Corporate Research and Development

The Toshiba Group, as a global enterprise, works on creating innovations to secure sustained growth with profit. The R&D Division is promoting the creation of new technologies such as a semiconductor LED that generates identical photons, enhancement of fundamental technologies and research & development contributing to current businesses.

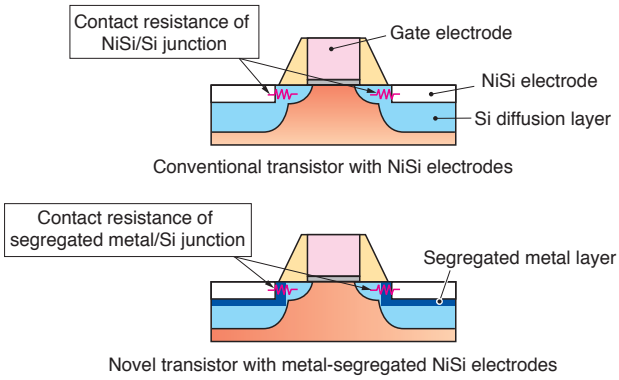
A Novel Source/Drain Silicide Technology for Next-Generation LSI

As transistors continue to be scaled down to improve performance, the contact resistance at the nickel silicide (NiSi)/silicon (Si) interface of the source/drain electrodes of Si transistors is expected to prevent further improvement in LSI performance in the near future.

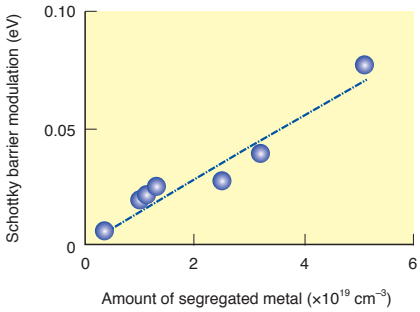
Toshiba has developed a novel silicide technology of segregating metals at the NiSi/Si interface, thus lowering contact resistance. The segregated metals lower the Schottky barrier height at the interface and reduce the contact resistance. Segregated metals suitable for nMOS and pMOS are selected respectively, while NiSi is used as the base electrode material for both types, which simplifies the nMOS and pMOS manufacturing processes and reduces cost.

The newly developed metal segregation technique will accelerate the development of 32-nm LSI generation and beyond.

Nickel silicide: Alloy of nickel and silicon
Schottky barrier: Energy barrier formed between metal and semiconductor
MOS: Metal-Oxide Semiconductor (field effect transistor)



Concept of metal segregation technique



Plots of Schottky barrier modulation vs. amount of segregated metal

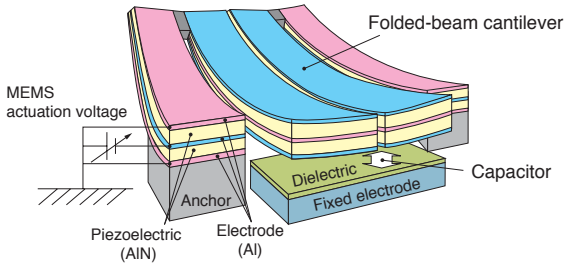
Piezoelectric MEMS Device with High Reliability for Wireless Communication Systems

Micro electro mechanical system (MEMS) devices which are fabricated by semiconductor processes and used to control electrical properties by mechanical actuation are expected to be critically important devices for novel RF circuits in wireless communication systems in view of their smaller volume and superior electrical properties.

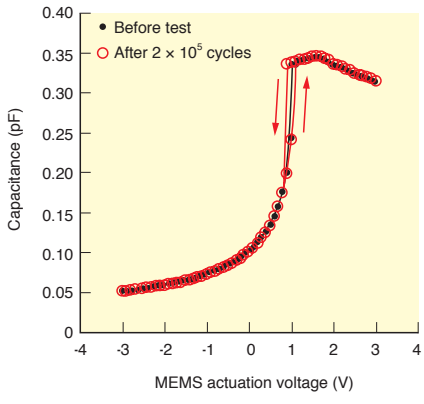
Toshiba has developed a folded-beam type tunable capacitor which features a novel design and enables capacitance tuning properties at a low operating voltage fabricated with piezoelectric aluminum nitride (AlN) thin films, whereas the reliability of electrical performance has been the most critical problem in the manufacture of commercial products.

