Fundamental and Advanced Technologies

Fundamental Technology
Advanced Technology

Fuji Electric is engaged in research and development of fundamental and advanced technologies to create new customer value through the realization of green transformations (GX) and digital transformations (DX).

A DC bus system is a promising GX technology to efficiently use decentralized power supplies, such as storage batteries and fuel cells, and a water electrolyzer to produce hydrogen, which is expected to become widely used. To improve energy conversion efficiency, we have developed bi-directional isolated DC/DC converters. By using a new conversion circuit system, we have demonstrated that high conversion efficiency can be maintained over a wide load range, and development is in progress to achieve DC bus systems.

With regard to the switchgear used in substation equipment, we have developed a technology to use built-in heat-absorber plates to cool high-temperature gas generated in short circuit arc accidents. This technology eliminates the need for an accessory structure for discharging hot gas to the outside, thereby improving the flexibility of switchgear in terms of where it can be installed.

We have been developing insulation technology to further reduce the size and weight of electrical equipment. For example, we have developed a technology to control the dispersion of fillers in insulating resin to prevent the decrease in withstand voltage caused by the aggregation of fillers when highly thermally conductive fillers are mixed with the resin. In the future, the technology will be applied to sealing materials for power semiconductors and substation equipment.

We have developed a 3.3-kV trench gate SiC superjunction metal-oxide-semiconductor field-effect transistor (SJ-MOSFET) chip to further reduce loss in power semiconductors. Compared with conventional trench gate MOSFETs, the total loss at 175°C has been reduced by half. Furthermore, for the vertical GaN-MOSFET, which we aim to put into practical application in the future, we expanded the chip area by combining a miniaturized active region achieved using ion implantation technology with multilayer wiring electrodes, thereby succeeding in increasing the output current to 1 A at maximum.

For the first time in the industry, we have developed a highly accurate scale generation prediction technology for complex geothermal steam properties, which was designed to be applied in geothermal power generation equipment. The use of this technology contributes to the efficient maintenance by assisting the formulation of appropriate maintenance plans for geothermal power generation equipment and preventing sudden failures.

To further reduce the power consumption of refrigerated and frozen showcases widely used in food sales, we are developing a functional coating technology that reduces the energy required for defrosting by preventing frost formation on heat exchangers installed in showcases.

Among DX we have developed is a technology to meet the requirements from electric utility companies that participate in the energy market, which has been opened as electricity deregulation. The technology is to forecast the price of electricity in the power market and create an exchange plan based on the forecast to maximize profits by effectively utilizing storage batteries. This allows the use of a wide range of information, such as nationwide supply and demand information, to improve prediction accuracy and track sudden price fluctuations based on short-term historical data.

We have developed a multi-factor authentication technology to enhance the security of web application softwares. The technology enables the combination of conventional password authentication with one-time password or client certificate authentication to enhance security.

We have developed a moving image recognition artificial intelligence (AI) technology with the aim of reducing the amount of labor required for monitoring work using cameras in places such as railway station platforms. The technology is capable of recognizing and tracking moving people and objects from recorded video footage in real time, and automatically determining their status.

We have developed an optimum production scheduling technology to improve production planning efficiency

in factories. Using optimization AI, optimum scheduling can be performed in a short amount of time by simply inputting conditions such as connections between processes and time information for manufacturing lines, thereby contributing to improvements in productivity and labor saving in factories.

In terms of model predictive control of programmable controllers used in process automation sites, we have developed a technology for automating the adjustment of control parameters, which previously depended on the experience of skilled workers. This allows plant operations to be performed in a stable manner while simultaneously reducing engineering costs.

In addition to technologies that contribute to customer DX, we have also developed technologies that support DX in research and development.

To achieve low noise in transformers, we have developed a simulation technology to estimate the noise caused by the magnetostriction of electromagnetic steel sheets for cores. By linking together magnetic field analysis, structural analysis, and acoustic analysis, the vibrations and noise caused by magnetostriction can be accurately estimated.

