanation. The main features are as follows:

(1) Automatic parameter learning using model structure optimization
(2) Automatic maintenance learning using close learning
(3) Inference basis explanation using quantification of input and output relation

Introducing this technology will expand applications in the industrial field.

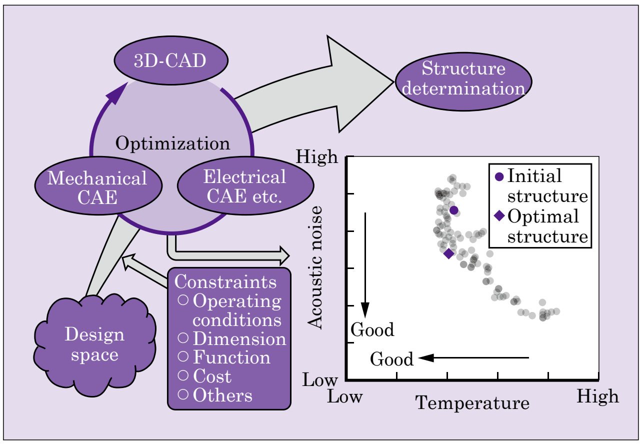
Fig.2 Example of inference basis explanation using deep learning technology



3 Approach of Computer Aided Engineering in Product Designing (Multi-Purpose Optimization)

Improvement of computing speed has enabled us to find out the mechanism of physical phenomena with large-scale calculation and shorten the calculation time. In addition to calculating representative conditions, optimal execution environment that involves hundreds of calculations are being created to improve functions and quality. Optimization in the mechanical simulation field requires automation of analysis condition settings such as the creation of a computational grid associated with changes in 3D-CAD shapes. Fuji Electric has used computer aided engineering for multi-purpose optimization with respect to the contradictory temperature and acoustic noise requirements for the cooling structure of power electronics equipment. We derived an optimal structure for parametric design factors by estimating noise in a short time in addition to automating 3D-CAD shapes and applying analysis condition settings. We have verified the derived structure on an actual equipment and confirmed the performance improvement. We will apply this front loading approach to product development.

Fig.3 Practical example of multi-purpose optimization



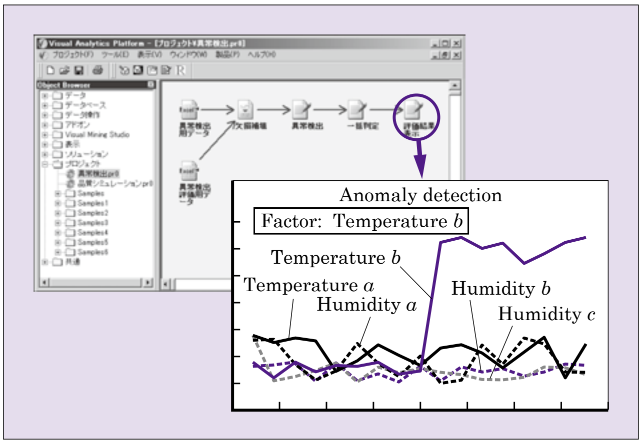
4 Data Analysis Platform Technology

Various types of data from each industrial classification are gathered through the cloud service that Fuji Electric is commercializing. To exploit these data as valuable information for new business, it is needed to create an environment for many engineers to easily analyze data. We have developed a data analysis platform using "Visual Mining Studio," which is a data mining product of NTT DATA Mathematical Systems Inc. The main features of the platform are as follows:

(1) Allow various types of analyses, such as correlation calculation, anomaly detection and quality simulation, by using Fuji Electric's unique data analysis engine.

(2) Provide analysis templates and standard procedure manuals to facilitate data analysis without any expertise.

