## Artificial Photosynthesis Technology for Generation of Fuel and Feedstock from Carbon Dioxide

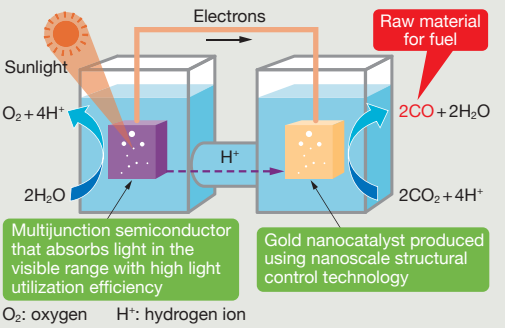
Attention is focused on renewable energy sources in response to the increasing concentration of carbon dioxide ($CO_2$) in the atmosphere, considered to be one of the causes of global warming, as well as concerns over the depletion of fossil fuel resources.

Artificial photosynthesis, a process that converts sunlight, $CO_2$, and water into carbohydrates, is expected to provide one of the solutions to this issue.

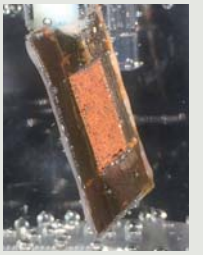
Toshiba has developed an artificial photosynthesis technology with a conversion efficiency(*) of 1.5%. This technology employs sunlight to produce carbon monoxide (CO), which is used for methanol synthesis.

The long-term goal of our research is to develop a technology compatible with $CO_2$ capture systems installed at thermal power plants, factories, and other sites. The purpose of such a technology is to convert $CO_2$ into a form of energy that can be stored and transported. To realize this goal, we will further enhance the level of catalytic activity and thereby improve conversion efficiency. Our aim is to achieve practical implementation in the 2020s.

(*) The efficiency at which sunlight energy is used to convert $CO_2$ and water into carbohydrates that are viable as a chemical feedstock or fuel




Mechanism of artificial photosynthesis technology



Photograph of CO generation by gold nanocatalyst

## World's Largest Total Key Size Achieved in Field Trial of Quantum Key Distribution

Working toward practical use of quantum key distribution (QKD) technology, Toshiba has conducted two field trials using installed optical fiber in Japan and the United Kingdom. QKD guarantees secure communication and prevents data leakage from transmission lines.

In Japan, we deployed the Toshiba QKD system to experiment with continuous key distribution over a 45 km fiber link between Koganei and Otemachi in Tokyo. Stable operation was achieved for 34 consecutive days. Due to the use of our latest active stabilization technology, a total key size of 878 Gbits was distributed at an average secure key rate of approximately 300 kbits per second (kbit/s). This is the largest total key size ever distributed in the world(*).

The other field trial was conducted in the UK using the Toshiba QKD system adapted for single-fiber operation. Toshiba Research Europe Ltd. successfully performed fast communications through a single fiber using wavelength-multiplexed data signals and weak photon signals. Field trial tests were carried out at the laboratories of BT plc near Ipswich, and quantum keys were exchanged over 26 km of installed fiber.

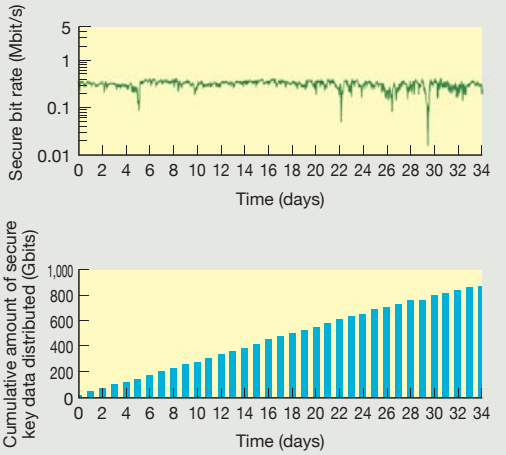
In one test, four co-propagating 10 Gbit/s data channels were wavelength-multiplexed with QKD signals carrying encoded encryption keys, and an average secure key rate of 160 kbit/s was achieved over a 12-hour period.

In another test, bidirectional 10 Gbit/s traffic was multiplexed with QKD signals, and an average secure key rate of 110 kbit/s was realized over a 12-hour period.

