Highlights

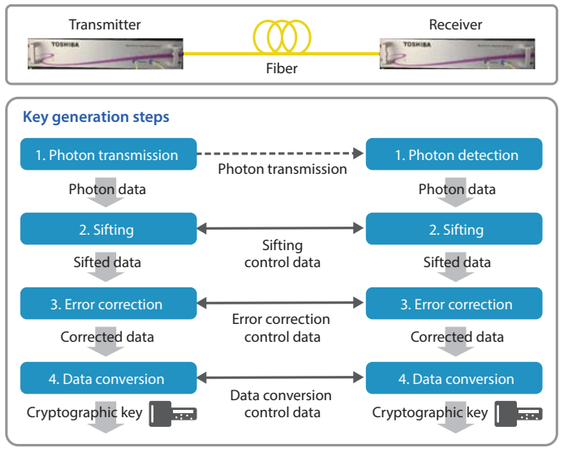
Corporate Research and Development

High-Speed Quantum Cryptography System

Quantum cryptography is a promising communication technology that guarantees communication security using the quantum properties of photon particles, which makes it resilient to attack even by quantum computers. Its first applications include backup of confidential data and transmission of medical data, which require cryptographic keys at a rate greater than that achievable with conventional quantum cryptography systems.

To solve this problem, Toshiba Corporation has developed a high-speed quantum cryptography system that provides a key rate of 13.7 Mbps, the first such system in the world to achieve a key rate exceeding 10 Mbps(*). This key rate was realized by using high-speed photon detectors, newly designed electronic hardware, a small-footprint error correction method optimized for photon error characteristics, massive parallel data conversion technology, and other innovations. These technologies will expand the applications of quantum cryptography.

(*) As of February 2018 (as researched by Toshiba Corporation)

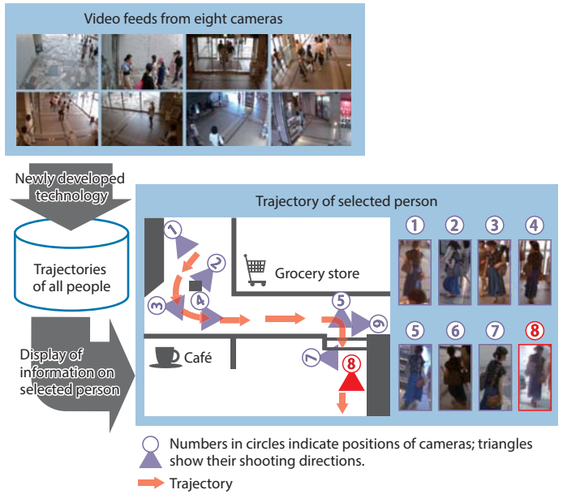


Flow of key generation processes of high-speed quantum cryptography system

High-Speed and High-Accuracy Person Re-identification Technology to Track Movements of People in Large Facilities

Toshiba Corporation has developed a technology that uses video feeds from multiple surveillance cameras to track the movements of people at high speed and high accuracy. This technology makes it much easier for security systems and statistical attribute analysis systems to reference the action history of any person in large facilities.

Since different video cameras capture a given person from different angles and distances, it is difficult to precisely identify the same person in multiple video feeds. To solve this problem, the newly developed technology combines two methods: (1) robust feature extraction that is not affected by differences in the settings of cameras and (2) an optimization method called constrained k-nearest-neighbor (kNN) kernel shift clustering that prevents images of different identities from being erroneously recognized as the same person. We confirmed that this technology can track the movements of 100 freely walking people in the video feeds from eight cameras at a practical level of accuracy.



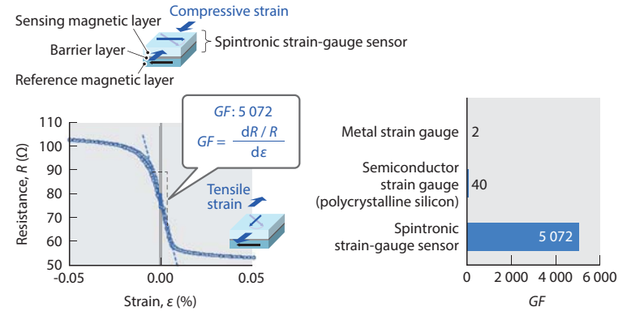
System for displaying trajectory and appearance of selected person from different images captured by multiple surveillance cameras

Highly Sensitive Spintronic Strain-Gauge Sensor Element and Demonstration of Spintronic MEMS Microphone

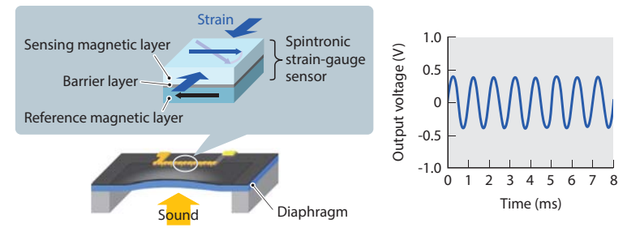
Microelectromechanical system (MEMS) technologies allow the mass production of sensors of minimal size. MEMS-based sensors are widely used in electronic equipment including smartphones, in-vehicle electronics, and Internet of Things (IoT) devices. Demand for improvement of the sensitivity of these sensors has been growing.

In response, Toshiba Corporation has developed spintronic MEMS technologies that combine MEMS technologies with spintronic technologies for hard disk drives (HDDs) and magnetic random access memories (MRAMs). By using an amorphous iron-boron (Fe-B) alloy with high magnetostriction, we have realized a spintronic strain-gauge sensor possessing extremely high strain sensitivity with a gauge factor (*GF*) of 5 072. This is 2 500 times the gauge factor of a conventional metal strain gauge and more than 100 times that of a conventional semiconductor strain gauge. We have also developed a prototype spintronic MEMS microphone that integrates this sensor element on a MEMS diaphragm, and have successfully demonstrated sound detection by such a device for the first time in the world(*).

(*) As of June 2017 at a Transducers 2017 presentation (as researched by Toshiba Corporation)



Comparison of performance of conventional strain gauges and spintronic strain-gauge sensor element



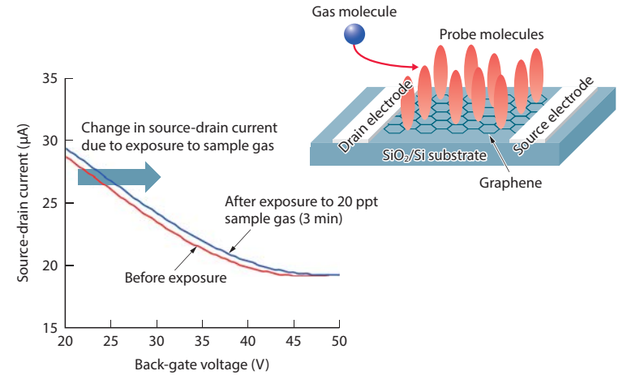
Demonstration of sound detection by prototype spintronic MEMS microphone

Ultrahigh-Sensitivity Gas Sensor Using Graphene Field-Effect Transistor

Portable gas sensors with ultrahigh sensitivity are required for security (e.g., dangerous substance detection), environmental (e.g., atmospheric pollution detection), and medical applications. Toshiba Corporation has developed a graphene field-effect transistor (FET) device capable of detecting a target gas with probe molecules deposited on the graphene channel layer.