We have developed a software execution infrastructure that can streamline the development of software for Internet of Things (IoT) systems. This makes it easy to port software between edge controllers with different hardware and operating systems, thereby reducing the labor hours required for development.

We have developed a technology to predict the fatigue life of electronic parts used in transportation machinery and other equipment that is subject to various vibrations from the outside. This enables designs that prevent accidents and failures, as well as the shortening of development periods as a result of the reduction of reliability testing processes. We are also developing technology to provide new customer value. We have developed a small, high-precision electric current sensor that uses no magnetic core. This sensor will contribute to the reduction of size and cost of the equipment in which it is used.

We are developing a technology to automatically clean the inside of counter fixtures that are being introduced in convenience stores. Furthermore, we are developing components that suppress food adhesion, as well as a technology that enhances the cleaning effect of hot water.

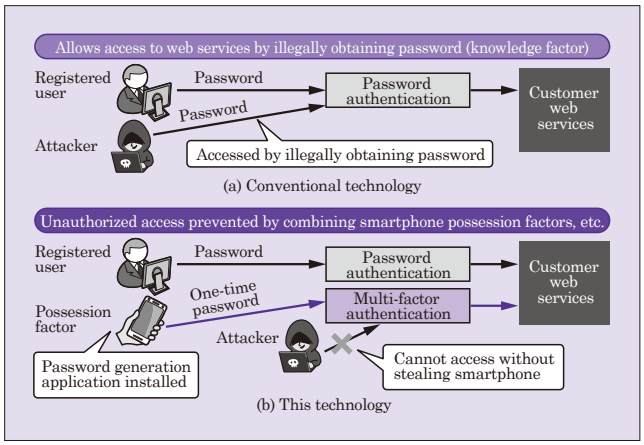
Fuji Electric will continue to strengthen such fundamental and advanced technologies and contribute to the creation of a sustainable society through the energy and environmental fields.

Fundamental Technology

1 Web Application Multi-Factor Authentication Technology

With the advancement of IoT and DX, the threat of cyberattacks has increased, and there is a need to strengthen the security of products and systems. Seen in many web applications, single-factor authentication methods, such as password authentication, are particularly easy to use, but when using such methods, it has become difficult to prevent fraud caused by spoofing. As such, strengthening authentication is an urgent challenge. To address this issue, Fuji Electric developed a multi-factor authentication technology that enables authentication using one-time passwords, client certificates, and other factors in addition to passwords. We have implemented this technology using open source software, converting necessary functions into a platform to eliminate the need for application modification, thereby facilitating the introduction of the technology into existing systems. We will promote the application of this technology to enhance the security of web applications.

Fig.1 Multi-factor authentication example (one-time password authentication)

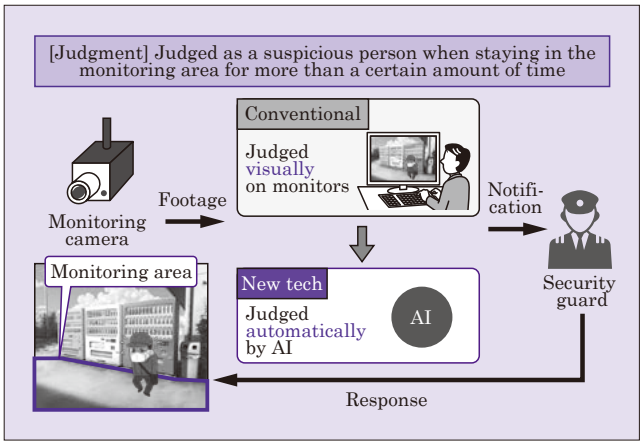


2 Status Monitoring Technology Using Moving Image Recognition AI

Monitoring operations using cameras need labor saving and reliable surveillance with reduced oversights and fewer judgment errors. Fuji Electric has developed a moving image recognition AI technology that recognizes and tracks people and objects in footage in real time and automatically determines the status of each object. When used to detect suspicious people, the AI determines that there is a suspicious person and notifies security staff if the person stays within a predetermined monitoring area for more than a certain amount of time. In this way, by automating monitoring work with AI, this technology enables labor saving and prevents oversights in monitoring operations. Moreover, by applying the expertise of monitoring personnel in the judgment rules, monitoring can be carried out in a consistent manner.