The field trial in Tokyo was partially implemented as commissioned research for the National Institute of Information and Communications Technology (NICT), Japan.

(*) As of September 2014 (as researched by Toshiba)

Quantum encryption key data distribution system



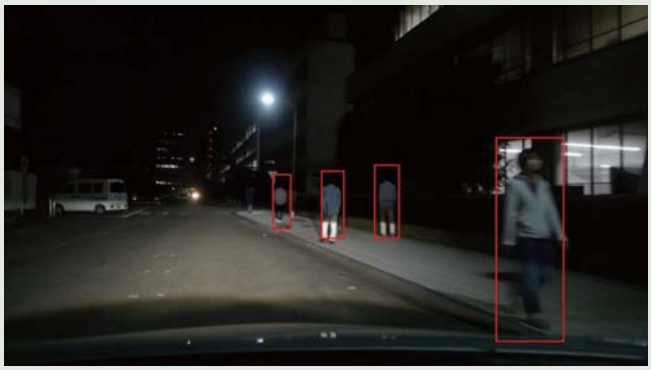

Results of field trial in Japan

## TMPV760 Series Image Recognition Processors Incorporating Advanced Image Recognition Technology for Driver Assistance Systems

Toshiba has developed an advanced image recognition technology for the TMPV760 series of image recognition processors designed for leading-edge driver assistance applications. The new series provides improved performance for nighttime pedestrian detection as well as the ability to detect stationary obstacles on the road with a monocular camera.

Many advanced driver assistance systems detect vehicles and pedestrians from camera images using pattern recognition techniques and utilize the detection results for autonomous emergency braking. To maintain the detection performance even at night, the new series employs novel feature descriptors based on color information.

Various types of obstacles exist on roads, making it difficult to detect all obstacles using pattern recognition that requires learning procedures for previously unknown patterns. In order to improve obstacle detection, we have adopted a three-dimensional (3D) reconstruction technique that infers 3D structures from monocular images to detect arbitrary objects.



Detection of pedestrians at night

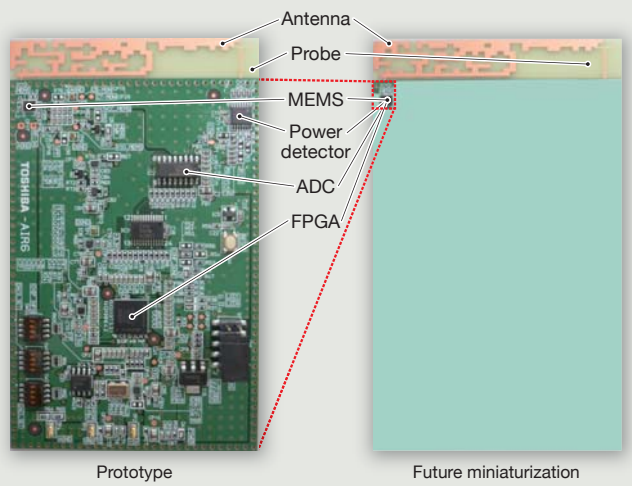

Detection of road obstacles using 3D reconstruction

## Automatic Tunable Antenna for Smartphones

The antenna efficiency of the transceiver in smartphones is often affected by approaching objects such as the user's hand. This can degrade the receiver sensitivity and increase the input power required for the transmitter.

To address this issue, Toshiba has developed an automatic tunable antenna that maintains optimal performance even in the presence of approaching objects. The new antenna has the same physical size as a conventional type. A field-programmable gate array (FPGA) controls the microelectromechanical system (MEMS) variable capacitors connecting the antenna and the transceiver so that the transmit power detected by a probe near the antenna is at its maximum level. This makes it possible to optimize the antenna efficiency by tracking changes in the surrounding environment.

Our next step is to develop a small integrated circuit (IC) incorporating these functions for smartphone and other compact wireless applications.