We conducted experiments to verify changes in the source-drain current of the FET when exposed to a phosphoric acid-based sample gas with concentrations ranging from several tens of ppt to several ppm. The results confirmed that this device works as an ultrahigh-sensitivity gas sensor. Our next step is to develop a gas type identification technique.

ppt: parts per trillion
ppm: parts per million



Si: silicon
SiO_2: silicon dioxide

Structure of gas sensor and its response to phosphoric acid-based sample gas

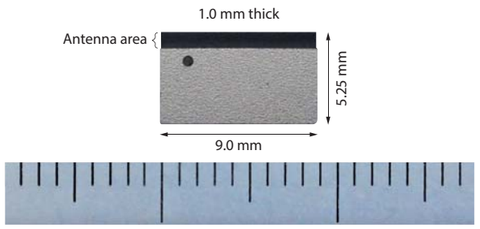
Ultrasmall Wireless Module Equipped with Antenna

Accompanying the prevalence of the IoT, demand for wireless modules equipped with an antenna is growing. Conventional antennas in wireless modules require a large keep-out zone on the printed circuit board (PCB) to maintain satisfactory antenna performance. However, the resulting increase in PCB area makes it difficult for the wireless module to be embedded in IoT applications. Furthermore, it is time-consuming to create an appropriate antenna design and obtain wireless certification.

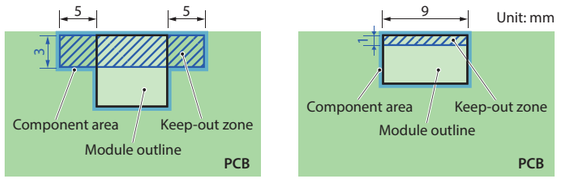
To resolve these issues, Toshiba Corporation has developed a Bluetooth® Low Energy (BLE) module equipped with a uniquely designed ultrasmall antenna suitable for IoT applications. The new BLE module requires a keep-out zone of only 9 mm^2 immediately below the module. The BLE module has a component area of only 47.25 mm^2, including the keep-out zone, the world's smallest for shielded modules(*).

(*) As of December 2017 (as researched by Toshiba Corporation)

The Bluetooth® word mark and logo are registered trademarks owned by Bluetooth SIG, Inc.



Prototype BLE module equipped with ultrasmall antenna



(a) Conventional module (b) Prototype of newly developed module

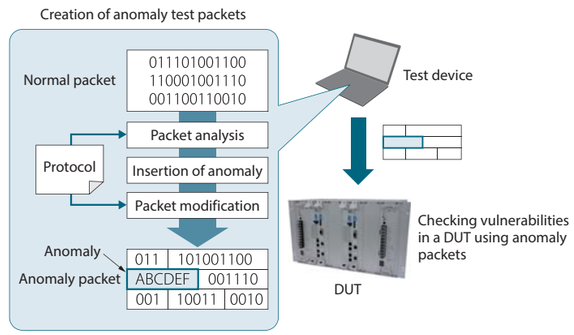
Keep-out zone and component area of module

Communication Robustness Testing Technology for Industrial Controllers

Toshiba Corporation has developed a communication robustness testing technology for checking whether critical infrastructures such as power systems can maintain services even in the event of cyberattacks. This technology examines vulnerabilities in a controller by:

- analyzing normal packets based on a specific communication protocol,
- generating anomaly test packets based on the controller status, and
- sending them to the controller.

We applied the newly developed technology to the "Unified Controller nv series type2" industrial controller as a device under test (DUT) and successfully verified its communication robustness. This technology can eliminate vulnerabilities from controllers in advance in order to ensure infrastructure security using secure controllers and systems.



Communication robustness testing technology based on protocols

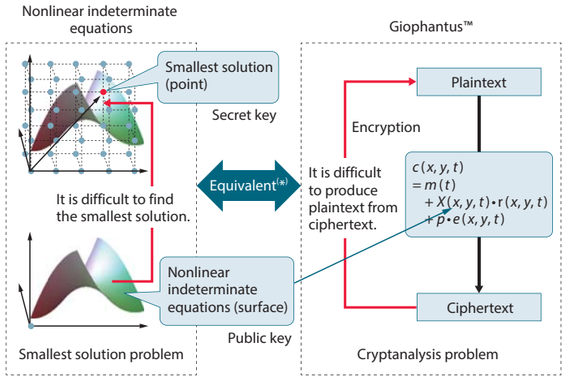
Giophantus™ Quantum-Computer-Resistant Public-Key Cryptosystem

Toshiba Corporation has developed Giophantus™, a public-key cryptosystem, in collaboration with the Hokkaido University of Education, Kyushu University, and the National Institute of Advanced Industrial Science and Technology (AIST). Its security is based on nonlinear indeterminate equations that are known to be computationally hard to solve even with a quantum computer.

Current public-key cryptosystems such as RSA (Rivest-Shamir-Adleman) will be broken when quantum computers capable of factoring very large numbers appear. Therefore, the development of quantum-computer-resistant public-key cryptosystems is of crucial importance.

The security of Giophantus™ relies on the computational hardness of finding the smallest solution of nonlinear indeterminate equations. Due to this intrinsic computational hardness, Giophantus™ does not need a long secret key, making high-speed processing possible. In addition, Giophantus™ provides a type of security known as "provable security."

We intend to apply Giophantus™ to social infrastructure and other long-term systems that will still remain in use in the coming era of quantum computers.



* If either one is solved, the other one can be solved. The current cryptanalysis problem is equivalent to the other problem related to the smallest solution problem in a nonlinear indefinite equation.