Stable operation in piezoelectric tunable capacitors has been achieved in our recent research to improve the design and process techniques. The voltage dependence of capacitance values under cyclic performance tests showed no deviation even at 200 000 cycles, confirming the potential of MEMS capacitors for RF components in wireless communication systems.

RF: Radio Frequency



Schematic of folded-beam type piezoelectric tunable capacitor



Electrical properties of folded-beam type piezoelectric tunable capacitor before and after cyclic performance test

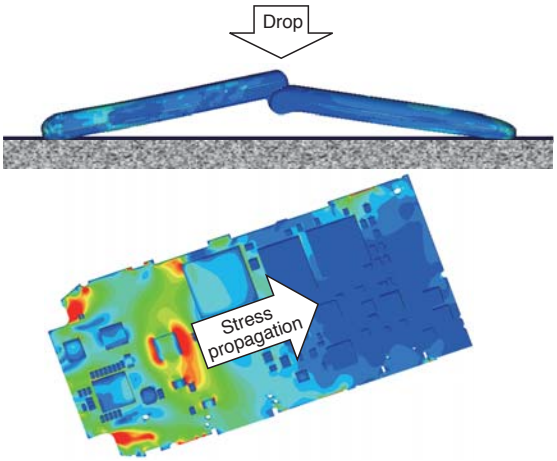
Advanced Structural Design Technology for Information and Telecommunication Products

The importance of structural design to ensure high reliability for information and telecommunication products is increasing. Design for impact durability has become essential as mobile products have become widespread.

Mobile products contain many parts assembled at high density, such as printed circuit boards, liquid crystal displays, and lithium ion batteries. On the other hand, mobile products have an intrinsic risk of being dropped on the ground or floor. If dropped, stress waves will be generated inside each part as the entire product deforms, which may cause severe damage and failure in these parts.

In usual reliability analysis with numerical simulation, detailed modeling can be performed only near particular evaluation points due to the computational load. However, it is desirable to apply detailed modeling to all parts in a mobile product in order to accurately assess complicated impact phenomena. Large-scale structural simulation may make such detailed modeling possible with the help of recent computer technologies. We incorporated the conventional reliability analysis method into a large-scale simulation and thus gained an overall picture of the physical process after the impact.

In this research, we chose a mobile phone as an example and demonstrated it is helpful for structural reliability design to figure out how transient stress waves run through all parts, as shown in the figure below.



Stress propagation running through a printed circuit board inside housing

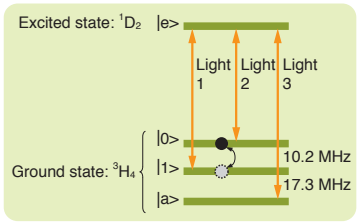
* This simulation was performed by using ADVC™, a commercial simulation code developed by Allied Engineering Corporation, on Blue Gene®/L in Watson Research Center, IBM Corporation.

"ADVC" is a trademark of Allied Engineering Corporation.
"Blue Gene" is a registered trademark of IBM Corporation.

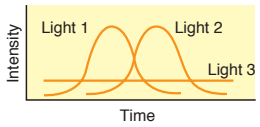
Stresses in mobile phone under drop impact (0.2 ms after drop impact)

Operation of a Single-Qubit Gate with a Solid-State EIT Medium

In quantum computation, information is represented by quantum bits (qubits), which are superpositions of quantum states. Quantum computers can efficiently solve problems that cannot actually be solved by conventional computers operating on existing principles. In order to develop quantum computers with solid-state components, materials with a long coherence time (quantum-state duration) and qubit operations that do not affect the quantum state are essential.



Energy states of Pr^{3+} and lights for gate operation

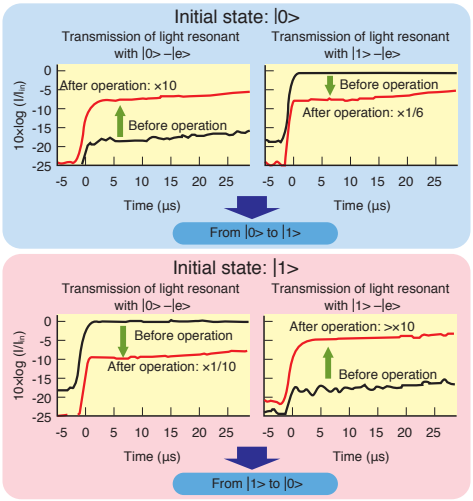


Time dependence of intensities of lights

Single-qubit-gate operation by adiabatic passage using three lights

Toshiba has succeeded in operating a single-qubit gate. It is equivalent to the NOT gate in conventional computers, by using the states of nuclear spins of Pr^{3+} (praseodymium ion) contained in a solid-state electromagnetically induced transparency (EIT) medium (Pr^{3+}: Y_2SiO_5), which have extremely long coherence time, as the quantum bits, and by applying a special operation method (adiabatic passage with three lights), which does not reduce the coherence time, to the qubits for the first time(*) .