ADC: analog-to-digital converter

Prototype and future miniaturization of automatic tunable antenna

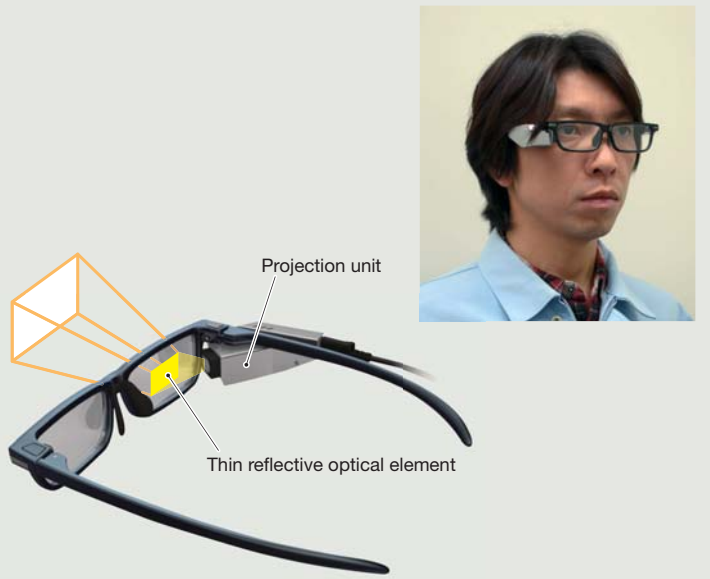
## Eyeglasses-Type Wearable Device

Toshiba has developed an eye-friendly, easy-to-wear eyeglasses-type wearable device that projects digital images into the wearer's field of vision.

Because of the aging of social infrastructure and the increasing sophistication of equipment, the volume and complexity of maintenance and inspection work have been increasing in recent years. The hands-free wearable device has been designed to improve worker productivity by providing visual guidance for work procedures, even when both hands are occupied.

In order to realize an eyeglasses-type wearable device, we developed a thin reflective optical element that reflects the images transmitted by a projection unit onto the wearer's eyes at a precisely calculated angle. The optical element is virtually transparent, giving the wearer a secondary display while maintaining clear visibility and keeping the hands free. Furthermore, by partnering with a company that specializes in optics, we were able to make the device light and comfortable with a weight of only 42 g excluding the cable, to minimize the wearer's fatigue when worn for extended periods of time.

The device is targeted mainly at enterprise applications in various fields such as logistics, manufacturing, medicine and healthcare, maintenance and inspection, and so on.



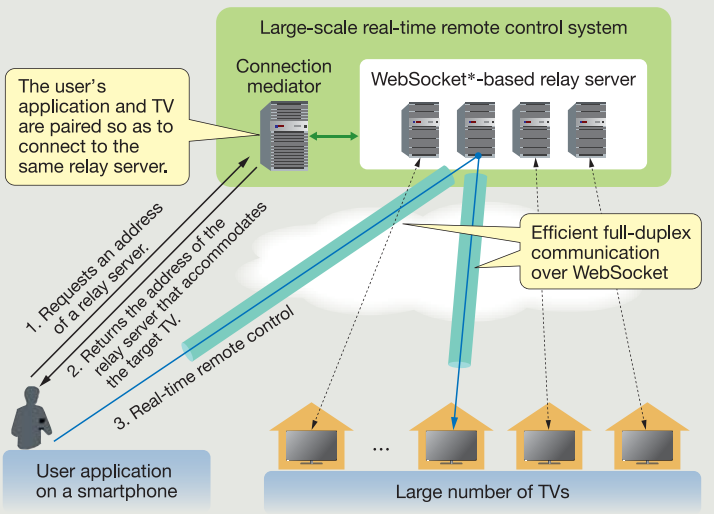

Eyeglasses-type wearable device

## Large-Scale Real-Time Remote Control System for Toshiba Cloud TVs

Toshiba has developed a large-scale real-time remote control system for the L64, L74, and M74 series of Toshiba cloud TVs. This remote control system allows users to program TV recordings and support center staff to quickly diagnose users' TVs from a remote site.

In order to ensure TV accessibility in various network environments, it is necessary for a remote control system to maintain long-lived connections with TVs. However, since a single relay server can accommodate only a limited number of connections, multiple servers are necessary to handle numerous TVs. It is also difficult to accommodate an increasing number of TVs without compromising the control latency.