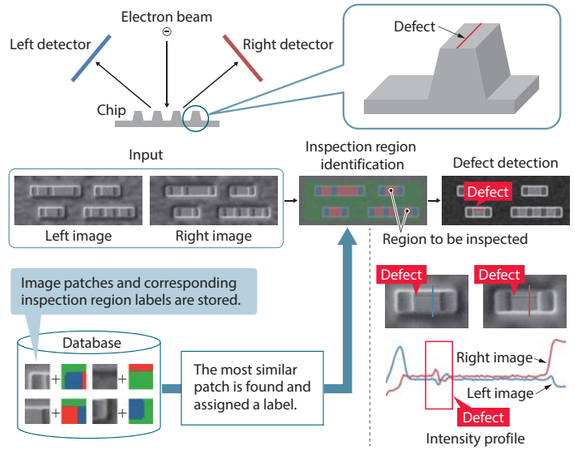
Relationship between smallest solution of nonlinear indeterminate equations and newly developed Giophantus™ public-key cryptosystem

Automatic Semiconductor Defect Detection Using Image Analysis

In order to make it possible to improve semiconductor fabrication processes more efficiently, Toshiba Corporation has developed an automatic defect detection technology that analyzes the structures of semiconductor wafer images.

Conventionally, defects have been visually counted using two scanning electron microscope (SEM) images captured by detectors placed on the left and right sides of a semiconductor chip. However, examination of the large numbers of images generated by this method is a tedious and time-consuming task.

We have developed a technology to solve this problem, in which a database that matches image patches to inspection region labels is created and the inspection regions in the images are identified using an efficient search method based on dimension reduction and tree search. Furthermore, the newly developed technology detects any area where the left and right images have reverse brightness and identifies it as a defect. As a result of these features, the automatic defect detection system provides the same precision as visual inspection.

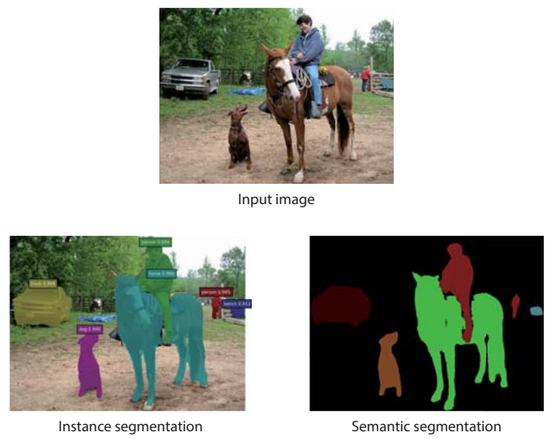


Outline of automatic defect detection processing technology

Effective Image Segmentation Technique Using Deep Learning

Toshiba Corporation has developed BiSeg, an image segmentation technique based on deep learning. BiSeg can estimate both instance segmentation, which detects and segments each object in an image, and semantic segmentation, which classifies each pixel in an image into object categories.

BiSeg performs these two segmentation tasks as two sub-networks sharing convolutional features of the same convolutional network. The sharing of features speeds up the estimation process of the network. The estimation results of the two sub-networks are combined in each object region candidate. Finally, an object segmentation mask is predicted as a posterior by means of Bayesian inference. We have confirmed that BiSeg provides good segmentation results irrespective of object categories and shapes.



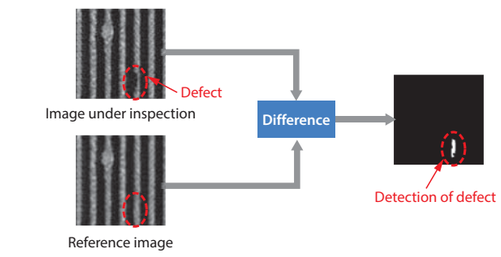
Example of images simultaneously estimated by instance and semantic segmentation

Comparative Inspection Technology for SEM Images Using Machine Learning

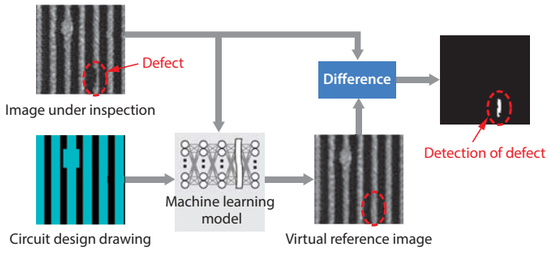
Toshiba Corporation has developed a comparative inspection technology using machine learning that can automatically detect edge roughness, pattern collapse, and other defects in semiconductor circuit patterns from SEM images.

The conventional method detects these defects by comparing an image under inspection with a reference image to find differences. However, the conventional method also needs to capture images of non-defective products to be used as references.

The newly developed technology models the correspondence relationship between a circuit design drawing and an SEM image in advance using machine learning. By using the learned model, the new technology can generate a virtual SEM image of a non-defective product from a design drawing and use it as a reference instead of an actual product image. This eliminates the step of imaging a non-defective product with SEM, reducing the measurement time and improving inspection efficiency.



Conventional comparative inspection of defects in wiring patterns



Comparative inspection using machine learning model

Application of Machine Learning to Analysis of Text Data

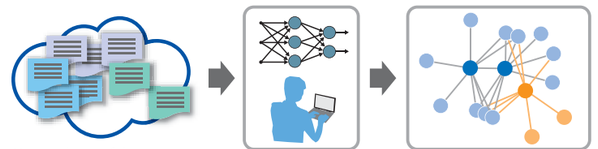
With the recent progress of IoT and big-data technologies, large amounts of information have become available. The current challenge is to gain insights and meaningful knowledge from these data.

To resolve this issue, Toshiba Corporation has developed a technology using machine learning that automatically extracts and visualizes useful information from unstructured text data such as design documents without requiring any technical knowledge.

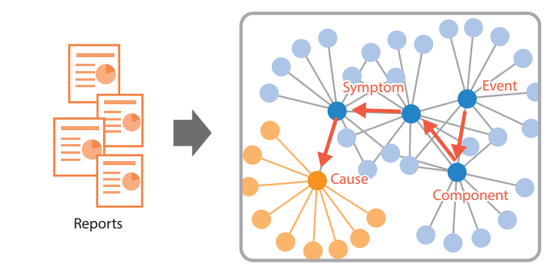
For example, the newly developed technology can find new know-how and unknown relationships between businesses and customers from design and purchase documents.

The new technology was used to learn dozens of reports and then extract and visualize useful information and knowledge using a connective search. As a result, an event name was traced to relevant components and causes.

This technique can be widely used for knowledge acquisition in various phases, encompassing design, development, procurement, production, logistics, maintenance, and sales.