The single-qubit gate constitutes a set of universal gates when combined with a two-qubit gate, which is a conditional gate between two qubits (equivalent to the AND gate in conventional computers). Toshiba aims to realize two-qubit gate operations that will lead to the development of scalable quantum computers using the coupling between qubits and a cavity mode.



I/I$_{in}$: Intensity of outgoing light/Intensity of incoming light

Change in the state by single-qubit-gate operation

(*) In January 2006, and the results were presented at academic conferences, in the press, etc.

High-Sensitivity Color CMOS Image Sensor

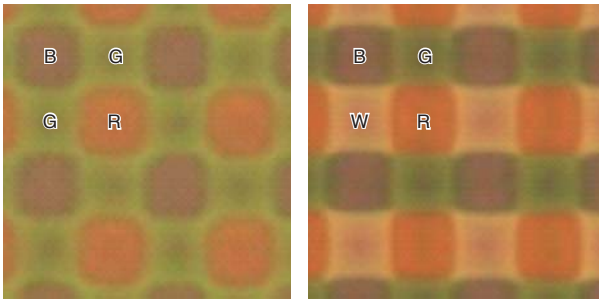
Toshiba has developed a high-sensitivity color CMOS image sensor with a new color film array (CFA) including novel “white pixels.”

CMOS image sensors are key components for mobile phones, digital still cameras, movie cameras, etc. With the rapid development of pixel shrinking technology for CMOS image sensors in recent years, degradation of sensitivity resulting from the required reduction in the photodiode area is becoming increasingly apparent and is the greatest challenge in developing CMOS sensors.

With the conventional color image sensor, on-chip color filters are fabricated on pixels, and the sensor detects red, green, and blue components to obtain color image data. Meanwhile, with the newly developed White-RGB CFA including white pixels, the white pixels without color filters result in high transmission in the entire visible light region.

High-sensitivity signals obtained by white pixels are separated into new RGB signals with a high signal-to-noise ratio, by referring to the color signals of surrounding pixels, thus significantly improving the sensitivity under low illumination conditions without degrading color reproducibility and resolution.

CMOS: Complementary Metal-Oxide Semiconductor



Optical microscopic images of conventional color filter array (left) and White-RGB color filter array (right)

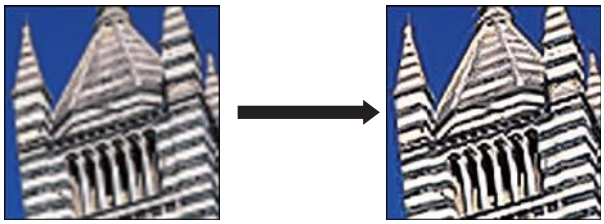
Conventional color filter array (left) and White-RGB color filter array (right)

Image Super-Resolution

Toshiba has developed a novel super-resolution technique for creating clear high-resolution still or video images from low-resolution ones.

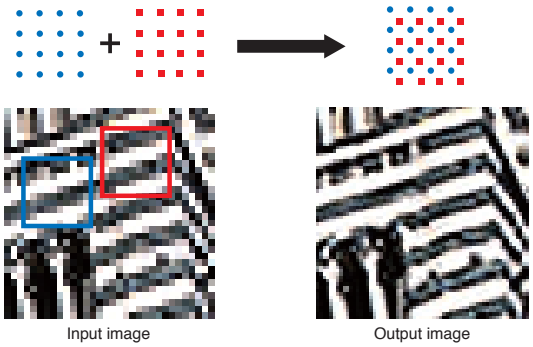
If part of an image is enlarged, the image quality degrades, and the image stays unclear even if smooth interpolation is performed between pixels (image on left, top).

The newly developed method finds patterns similar to each part of the input image, overlaps the patterns found, and increases the pixel density (images on bottom) to obtain a clearer image (image on right, top). The conventional techniques of improving image resolution use multiple images of the same object and require significant processing time. On the contrary, the new technique requires only one image and shorter processing time, making it suitable for real-time moving-image up-converting processes such as displaying conventional standard-size pictures on a high-definition television. The method, which is also applicable to a single image like a photograph, is expected to find a broad range of applications.