To address these requirements, we have developed a novel system architecture incorporating a new device called a connection mediator, in which a TV and a user's application on a smartphone are paired so as to connect to the same relay server. The remote control system based on this architecture provides high scalability, guaranteeing one-hop forwarding. This makes low-latency communication possible even when a system consists of many relay servers to accommodate a large number of TVs.



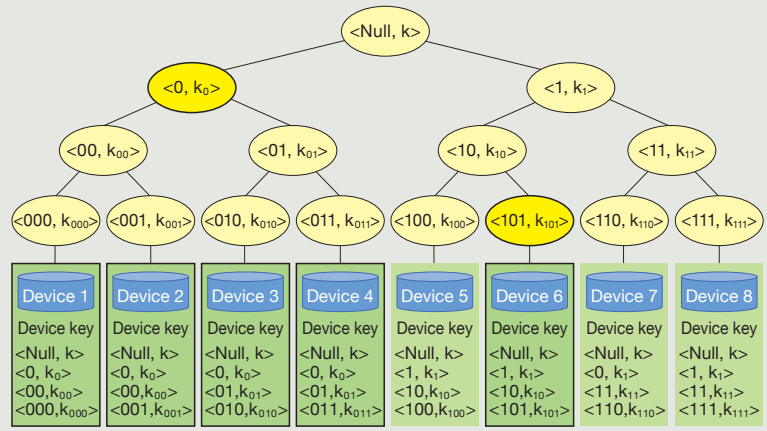

*A standardized protocol for full-duplex communications on the Internet

Architecture of large-scale real-time remote control system for cloud TVs in European market to connect users' applications with their TV using same server

## IEEE 802.21d Standardization for Security of Multicast Communications

Toshiba Corporation and Landis+Gyr AG have played a key role in the Institute of Electrical and Electronics Engineers (IEEE) 802.21d Task Group to standardize a security mechanism for multicast communications. The IEEE 802.21d standard document will be published within 2015.

With the diffusion of the Internet of Things (IoT), devices are becoming increasingly interconnected and controlled via networks. Multicast communication is an efficient means of controlling a huge number of devices where the same control information is addressed to a group of destination devices simultaneously. However, in order to implement multicast communication, it is necessary to improve data security to protect control information.




∗1: <Index, Key> is assigned to each node in the management tree.
∗2: Distribution of a group key to a group to which Devices 1, 2, 3, 4, and 6 belong. The group key is encrypted by Key $k_0$ and Key $k_{101}$, respectively.

Example of management tree for eight devices

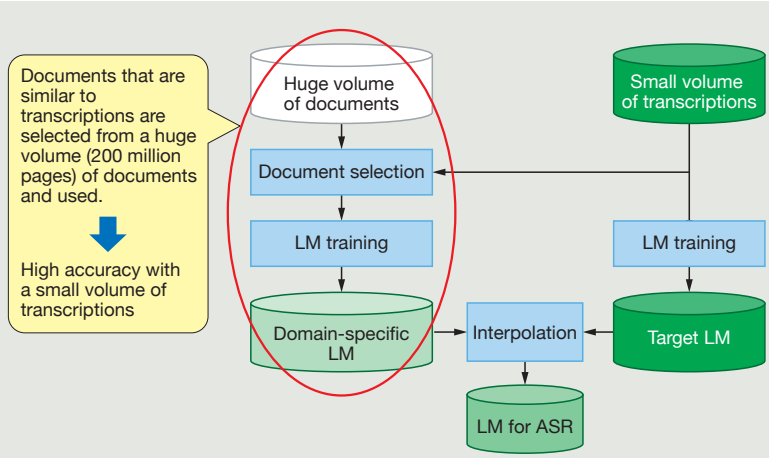
IEEE 802.21d uses a group key and a digital signature to protect data payloads of multicast packets. To preserve confidentiality, data payloads are encrypted using a group key that is known to the members of the relevant group, and the identity of the sender of the payload is authenticated by a digital signature.

Group management is important for flexible and scalable multicast communication. The group key block (GKB) defined in IEEE 802.21d allows scalable group key management using a management tree. In this scheme, management trees can be scaled from the level of small home area networks consisting of several dozen devices managed by a few groups to large smart metering systems consisting of several tens of millions of devices managed by several tens of thousands of groups.