We will promote the application of this technology to contribute to the creation of a safe and secure society.

Fig.2 Example of application in the monitoring of suspicious people



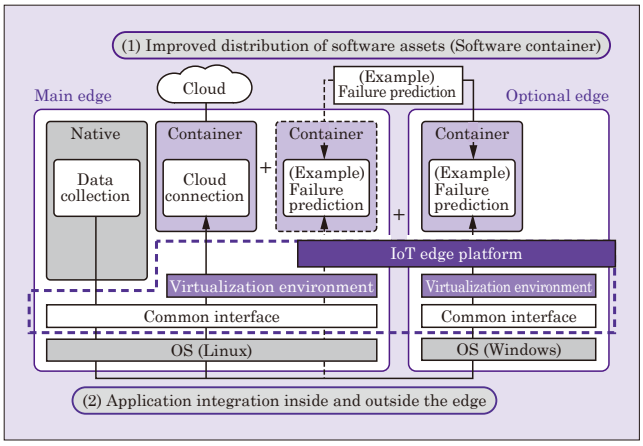
3 IoT Edge Platform

IoT systems are shifting from cloud-centric configurations to field-based edge-centric configurations designed to improve security, reduce traffic, and provide high-speed responses. At the same time, the extension of functions on systems that have already been installed has led to the issue of processing performance degradation due to the limitations of the hardware available for maintaining existing functions. To address this issue, Fuji Electric has developed an IoT edge platform with the following features:

(1) Adopt of software containers and virtual environments improves the distribution of existing assets, including software with different operating systems, reducing development costs.

(2) A common interface can associate the platform with applications inside and outside the edge regardless of the operating system to distribute processing and improve performance by adding edge devices.

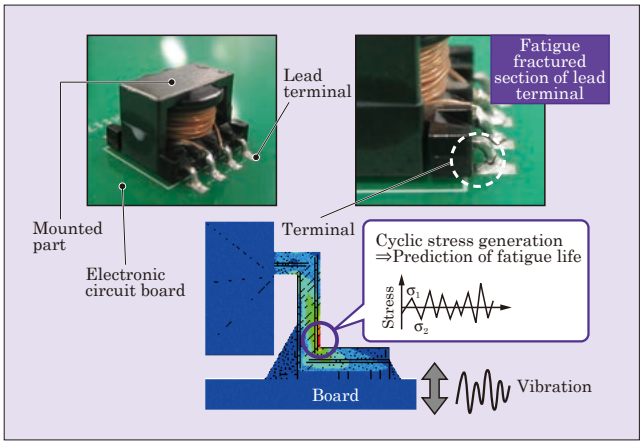
Fig.3 IoT system configuration example



4 Fatigue Life Prediction Technology for Electronic Parts

In the products that are subject to various external vibrations, such as transportation equipment (cars, railcars, and ships), a fatigue failure of an internal electronic component can occur, leading to serious accidents. The precautions against it are thus needed. To address this problem, Fuji Electric has developed a technology to predict the fatigue life of electronic circuit boards, which had been difficult to predict in the past. Damage caused by vibrations often occurs in places where stress especially increases, such as bent lead terminals of the parts mounted on electronic circuit boards, and it is important to understand this stress accurately to achieve life prediction. In response, by formulating the fatigue characteristics of the material by taking into account the concentration of stress due to bent shapes, and by developing a method capable of estimating the stress at bent sections with high accuracy, we have achieved life prediction for lead terminals of electronic parts. Using this method, the lifespan can be predicted with half of the error of the conventional method, thereby contributing to the improvement of reliability of electronic equipment and shorter development periods.