Fig.4 Example of analysis template (Anomaly detection)

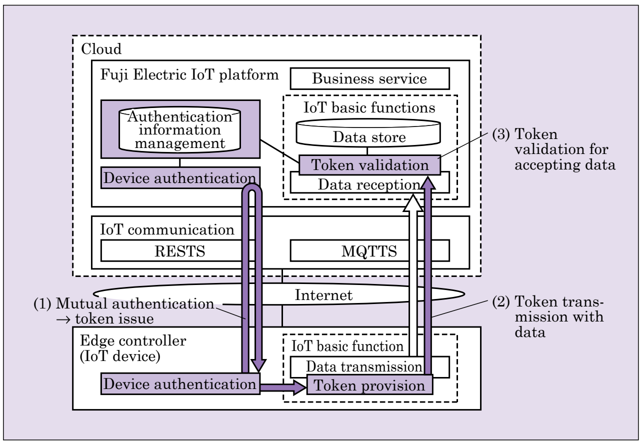


5 Device Authentication Mechanism for IoT System

In IoT systems, services on a cloud collect data from IoT devices via the Internet. Therefore, there is a risk of unauthorized device connection to the services.

Fuji Electric has developed an authentication mechanism for the IoT devices. In advance of transmitting data, an IoT device interacts with the cloud for mutual authentication and receives a token [see Fig. 5 (1)]. When the IoT device transmits data to the cloud, the token is also sent as an attachment [see Fig. 5 (2)]. The data receiving function in the cloud only accepts data with a valid token [see Fig. 5 (3)]. As a result, data from unauthorized devices are excluded. We will apply this mechanism to IoT devices such as edge devices, which are connected to our IoT platform, to keep our IoT systems safe and secure.

Fig.5 IoT system configuration applying device authentication



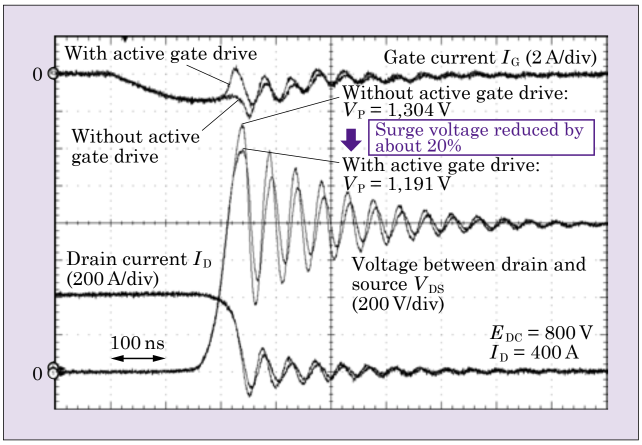
Advanced Technology

1 Active Gate Driving Technology for SiC-MOSFET

SiC-MOSFETs, which operate at high speed with low loss, are expected to help reduce the size and improve the efficiency of power electronics equipment. However, the application of SiC-MOSFETs has been restricted because of their excessive switching surge voltage, therefore their performance has not been fully used.

Fuji Electric has developed an active gate driving technology to maximize the performance of SiC-MOSFETs. As shown in Fig. 6, the device can switch at high speed with its surge voltage suppressed by the unique control method that stops the flow of the gate current for a certain period when the drain current is reduced. We confirmed that this method reduced turn-off surge voltages by about 20%, and the turn-off loss had similar switching characteristics compared with those during normal driving.

Fig.6 Surge voltage suppression with active gate driving technology



2 Solid Oxide Fuel Cell for Commercial Use

Fuji Electric is now developing solid oxide fuel cells (SOFC) in addition to 100-kW phosphoric acid fuel cells (PAFC), which are available now. We have been participating in "Technical development for promoting practical realization of SOFC" of New Energy and Industrial Technology Development Organization (NEDO) since FY2014, presuming a cogeneration system for commercial use of dozens of kilowatts. In FY2017, we conducted the electricity generation test of a 50-kW class prototype systems at the Chiba Factory and verified its continuous rating operation for 3,000 hours or longer. As the result, we have achieved the target performance, which is an AC power generation efficiency of 50% or more and exhaust heat recovery efficiency of 30% or more. In FY2018, we are conducting a field demonstration and plan to develop a commercial product to be launched at the end of FY2018.

Fig.7 Solid oxide fuel cell for commercial use (prototype system)

3 Robust Design of Anti-Sway Control System for Cranes

Fuji Electric has developed the anti-sway control system for cranes used in the factory automation field. We have developed a control design method that can resist disturbance such as wind that swings suspended loads. The main features are as follows:

(1) Readjustment of control parameters is unnecessary.