Automatic extraction of knowledge from text analysis



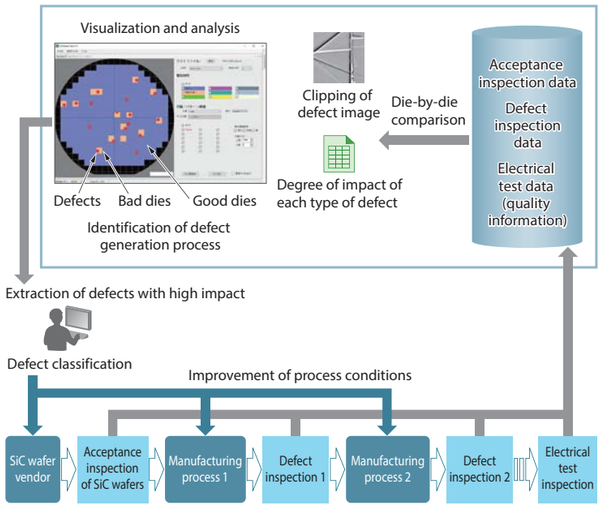
Example of knowledge extraction from reports

Quality Control System for Diagnosing Process of Defect Generation in SiC Semiconductors

Toshiba Corporation has developed a quality control system that allows die-by-die comparison of acceptance inspection data, defect inspection data from manufacturing lines, or electrical test data providing information on the quality of semiconductor devices.

This system can display good and bad dies on wafer maps and capture images of defects for analysis. The system can also separate initial crystal defects in a wafer from those generated in the manufacturing process. The newly developed system thus considerably simplifies the task of determining the defect generation process and the degree of impact of each type of defect. By determining the defect generation process and improving the process conditions as appropriate, reductions in the number of defects and manufacturing waste can be achieved.

Since silicon carbide (SiC) semiconductor devices are a focus of expectations as next-generation power devices, we have been using this system on our manufacturing lines for SiC devices in order to enhance the efficiency of quality improvement.



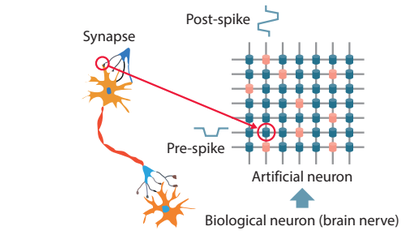
Outline of quality control system for SiC semiconductor manufacturing lines

Neuromorphic Technology Using Metal Oxide Devices to Mimic Memory Processes of Human Brain

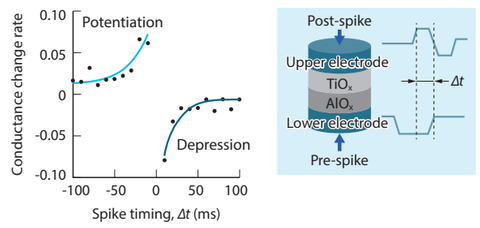
Inspired by neuromorphic computers, Toshiba Corporation has developed a neuromorphic technology using metal oxide devices that makes it possible to update memory employing the spike-timing-dependent plasticity of neurons. This neuromorphic technology is designed to reduce the power consumption of the learning process of artificial intelligence (AI) in IoT and edge computing.

We fabricated crossbar-shaped artificial neurons using metal oxide devices and controlled continuous resistance changes with nonvolatility by timing the application of electrical stimulations (spikes) to both terminals of the devices. Furthermore, we combined the newly developed neuromorphic technology with learning algorithms of artificial neural networks for deep learning to confirm the operating principles of learning processes in tiny analog electronic circuits.

As the next step, we will speed up the learning operation by using massive parallelism and demonstrate its ultralow power performance.



(a) Artificial neuron using crossbars



(b) Spike-timing-dependent plasticity

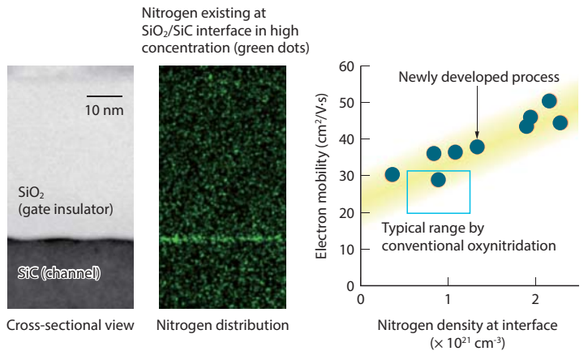
TiO_x: titanium oxide AlO_x: aluminum oxide

Spike-timing-dependent plasticity at synapses in artificial neuron

Gate Insulator Process Technology for Reducing On-Resistance of SiC MOSFETs

The use of SiC power semiconductor devices helps to reduce the size and increase the efficiency of inverters. Toshiba Corporation has developed an innovative gate insulator process that reduces the on-resistance of SiC metal-oxide-semiconductor field-effect transistors (MOSFETs).

It is important to introduce nitrogen into the interface between the gate insulator and the SiC channel region in order to improve electron mobility and thereby reduce the MOSFET on-resistance. Conventionally, an oxynitridation technique has been widely used for interface nitridation. The newly developed process technology consists of low-temperature oxidation and high-temperature nitrogen annealing. This technology allows high-density nitridation while avoiding damage to the material due to nitridation. Consequently, a 60% increase in electron mobility is achieved, which is expected to deliver a 20% reduction in on-resistance without compromising the reliability of devices.



Improvement of electron mobility due to higher nitrogen density at interface between SiO_2 and SiC through nitrogen introduction

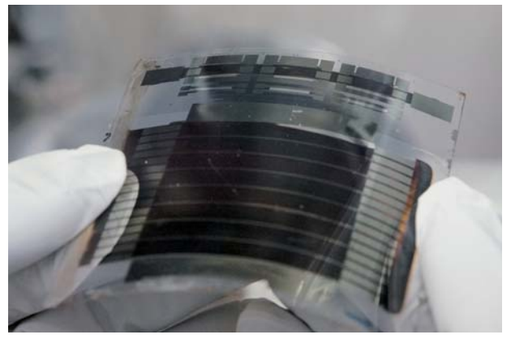
5 × 5 cm Film-Based Perovskite Photovoltaic Mini-Module with Conversion Efficiency of 13.7%

Toshiba Corporation is developing lightweight and flexible film-based perovskite photovoltaic (PV) modules(*1) for installation on walls, windows, or roofs of low-load-bearing structures. We have developed an approximately 5 × 5 cm film-based perovskite PV mini-module with an energy conversion efficiency of 13.7%(*2). We achieved this result by developing a unique film-coating technology and a scribing process technology suitable for module fabrication on polymer films.

This work is part of the "Development of high performance and reliable PV modules to reduce levelized cost of energy" project supported by the New Energy and Industrial Technology Development Organization (NEDO) of Japan.

(*1) Perovskite PV cells contain a hybrid organic-inorganic material as the light-absorbing active layer and have a crystal structure identical to that of calcium titanate. They are attracting considerable attention because they can be fabricated using a low-temperature coating process and are expected to be less costly than silicon solar cells.