Fig.4 Lead terminal fatigue failure due to vibrations

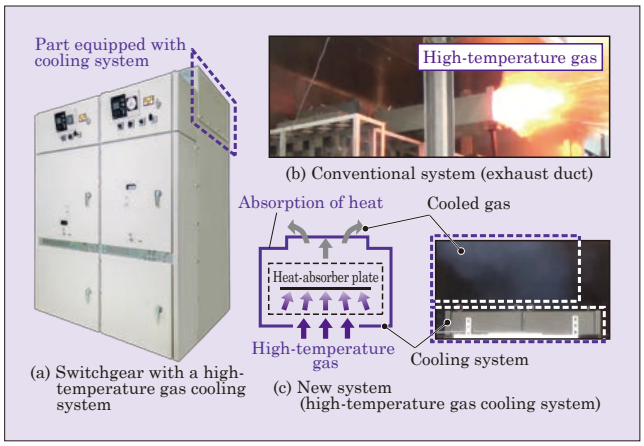


Advanced Technology

1 High-Temperature Gas Cooling Technology to Increase Flexibility in Selecting Switchgear Installation Sites

For switchgear used in substation equipment, the safety of the surroundings must also be ensured for when short circuit arc accidents occur. Until now, in case of short circuit arc accidents, switchgear installed indoors discharged high-temperature gas through the exhaust duct. However, there is a limited number of places where high-temperature gas can be discharged outdoors in chemical factories to prevent the occurrence of secondary disasters due to the ignition of chemical substances, and therefore, switchgear installation sites have been restricted. Fuji Electric has developed a technology to cool the gas temperature by proactively bringing the high-temperature gas generated in short circuit arc accidents into contact with heat-absorber plates. By equipping switchgear with a cooling system using this technology, it becomes possible to safely treat the gas generated during accidents inside the switchgear.

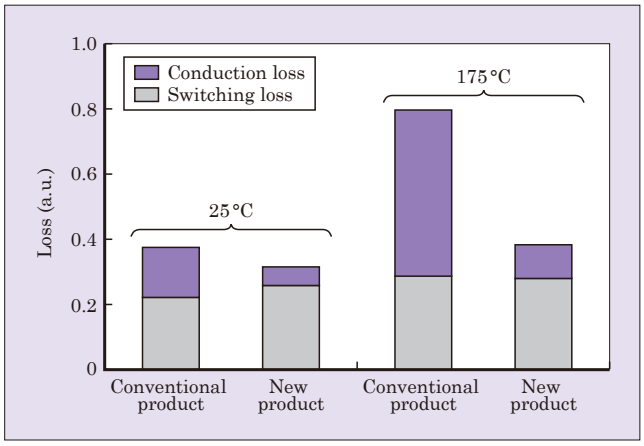
Fig.5 Differences in characteristics at the time of internal short circuit arc accidents



2 3.3-kV SiC Super-Junction MOSFET

Demand for low-loss SiC power semiconductors is increasing with the aim of using energy efficiently. Fuji Electric participated in the joint research body Tsukuba Power-Electronics Constellations (TPEC) and developed a 3.3-kV trench gate SiC super-junction (SJ) MOSFET chip, which is expected to further reduce losses. We evaluated the switching loss of the developed product and estimated the total loss in synchronous rectification. The trench gate SiC SJ-MOSFET has a slightly larger switching loss than the conventional trench gate SiC-MOSFET, but the conduction loss is smaller. As a result, the total loss per chip of the developed product was reduced by approximately 50% at 175°C compared to the conventional trench gate SiC-MOSFET.