## Automatic Speech Recognition for Contact Center Solution

Toshiba has developed an automatic speech recognition (ASR) system for contact center applications that transcribe spoken words to text.

In order to achieve a sufficiently high recognition accuracy to be able to understand the content of conversations from the recognition results, ASR language models (LMs) must be customized according to the needs of each contact center. Previously, in order to customize LMs, we had to manually transcribe approximately 100 hours of speech recorded at each contact center, incurring extremely high costs.




Domain-specific language modeling technology for telephone speech recognition

To solve this problem, we have developed a domain-specific language modeling technology to search a huge volume of documents gathered from websites and select those similar to transcriptions. The selected documents are utilized to train the LMs. Consequently, we have achieved a character accuracy exceeding 85% with only 20 hours of transcription, thus reducing customization costs for practical ASR systems to one-fifth.

This technology is incorporated in the T-SQUAREx customer relationship management (CRM) solution. It is also utilized for interactive voice search available with the REGZA Z10X series of liquid crystal display (LCD) TVs to allow viewers to find desired programs quickly.

## Low-Power STT-MRAM for Cache Memory Applications

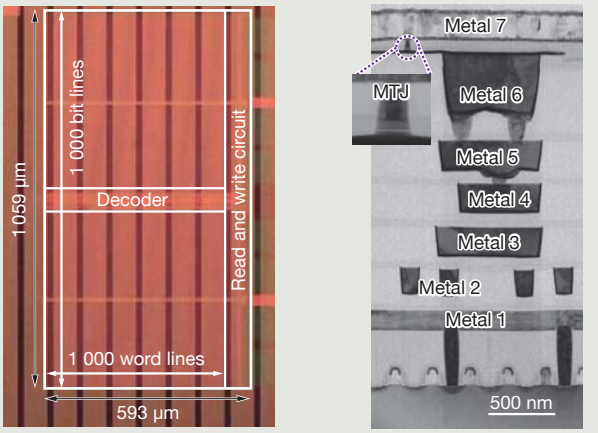
The spin-transfer torque magnetoresistive random-access memory (STT-MRAM) is a fast and low-power nonvolatile memory that utilizes changes in electrical resistance caused by magnetization. STT-MRAM is expected to be used for cache memory applications to reduce the power consumption of mobile devices.

Toshiba has developed magnetic tunneling junction (MTJ) devices with low switching power, as well as a process technology to integrate them in advanced logic ICs.

Previously, a special manufacturing process was necessary to prevent the degradation of MTJ characteristics due to the thermal process of complementary metal-oxide semiconductor (CMOS) fabrication. To overcome this problem, we developed the "MTJ-last" process in which the MTJ is formed on the upper metal layer so that it is followed only by a low-temperature process.

Test chips fabricated using a 65 nm process achieved a 60% reduction in power consumption compared with static RAM (SRAM), which requires a constant power supply for operation.

This work was partly supported under the Normally-Off Computing Project of the New Energy and Industrial Technology Development Organization (NEDO).



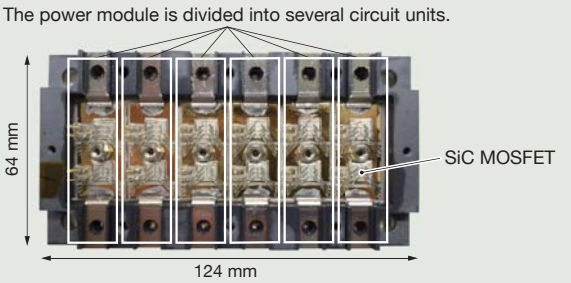

Chip and cross-sectional transmission electron microscope (TEM) image of STT-MRAM fabricated by newly developed MTJ-last process

## Low-Inductance All-SiC Module

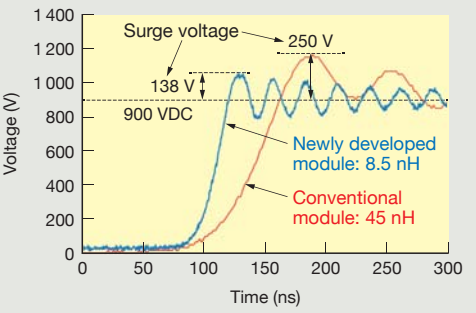
Silicon carbide (SiC) devices are a focus of expectations as indispensable next-generation power devices for the realization of high-efficiency, compact, and lightweight power converters. One of the advantages of SiC power devices is their high switching speed, resulting in lower switching losses than conventional silicon devices. However, it is necessary to further reduce parasitic inductance in power converter circuits in order to increase the switching frequency.