(*2) Measured by Toshiba Corporation



Film-based perovskite PV module

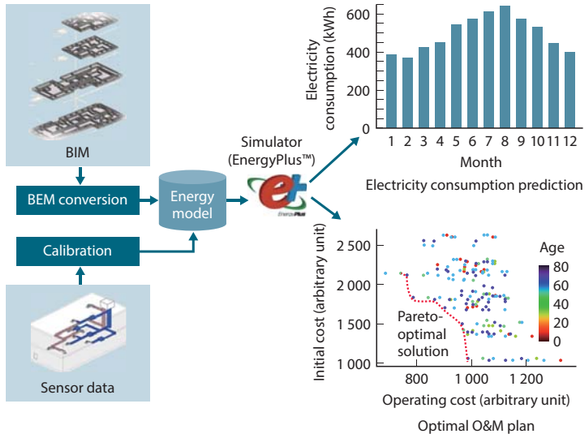
Building Energy Modeling for Energy Saving and O&M Optimization

Toshiba Corporation has developed technologies for the optimal operation and maintenance (O&M) of buildings, which perform the following functions:

- A building energy model (BEM) is created from a building information model (BIM).
- The BEM is calibrated based on energy consumption and environmental sensor data.
- Long-term investment and O&M plans are created using the calibrated BEM.

We have collaborated with Carnegie Mellon University in the United States to improve the technology for BEM calibration. By combining the results of this collaboration with our own BIM-to-BEM conversion technique and simulation and optimization acceleration technologies, we have succeeded in generating a facility investment plan for existing buildings in the United States with the minimum total cost.

EnergyPlus is a trademark of the United States Department of Energy.



O&M service applying building energy modeling for energy saving and operational optimization

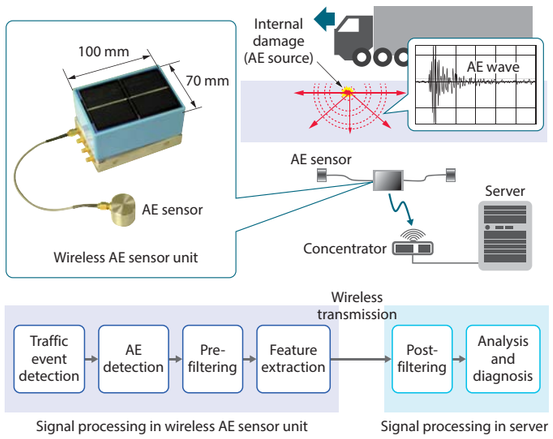
Wireless AE Sensor Unit for Bridge Deterioration Diagnosis System

The increase in the number of aging infrastructures such as bridges and tunnels in recent years has become a major social issue in various countries. This has given rise to the need for a deterioration sensing technology that can reduce labor costs and facilitate efficient maintenance.

In response, Toshiba Corporation has developed a palm-sized sensor unit for a bridge deterioration diagnosis system applying acoustic emission (AE) sensing. This sensor unit detects ultrasonic elastic waves generated by internal damage when a large vehicle imposes a heavy load on the bridge deck. The features of the signal are then extracted from these waves and wirelessly transmitted for damage diagnosis. In addition, low power consumption has been realized by applying event-driven power management that shifts the sensor unit from sleep mode to active mode in synchronicity with the passage of large vehicles.

We have successfully confirmed self-powered operation of the sensor unit using solar cells attached to the side beam of a highway bridge in service. A long-term field test is still under way. We are aiming to put this technology to practical use as a bridge health monitoring system, utilizing its novel advantages of wireless and self-powered AE sensing operation performed by a compact palm-sized unit.

This work was partly supported by NEDO.



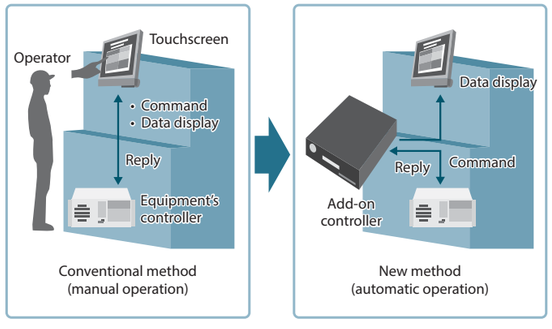
Configuration of bridge deterioration diagnosis system applying wireless AE sensor unit with solar cells

Add-On Control Technique for Automating 200 mm Semiconductor Manufacturing

Toshiba Corporation has developed an add-on controller for automating the operation of semiconductor manufacturing equipment. The controller can obtain screen signals from the equipment and visually display the equipment conditions. In addition, the controller can operate the equipment by generating and sending keyboard, mouse, and touchscreen signals. These two functions automate the equipment's operation.

On our 200 mm semiconductor manufacturing lines, operators manually carry wafers and operate the equipment. We applied the newly developed controller to 200 mm semiconductor manufacturing equipment in order to automate the start-up operation. This has successfully reduced the waiting time of operators after they set wafers to the equipment and helped to improve their productivity.

Our next step is to automate wafer transportation in order to realize a fully automated manufacturing line.



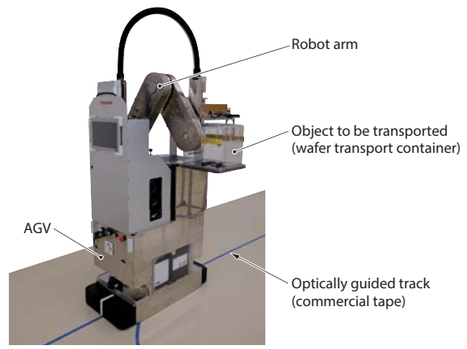
Automation of 200 mm semiconductor manufacturing equipment by means of add-on controller

Automated Guided Vehicle Equipped with Robot Arm Offering Enhanced Safety and Low Power Consumption

In order to alleviate the shortage of factory workers, Toshiba Corporation has developed an automated guided vehicle (AGV) equipped with a robot arm that can work while moving inside a factory. This AGV can handle tasks such as arranging and carrying parts.

The two-wheeled AGV follows a marker line for navigation. It is equipped with a unique detachable robot arm that can operate separately from the AGV. The elbow joint of the robot arm is configured vertically to reduce interference between workers, peripheral devices, and the robot. In addition, a spring mechanism is used to pull the arm in order to reduce the weight of the AGV. This has made it possible to reduce the output of the motor, enhancing safety and reducing power consumption. Since the AGV is guided along commercially available plastic tape, the installation cost is low. This AGV was developed with the aim of eliminating manual transportation, focusing on the transfer of wafers between semiconductor manufacturing processes.

We will continue to perform functional verification at the factories of the Toshiba Group in order to achieve practical use at an early stage.