Fig.6 Loss comparison between the conventional trench gate type and SJ-MOSFET

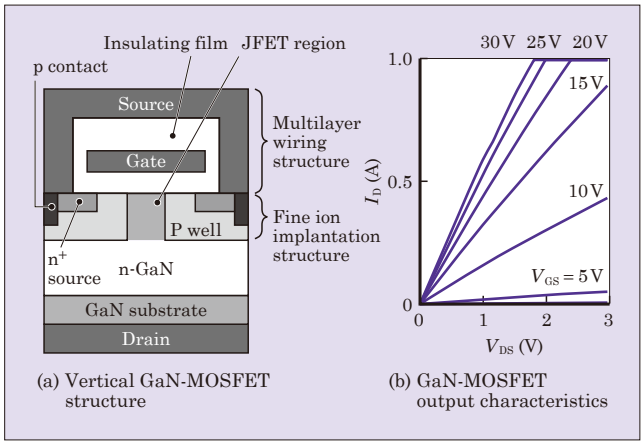


3 Vertical GaN-MOSFET with Currents of Several Amperes

Vertical MOSFETs with gallium nitride (GaN) are expected to be next-generation power devices that feature lower loss than silicon carbide (SiC). The development of GaN devices needs microstructure fabrication to reduce loss and area expansion to increase currents. Fuji Electric has increased the area of the chip by combining fine active region fabrication using ion implantation technology with corresponding wiring electrodes, thereby increasing currents up to 1 A. This operating current is the world's maximum as that of vertical GaN device fabricated using ion implantation technology, which is essential for high reliability.

In the future, we will further increase operating currents to enhance device performance that surpasses SiC-MOSFETs.

Fig.7 Vertical GaN-MOSFET structure and electrical properties

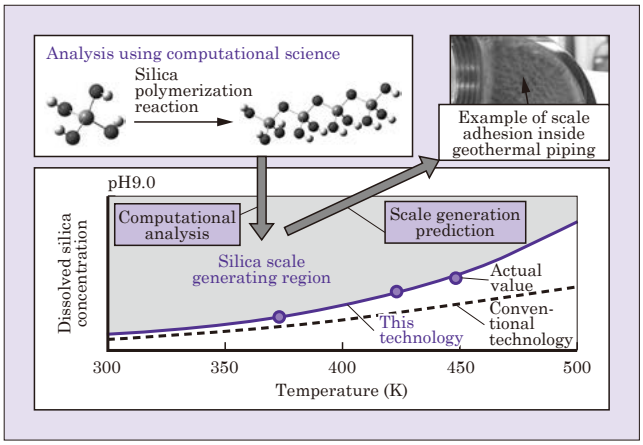


Advanced Technology

4 Technology to Predict Silica Scale Generation with Computational Science

Silica scaling results in flow rate reduction or improper performance in power generation. To preserve the power generation capacity, maintenance work is required to remove scales. Therefore, the prediction of the silica scale generation quantity is required, but conventional empirical prediction equations are not practical because they are not applicable when the properties of geothermal fluids change. To address this issue, Fuji Electric has developed the first non-empirical scale generation prediction technology in the industry, taking into account the pH and temperature dependence of geothermal fluids with computational science. This technology reproduces the polymerization process of silica scale generation from dissolved silica to generate scale, taking into account the type and concentration of impurities in the geothermal water, which are different for each geothermal power plant, thereby enabling highly accurate predictions. By planning maintenance schedules appropriately based on this newly developed scale generation prediction technology, it is possible to avoid reductions in power generation and sudden shutdowns of geothermal power generation facilities.

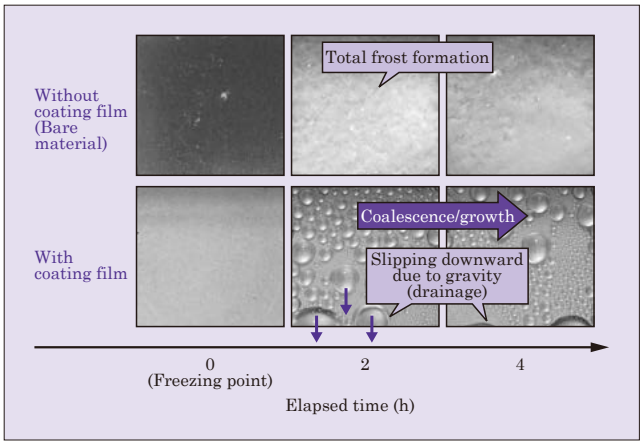
Fig.8 Prediction of silica scale dissolution curves