To address this need, Toshiba has developed a power module with very low parasitic inductance by connecting its circuit building blocks in parallel. This structure reduces the parasitic inductance in accordance with the number of parallel-connected circuit building blocks.

The new 1 700 V-360 A all-SiC power module consists of SiC MOS field-effect transistors (MOSFETs) and SiC Schottky barrier diodes (SBDs), and exhibits a very low parasitic inductance of 8.5 nH, an 80% reduction compared with that of the conventional module. In addition, due to the combination of low surge voltage and high switching speed, the new all-SiC power module achieves a 60% reduction in switching loss.




1 700 V-360 A all-SiC module with low parasitic inductance (8.5 nH)



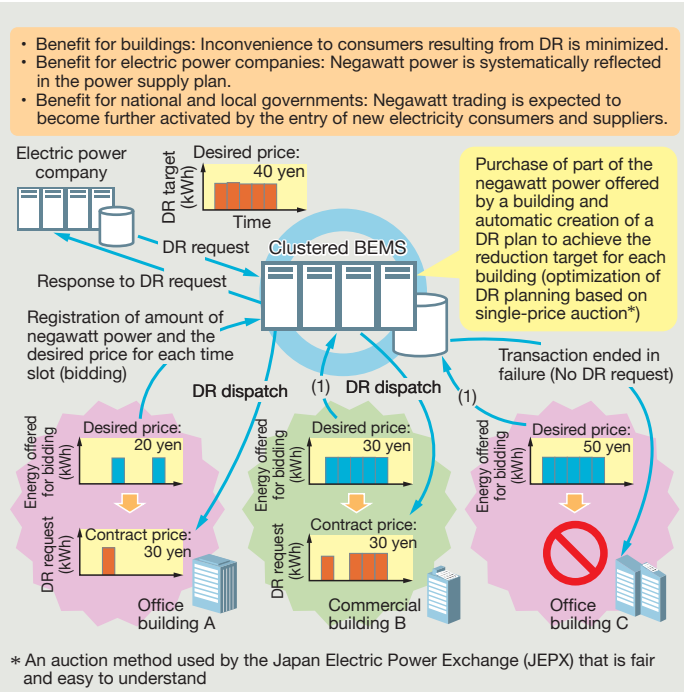

Drain-source voltage waveforms at turn-off of conventional and newly developed modules (circuit conditions: 900 VDC, 400 A load current)

## Dispatch Planning System for Commitment-Based Demand Response Program

Toshiba has developed a dispatch planning system for a commitment-based demand response (DR) program.

When the dispatch planning engine receives a DR request from an electric power company, it automatically plans a DR schedule based on the amount of negawatt power(*) and the desired price for each time slot that have been registered by the consumers in advance. Thus, the engine requests an appropriate demand reduction target for each consumer. The dispatch planning engine helps to eliminate instability in power reduction, which has been a problem with the conventional price-based DR program, and can be utilized in supply planning by electric power companies.

As a sub-project of the Yokohama Smart City Project (YSCP), a commitment-based DR experiment has been conducted using a clustered building energy management system (BEMS) for 10 consumers including buildings and factories. As a result, the necessary amount of incentive to achieve the target was reduced to around 60% compared with that for the price-based DR program, while realizing an average reduction rate of more than 90% with respect to the reduction target for each customer.