The control parameters do not need to be readjusted when the weight of the suspended load or rope length is changed.

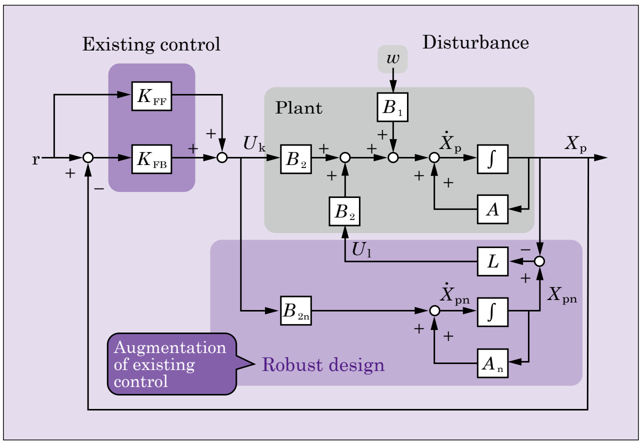
(2) The introduction cost is reduced.

The introduction cost can be reduced because the robust design for augmenting the existing control requires little system modification (see Fig. 8).

(3) The robustness is improved.

A simulation of a harbor crane showed that the anti-swing control performance of the suspended load with respect to disturbance improved by 32.9%.

Fig.8 Block diagram of robust design



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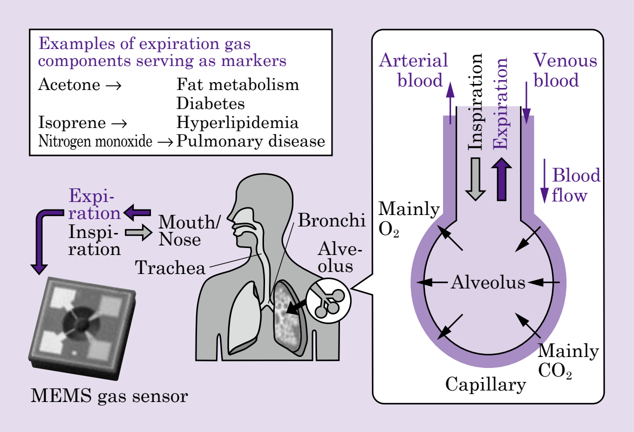
4 Breath Measurement Technology Using MEMS Gas Sensors

Fuji Electric has been studying breath measurement using a MEMS gas sensor as an application of the world's first battery-powered methane sensors for a utility gas alarm. Human breath contains volatile gases that were in the blood, and our study is based on the concept that measuring them in the breath is an effective way to provide health care. Recently, breath acetone produced during the metabolism of fat has been attracting attention as an index for training and dieting, and a diabetic marker. Against the backdrop, we have developed a breath acetone sensor. The catalyst technology optimized for detecting acetone can distinguish breath acetone from breath alcohol, which had been impossible with the conventional technology. Furthermore, the accuracy of detecting breath acetone has been improved by reducing the detection sensitivity of breath alcohol. The MEMS gas sensor allows high-sensitivity detection with sensor drive technology and can detect breath acetone concentration in the range of 0.1 to 20 ppm.

Fig.9 Breath measurement using MEMS gas sensor

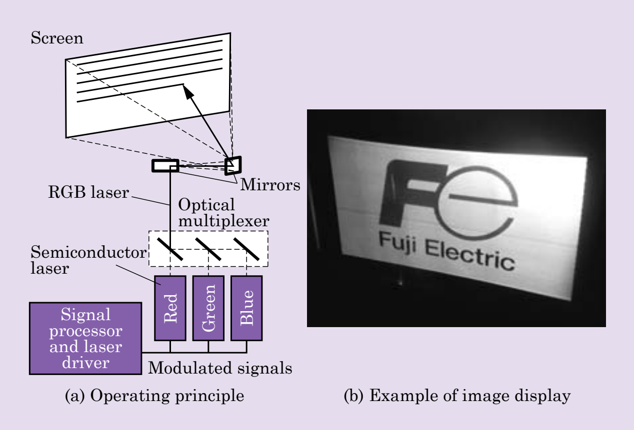


5 Laser Display Technology with High Visibility

Recently, digital signage for interactive advertisements and worker support that use videos has come to be used in various fields. There is increasing demand for a video display device that can project images at various places. Fuji Electric has established laser display technology with high visibility for projecting focus-free images that are in focus regardless of the distance with and the angle of the projection plane. The conventional laser display has a problem of low visibility in bright places.