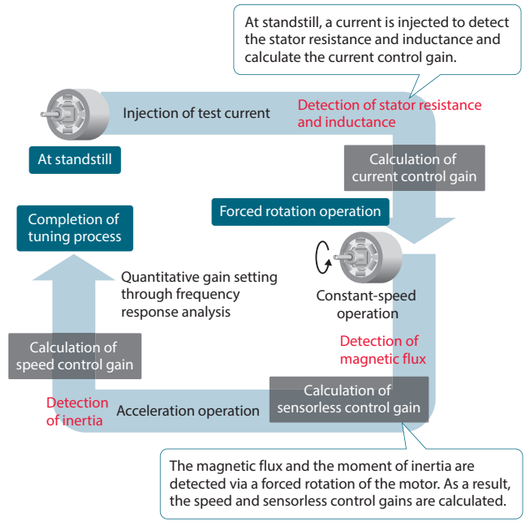
AGV equipped with robot arm for component distribution in factory

Automatic Tuning Technique for Sensorless PMSM Drive

In recent years, highly efficient permanent magnet synchronous motors (PMSMs) have come into widespread use in a large number of applications including home appliances and industrial equipment. In addition, since sensors are required to detect the rotor position in a PMSM, the demand for position sensorless control is increasing.

In order to achieve sensorless control of a PMSM, it is necessary to set motor parameters such as the stator resistance and inductance and to tune the current, speed, and sensorless control gains. However, conventional methods have two problems. First, specialist knowledge and extensive experience of motor control are required to measure the motor parameters and tune the control gains. The second problem is the lead time necessary for measurement and tuning.

To address these problems, Toshiba Corporation has automated the measurement and tuning processes by calculating the motor parameters and gains from the current, voltage, and rotational speed of the PMSM. Sensorless control based on automatically tuned parameters provides robustness and arbitrary responsiveness, thus realizing a stable PMSM drive. The automatic tuning technique was realized using a microcontroller of Toshiba Electronic Devices & Storage Corporation specifically designed for motor control.



Flow of processes for automatically tuning parameters of PMSM

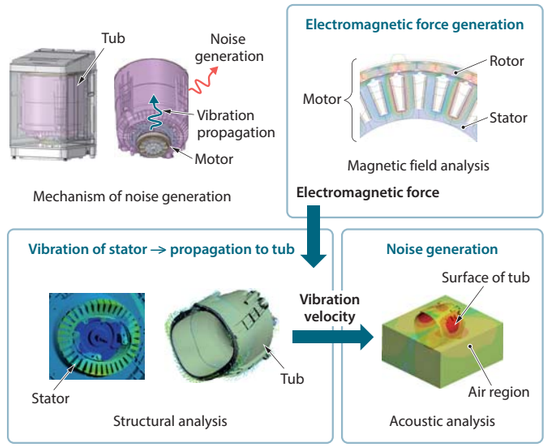
Technology for Analysis of Noise from Electromagnetic Force Generated in Motor

Toshiba Corporation has developed a technology to predict noise from the electromagnetic force generated in a motor using magnetic-structural-acoustic coupled analysis.

A motor consists of a rotor and a stator. The electromagnetic force generated in the motor vibrates the stator. The vibration propagates to the structural parts, generating noise. By understanding the excited vibration mode, it is possible to optimize the structure of parts. The analysis results are output at the sound pressure and sound power levels and can be directly compared with actual measurements.

We applied this technique to analysis of the noise generated by a top-loading washing machine. The electromagnetic force generated in the motor of the washing machine propagated to structures such as mechanical parts and the tub, and the vibrations on the surfaces of these structures then radiated to the ambient air as sound.

Our next step is to analyze and evaluate noise at an early stage of the product design process and optimize the product design to reduce noise. In addition, the newly developed technique will contribute to reductions in product development costs by decreasing the number of prototypes and design iterations required.



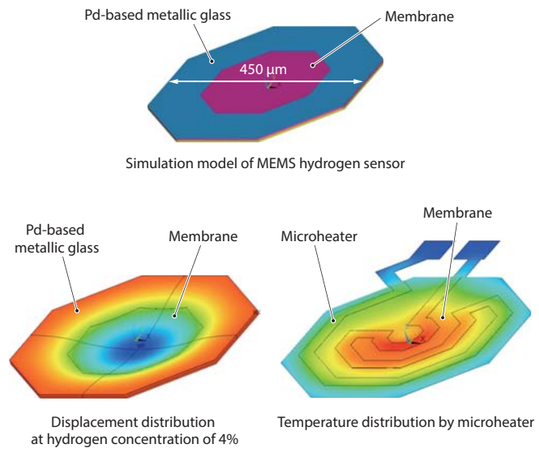
Flow of magnetic-structural-acoustic coupled analysis to predict noise from electromagnetic force generated in motor of top-loading washing machines

Structural and Heat Transfer Simulation Technology for MEMS Sensors

To facilitate the design of MEMS sensors, Toshiba Corporation has developed a structural and heat transfer simulation technology for estimating their performance and reliability.

MEMS hydrogen sensors are capable of achieving high-speed response and low power consumption. We modeled the relationship between the hydrogen occlusion and volume expansion of the palladium (Pd)-based metallic glass sensing membrane of a MEMS hydrogen sensor. This model makes it possible to estimate changes in the capacitance (responsiveness) of the sensor with respect to hydrogen concentration. In addition, the newly developed thermal simulation technology can estimate the film temperature distribution and power consumption achieved by the intermittently driven microheater that is used to reduce the effect of humidity.

We will apply this technology to the design of inertia, acoustic, and other MEMS sensors that are required in large quantities for IoT applications. The new technology will help to improve their performance and shorten their development time.



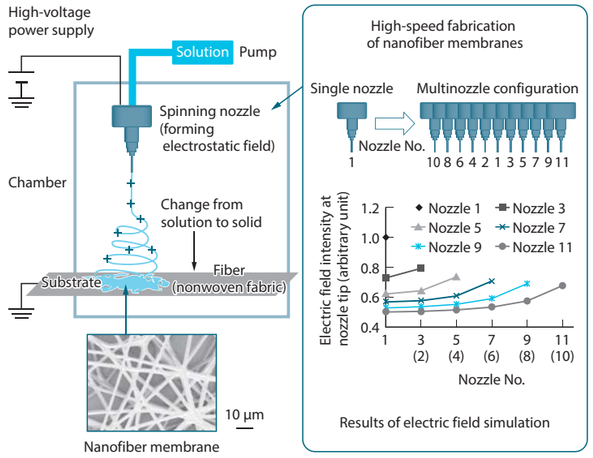
Estimation of MEMS hydrogen sensor performance by means of structural and heat transfer simulations

Multinozzle Electrospinning Method for High-Speed Fabrication of Nanofiber Membranes

Electrospinning is a fiber production method for producing nonwoven fabrics consisting of nanofibers. When a high voltage is applied to a spinning nozzle filled with polymer solution, the charged polymer solution is drawn out from the nozzle by electrostatic force and transformed into fibers through volatilization of the solvent, forming nanofiber membranes on a substrate.