Outline of DR dispatch planning in YSCP

(*) Energy regarded as surplus by the supplier side as a result of customers' efforts to save, create, and store energy

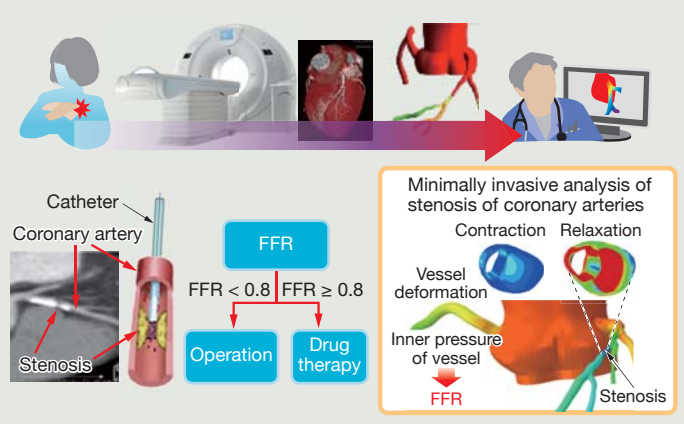
## Minimally Invasive Diagnosis of Coronary Stenosis Based on Structural and Fluid Analysis Using 4D-CT Image Tracking

Fractional flow reserve (FFR) is an index of the physiological significance of a coronary stenosis and is defined as the ratio of maximal blood flow through a stenotic artery to normal maximal flow. An FFR value of 0.80 is predictive of a coronary stenosis responsible for ischemia with an accuracy exceeding 90%.

By using computational blood flow simulation, a computed tomography (CT)-derived FFR (CT-FFR) can be computed from coronary computed tomographic angiography images with minimal invasion. In order to estimate CT-FFR accurately, it is important to take into account the effects of myocardial contraction and relaxation during the cardiac cycle, patient-specific boundary conditions for coronary artery outlets, and vessel stiffness.

Toshiba has developed a novel four-dimensional(*) (4D)-CT analysis method based on 4D-CT image tracking and structural and fluid analysis, in which the vessel deformation and volume variation data are used to identify analysis conditions such as boundary pressure conditions and stiffness of vessels. This method can estimate the CT-FFR, pressure, and flow rate under the identified analysis conditions.

Verification of this method has been carried out by comparing the 4D-CT-FFR analysis results derived from clinical 4D-CT datasets with invasive measurements of FFR and phantom experiments of flexible tubes with and without stenosis.




Minimally invasive analysis of stenosis of coronary arteries

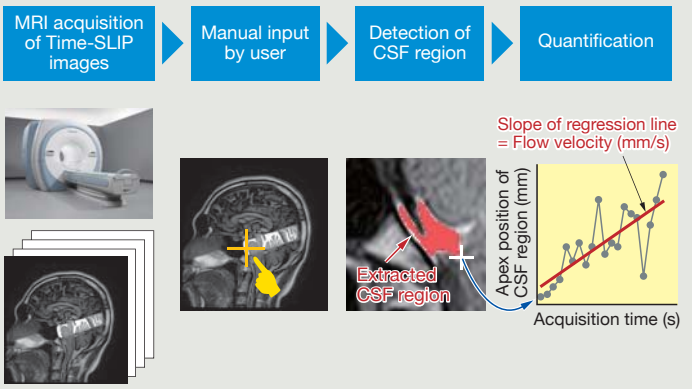
(*) In this field, "four-dimensional" refers to the three spatial axes and the time axis, to show movement.

## Automated Quantification Technology for Cerebrospinal Fluid Dynamics Based on Magnetic Resonance Image Analysis

Time-spatial labeling inversion pulse (Time-SLIP), which is a non-contrast-enhanced magnetic resonance imaging (MRI) technology for the visualization of blood flow and cerebrospinal fluid (CSF) dynamics, is used for diagnosis of neurological diseases related to CSF including idiopathic normal-pressure hydrocephalus (iNPH), one of the causes of dementia. However, physicians must subjectively evaluate the velocity of CSF dynamics through observation of Time-SLIP images because no quantification technique exists that can express the values numerically.

To address this issue, Toshiba has developed a novel automated quantification technology for CSF dynamics utilizing MR image analysis.

When a point in Time-SLIP images is specified to indicate the observation site, the CSF region is automatically obtained using a CSF existence probability map, which is calculated based on signal features such as the maximum signal intensity, standard deviation, and signal transition for each pixel. Subsequently, the CSF flow velocity is calculated using the slope of a regression line between the CSF position and its acquisition time.