We thus use the characteristics of human vision to develop laser beam technology that improves visibility while suppressing the laser beam output, achieving safe and highly visible lasers. We will consider how to apply this technology to digital signage in the fields of factory automation and food distribution.

Fig.10 Operation principle of laser display prototype and example of image display

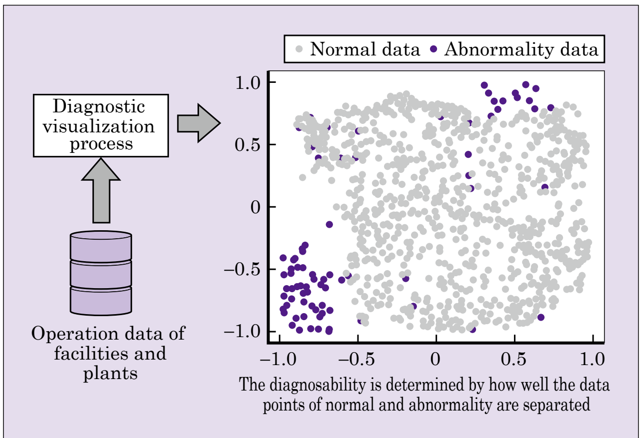


6 Diagnostic Visualization Technology and Non-Linear Diagnosis Technology

There in an increasing demand for abnormality diagnosis technology of facilities and plants using data, and more complicated targets than before are required to diagnose. In abnormality diagnosis, it is important to quickly determine diagnosability with the obtained data, present it to the customer, and construct a high performance model.

Fuji Electric has been developing diagnostic visualization technology for determining abnormality diagnosability on the basis of operation data of the diagnostic target and non-linear diagnosis technology that can diagnose complicated abnormalities of facilities and plants. We have applied the diagnostic visualization technology to an actual project and verified that the determination of diagnosability, a process that has taken more than one week, can be completed in half a day. In addition, the non-linear diagnosis technology improved by more than 20% the diagnostic performance of objects that had been difficult to diagnose with conventional technology.

Fig.11 Example of diagnostic visualization technology

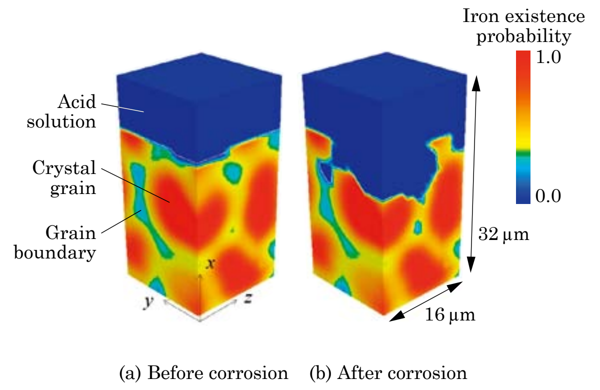


Advanced Technology

7 Corrosion Simulation Technology

Fuji Electric develops products that can operate under severe corrosive environments, such as a geothermal turbine and a cleaning system for marine exhaust gas. To ensure long and stable operation of products, technology is required for accurately predicting the progress of corrosion over time. Corrosive environment differs depending on product, and corrosion includes various modes; the corrosion prediction technology needs to deal with all the conditions. We have thus developed corrosion simulation technology that supports each corrosive environment and corrosion mode using a multi-phase field method. The technology can uniformly deal with ion diffusion in corrosive liquids and metal melting on the surface of products, and so can be used for various corrosion environments of products. The technology also deals with various corrosion modes including pitting corrosion by incorporating the unevenness of metal structures into the calculation model. We will apply this technology to product design.

Fig.12 Simulation result of pitting progress of corrosion of iron



Fuji Electric

Innovating Energy Technology