For industrial applications, there is a need to increase the amount of raw material supplied per unit time in order to achieve high-speed fabrication of nanofiber membranes. Since there is a limit to the amount of raw material that can be supplied per nozzle, it is important to increase the number of nozzles.

To create a multinozzle head, it is necessary to determine the shape and arrangement of the nozzles while taking into consideration the electric field interference among nozzles that occurs when a high voltage is applied. Based on the results of electric field simulations, Toshiba Corporation realized a multinozzle head that is capable of suppressing nozzle-to-nozzle differences in the intensity of the generated electric field. This multinozzle head makes it possible to fabricate nanofiber membranes at high speed with electrospinning.



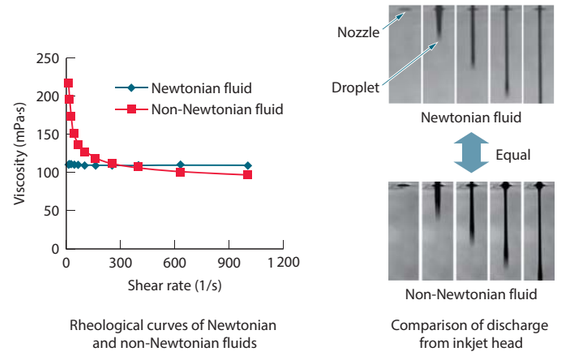
Multinozzle electrospinning method for high-speed fabrication of nanofiber membranes

Application of Inkjet Technology to Non-Newtonian Fluid Ejection

Inkjet printing, which has higher material utilization efficiency than screen printing and other methods, is widely used for industrial applications including the printing of advertisements and the manufacturing of building materials, ornaments, and electronic devices. This technology has a constraint on the viscosity of coating materials used. Generally, inkjet printers use Newtonian fluids with a viscosity of 10 to 20 mPa·s that are not affected by shear stress.

However, most coating materials have high viscosity, and the viscosity of many non-Newtonian fluids is affected by shear stress. It is therefore difficult to eject coating materials from ordinary inkjet heads.

To address this problem, Toshiba Corporation performed fluid analyses to clarify differences in ejection between non-Newtonian and Newtonian fluids. Based on the analysis results, we optimized the flow path structure and driving conditions of an inkjet head so that it can accommodate both Newtonian and non-Newtonian fluids. This improved inkjet head will further expand the range of inkjet applications.



Comparison of discharge from inkjet head in case of Newtonian and non-Newtonian fluid ejection

Deposition Process for Copper and Aluminum in 3D Metal Printing

Toshiba Corporation has developed a deposition process for copper and aluminum alloys for three-dimensional (3D) printing based on laser metal deposition (LMD) technology.

To achieve practical use of 3D metal printers, it is crucial to demonstrate successful deposition of various metals. Copper and aluminum, which are used as materials for heat sinks, require a high-power laser since they absorb only a small fraction of laser energy. It is difficult to use laser sintering for these materials in conventional powder bed 3D printers because a high-power laser spatters the material powder. In LMD, however, a powder nozzle supplies metal powder to the focus of the laser beam using a carrier gas, enabling high-power laser sintering and deposition.

With this as a background, we optimized the deposition process of a prototype 3D printer equipped with a 6 kW laser and successfully deposited parts using pure copper and pure aluminum. These deposited parts exhibited almost the same tensile strength as bulk parts.

This work was supported by the Technology Research Association for Future Additive Manufacturing (TRAFAM).

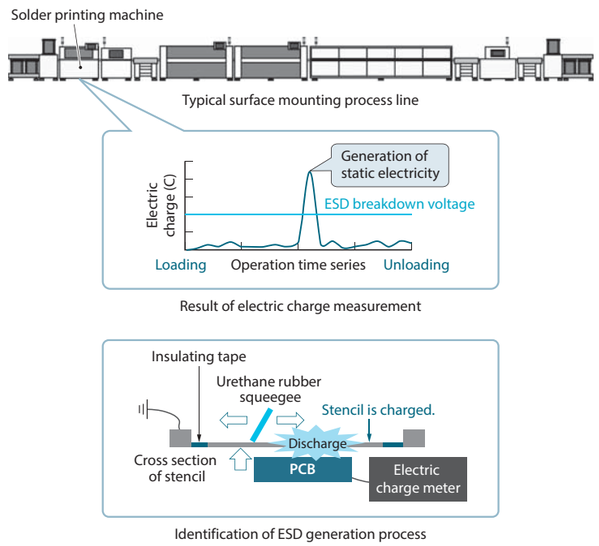
Prototype 3D metal printer and samples made of copper and aluminum, respectively

Development of Static Electricity Measurement Technology for PCB Assembly Process

Due to the ongoing shrinkage of wire width and spacing, the electrostatic discharge (ESD) breakdown voltage of semiconductor devices is decreasing. Semiconductor devices damaged by ESD contribute to in-process defects even in the PCB assembly process as well as market defects. However, it is difficult to identify where in the PCB assembly process an ESD event occurs using the conventional method, particular inside machines.

In order to solve this problem, Toshiba Corporation has developed a new method for measuring the amount of electric charge on a specific PCB trace. This method can easily identify where an ESD event occurs, even inside operating machines.

Consequently, we have significantly reduced the time required for defect analysis and the cost of improvements. In addition, the new method helps to maintain stable in-process quality.



Example of result of static electricity measurement in PCB assembly process

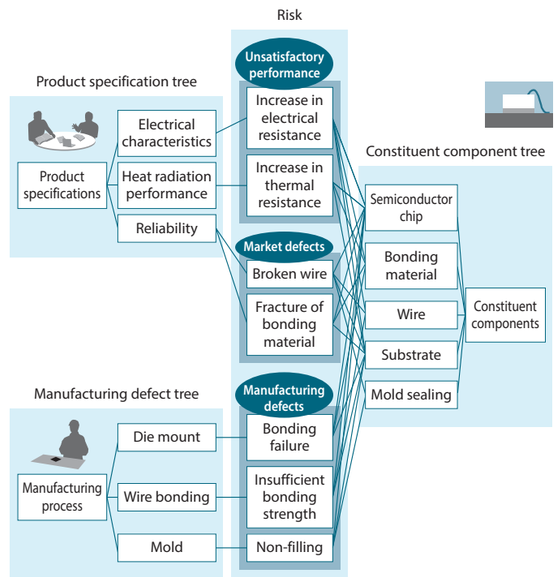
Technology to Extract Risks in Product Development Processes

Toshiba Corporation has developed a technology to exhaustively extract all risks that could hinder the realization of products required by the market at the initial phase of development.