5 Frost-Free Technology for Heat Exchangers Using Functional Coating

To realize a decarbonized society, there is an increasing demand for energy saving in the use of refrigerated and frozen showcases in stores. When frost forms on the heat exchanger in showcases, the heat exchange efficiency decreases, and power consumption increases. To address this issue, Fuji Electric has worked with Kansai University to develop a frost-free technology that prevents frost formation by applying a special functional coating to heat exchangers. On the surface of the coating film of the functional coating, water remains in a supercooled state in which it does not freeze even at temperatures below 0°C. When applying functional coating to aluminum material, which is the main material used in heat exchangers, we confirmed that the water droplets caused by condensation on the surface remained unfrozen for more than 6 hours at −6°C, the temperature required for refrigerated showcases. We also confirmed that the water droplets grew over time and slid down due to their own weight. In the future, we will promote applications of this technology to actual showcases, thereby contributing to energy saving.

Fig.9 Observation results at −6°C cooling

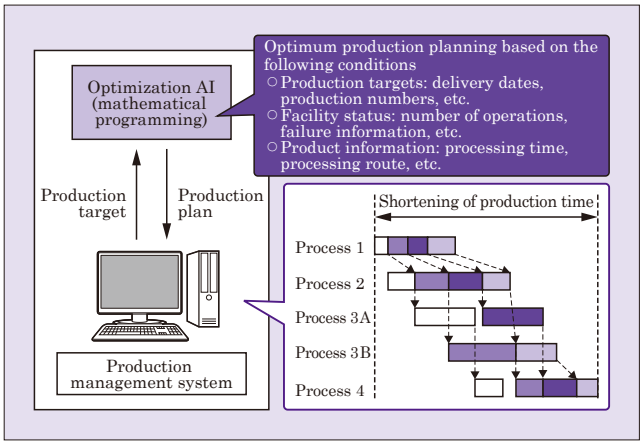


6 Optimum Production Scheduling Technology

Factory production plans used to be prepared by skilled workers who took time to consider various conditions, and even in cases that necessitated a change of plans due to sudden factors such as equipment failures, it was not possible to respond quickly. In addition, this method of developing plans was based on past experience and was not necessarily optimized. To address these issues, Fuji Electric has developed a technology to automate and maximize the efficiency of production scheduling by applying optimization AI (mathematical programming). The main features are as follows:

(1) Ability to perform scheduling in time spans of several seconds to 10 minutes can quickly respond to sudden changes in plans.
(2) Optimum scheduling can be achieved by simply providing manufacturing line conditions, such as process times and connections between processes, and scheduling objectives, such as production time reduction and production leveling.

Fig.10 Production management system configuration



Advanced Technology

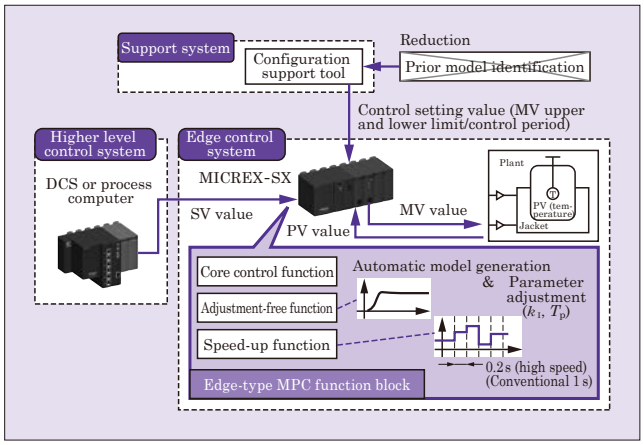
7 Edge-Type Model Predictive Control Technology with Automatic Model Creation

The "MICREX-SX" programmable controller can incorporate an edge-type model predictive control (MPC) function to highly increase control precision by performing optimization while predicting the future response of the plant. Fuji Electric has developed an adjustment-free function and a speed-up function designed to stabilize operations and reduce engineering costs at plants. The main features are as follows:

(1) Ability to automatically create plant models online using the controlled variable and the manipulated variable measured during operation can automatically adjust control parameters, such as gains and time constants, thereby reducing prior model identification tests that were required in the past.