Flow of CSF dynamics quantification method

The newly developed technology was validated by means of a water phantom study. Specifically, we confirmed a 0.99 correlation between actual and measured CSF flow velocities.

This technology is expected to improve the diagnosis of CSF-related diseases such as dementia caused by iNPH.

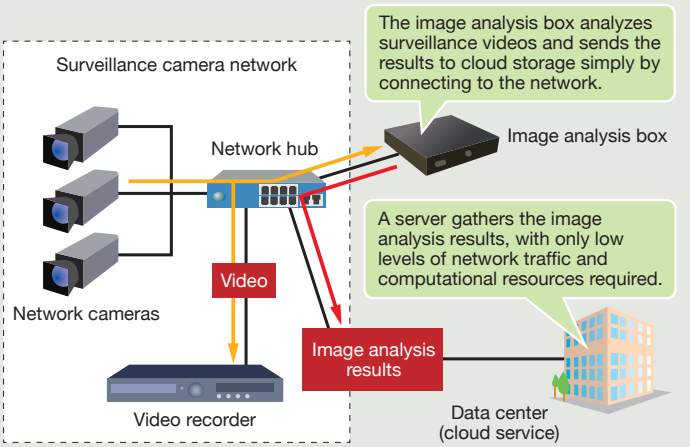
## Image Analysis Box for Intelligent Surveillance Camera Network

Toshiba has developed an image analysis box that analyzes the video images captured by surveillance cameras. The image analysis results can be sent to a storage server simply by connecting to the local area network on which the cameras reside.

The analysis results, which consist of items of information related to people that are observed by the cameras including their positions, can easily be sent to cloud storage via the Internet because the volume of the data is much smaller than that of the original video data.

The gathered information can be utilized for various systems related to human activities, including crime prevention systems for detecting intruders, and market analysis systems for estimating the age and gender of customers.

Since the image analysis function is implemented by software on the TMPV7506XBG image recognition processor, it can be tailored according to the specific application requirements.




Overview of surveillance system utilizing image analysis box

## Breath Analyzer Using Quantum Cascade Laser

Accompanying the increase in people's health consciousness together with escalating national medical expenditures, the importance of preventive healthcare is growing.

Against this background, Toshiba has developed a breath analyzer that provides simple and pain-free health examinations by measuring only a very small amount of breath. Exhaled breath contains more than 500 types of gas in trace amounts (in parts per billion (ppb) to parts per million (ppm) concentrations). Thus, when measured with high sensitivity, exhaled breath can be used to detect diseases and manage physical conditions.

Despite its compact tabletop size, the new breath analyzer provides sub-ppm sensitivity equivalent to the precision of a floor-standing mass spectrograph. This miniaturization has been achieved by using infrared quantum cascade laser (QCL)-based absorption spectroscopy. The new breath analyzer can detect acetone or acetaldehyde in exhaled breath at high speed (in approximately one minute).

Toshiba will collaborate with Waseda University and other external organizations to demonstrate the usability of this breath analyzer and commercialize it for proven applications in stages.


Breath analyzer using QCL-based absorption spectroscopy

## Electrolyzed Sulfuric Acid for Low-Cost Metal Removal Process in Semiconductor Manufacturing

To reduce the cost of manufacturing semiconductor devices, Toshiba has introduced the use of electrolyzed sulfuric acid solutions into the metal removal process.

Persulfuric acids such as peroxymonosulfuric and peroxydisulfuric acids are indispensable in the etching of metal films. Conventionally, persulfuric acid was produced by mixing sulfuric acid and hydrogen peroxide solutions. The main drawback of this process was the short lifetime of the chemical solution. This is because the reaction of a metal component with a hydrogen peroxide solution decomposes the hydrogen peroxide solution, decreasing the amount of persulfuric acid produced.

In contrast, electrolyzed sulfuric acid generation does not use a hydrogen peroxide solution. Instead, this method electrolyzes a sulfuric acid solution to generate persulfuric acid, making it possible to extend the lifetime of the chemical solution.

We have introduced this technology into the metal removal process at Yokkaichi Operations, Japan. The new technology will help to reduce the use of chemical liquids and cut manufacturing costs.

Electrolyzed sulfuric acid generating device introduced into metal etching process