For product realization, it is necessary to simultaneously satisfy performance, reliability, and manufacturability requirements. As a consequence of the trend toward more sophisticated and complex products in recent years, however, risks that could hamper efforts to meet all of these requirements are increasing. For example, improving performance may degrade reliability and manufacturability. It is therefore important to exhaustively extract risks incurred by design changes and verify them.

To address this need, we have created a technology breakdown tree that visually represents the relationships among product specifications, manufacturing processes, constituent components, and risks in order to obtain an overview of the entire product. The technology breakdown tree simplifies the extraction of all risks that may be incurred by design changes. For example, changing the bonding material of a semiconductor device may result in an increase in electrical or thermal resistance, a fracture of the bonding material, or a bonding failure.

We have applied this technology to the development of semiconductor products and will expand its application to other products.

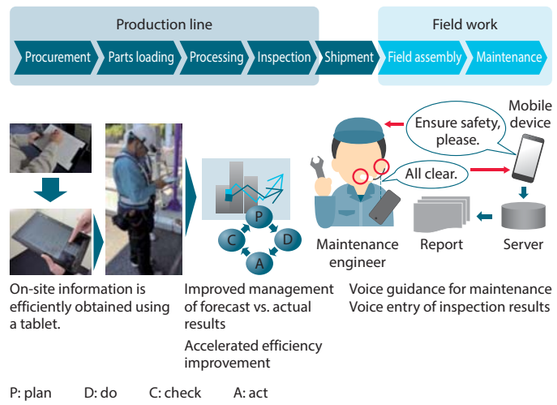


Technology breakdown tree to extract development risks in product design phase

Improvement of Productivity of Field Work for Social Infrastructure Products

Industrial engineering (IE) technologies were developed to improve the productivity of assembly work on factory production lines. Toshiba Corporation is now using IE technologies for field assembly of social infrastructure products. We are developing and implementing tablet-based tools that are effective for the management of field work.

For field assembly, we utilize a tablet to efficiently obtain on-site data, including the actual work hours required to complete field work and the progress of construction. Furthermore, these data are analyzed using an IE technique to identify and correct problems. The effects of corrective actions are quantitively measured so as to be iterated through the plan-do-check-act (PDCA) cycle. To expand the application of this tool to maintenance and inspection work, we are also developing voice guidance and voice input functions. We have already tested these functions, working toward practical use. We will continue to utilize IE technologies and tools that are effective in improving the productivity of field and maintenance work.



Improvement of productivity through application of IE technologies to field work

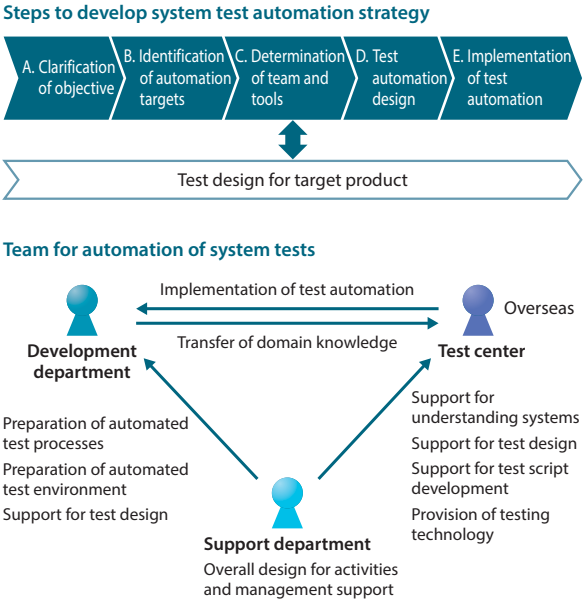
System Test Automation Techniques

In addition to the development of new software for incorporation into various products, the development of derivative software is increasing in the Toshiba Group. This approach is effective for the renovation of existing software. However, a large number of test cases need to be examined in order to assure the quality of derivative software prior to incorporation into a new product. This makes it difficult to reduce work hours required for testing and test periods.

The Toshiba Group has been implementing a broad array of measures to rectify this situation through the development and introduction of system test automation techniques, as follows:

- preparation of guidelines for the introduction and promotion of test automation
- development of test automation processes
- organization of a test automation team utilizing overseas resources
- maintenance of a unified management environment for test specifications and test scripts
- development of techniques for generating easy-to-maintain test scripts.

We have conducted simulation experiments applying these techniques to a large-scale social infrastructure system and confirmed that they deliver a 30% reduction in the test costs of subsequent system models and a 40% reduction in initial introduction costs.



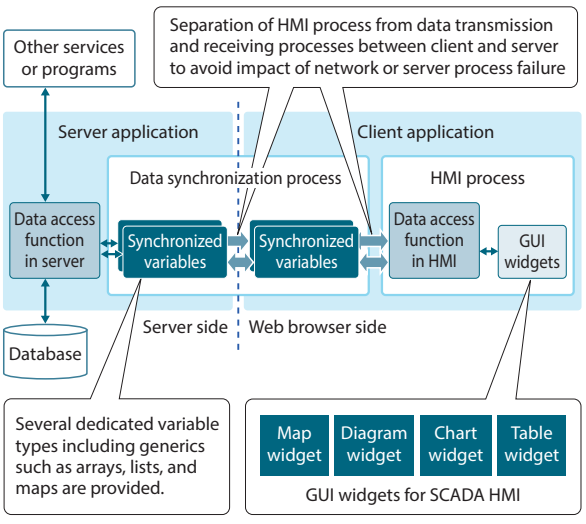
Strategy formulation steps and team for automation of system tests

DAFW Web Application Development Framework for SCADA Systems

Web technology is useful in developing a human-machine interface (HMI) for supervisory control and data acquisition (SCADA) systems so as to ensure compatibility across various types of devices such as PCs and tablets. The HMI for SCADA systems should remain in operation even in the event of a network or server process failure. However, this is generally infeasible because the HMIs of typical Web applications directly access a server to obtain data.

To solve this problem, Toshiba Corporation has developed DAFW, a Web application development framework specifically designed for SCADA systems. In DAFW, a Web browser keeps a copy of the up-to-date data on the server. This is accomplished by a data synchronization function, which establishes consistency among data from the server to the Web browser and vice versa. The HMI process can therefore be separated from the data synchronization process so that a network or server process failure will not directly affect HMI operation.

Data synchronization provides several dedicated variable types including generics such as arrays, lists, and maps to make predefined data types available. In addition, DAFW provides diagram, chart, and other Web-based graphical user interface (GUI) widgets so that the developer can easily create SCADA HMIs in Web browsers.



Architecture of DAFW Web application development framework for SCADA systems

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