(2) Control period sped up from the conventional 1 s to 0.2 s further improves control accuracy and response speed.

Fig.11 Example of edge-type model predictive control system



8 Technology of Current Measurement with Coreless Coils on a Printed Circuit Board

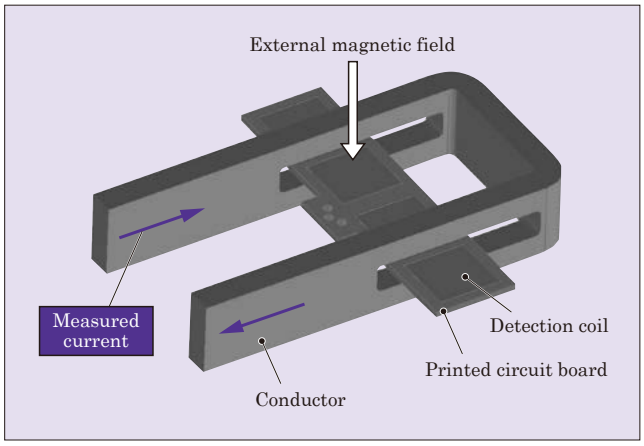
High-precision current sensors used in power monitoring are large and expensive because they use a magnetic core. To address this issue, Fuji Electric has developed a small, high-precision current sensor that uses no magnetic core. Equipping smart meters and other equipment with this current sensor will help reduce their size and costs. The features are as follows:

(1) Use of detection coils formed on a printed circuit board eliminates the need for magnetic cores, thereby reducing size and cost.

(2) Detection coils placed on both the left and right sides with respect to the energizing direction of the measured current offset the effect of the external magnetic field while detecting the magnetic field caused by the measured current, thereby achieving high accuracy.

(3) A board with multiple coils placed in a through hole in the center of the conductor to suppress the effect of the magnetic field of the measured current fluctuating due to the displacement of the board position, thereby stabilizing current measurement.

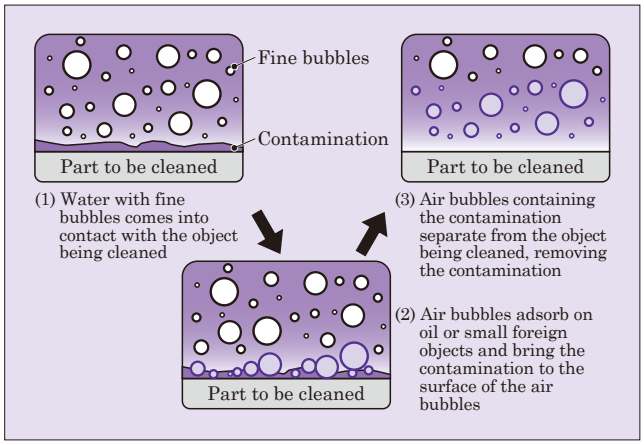
Fig.12 Coreless current sensor structure diagram



9 Automatic Cleaning Technology for Food Equipment Parts

The retail industry needs sanitation management in accordance with HACCP to ensure food safety and security. Counter fixtures in convenience stores, such as coffee machines, need washing to maintain sanitation conditions, and disassemble internal parts to clean with a dishwasher poses issues in terms of securing human resources and working hours. To address these issues, Fuji Electric is developing a technology to automatically clean parts that come into contact with foodstuff. For example, we are promoting the use of fine bubbles for the removal of coffee oil that adheres to coffee machines. As a result of hydrophobic interaction, the bubbles adsorb on coffee oil, which does not mix with water, thereby reducing the amount of residue to less than half of the amount achieved by using the method of only pouring hot water. Going forward, we will further improve the cleaning power of this technology by optimizing the bubble diameter and other factors.

Fig.13 Cleaning Mechanism using fine bubbles



Fuji Electric

Innovating Energy Technology