Conventional pixel interpolation — Developed method

Results of enlargement using interpolation and super-resolution technique



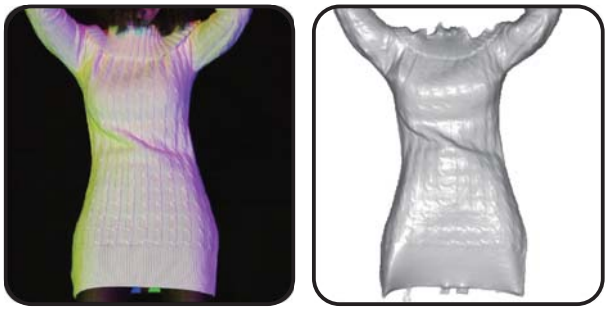
Input image — Output image

Newly developed method

Photometric Video for Deformable Object 3D Model

Toshiba has developed an algorithm and the associated capture methodology to acquire and track the detailed three-dimensional (3D) shape, bends, and wrinkles of deforming surfaces. Moving 3D data is the next milestone for 3D capture systems and its applications range from face capture in interactive computer games to cloth simulation in future online shopping and virtual dressing rooms. Until now, such moving 3D data has been extremely difficult to obtain by methods that rely on known surface features, structured light, or silhouettes. Multispectral photometric stereo is an attractive alternative because it can recover a dense normal field from an untextured surface. We show how to capture such data and register it over time to generate a single deforming surface. Experiments were performed on video sequences of untextured cloth, filmed under spatially separated red, green, and blue light sources.

The proposed technique for acquiring complex motion data from real moving cloth uses a practical setup that consists of an ordinary video camera and three colored light sources. The key observation is that in an environment where red, green, and blue light are emitted from different directions, a Lambertian surface will reflect each of those colors simultaneously without any mixing of the frequencies. The quantities of red, green and blue light reflected are a linear function of the surface normal direction. A color camera can measure these quantities, from which an estimate of the surface normal direction can be obtained.



One frame of video　　Reconstructed 3D model

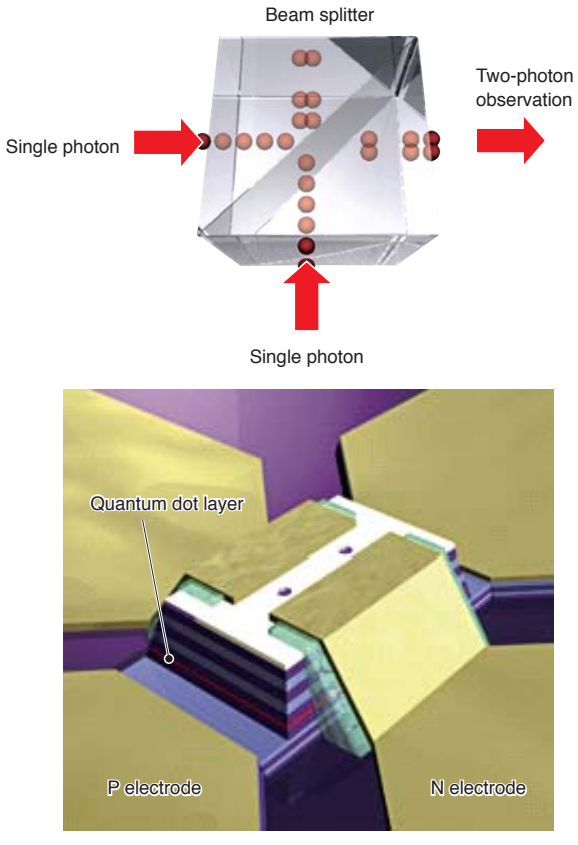
3D model of deforming sweater

Semiconductor LED Generates Identical Photons

Toshiba Research Europe in Cambridge (UK) has developed a semiconductor LED that emits single photons suitable for photonic quantum computing and long distance quantum communications. Our advance is to ensure the LED emits identical photons at an exact time, with a precise wavelength. We achieved this using a fast electrical pulse to control the emission energy of a single state within a semiconductor quantum dot in the LED.

Two-photon interference is successfully observed with photons from the LED. After firing two consecutive photons onto a 50% reflecting, 50% transmitting beamsplitter, the photons interfere and leave the splitter in the same direction. The fact that this effect can be observed with a small, robust and simple LED is promising for future quantum applications.

LED: Light Emitting Diode



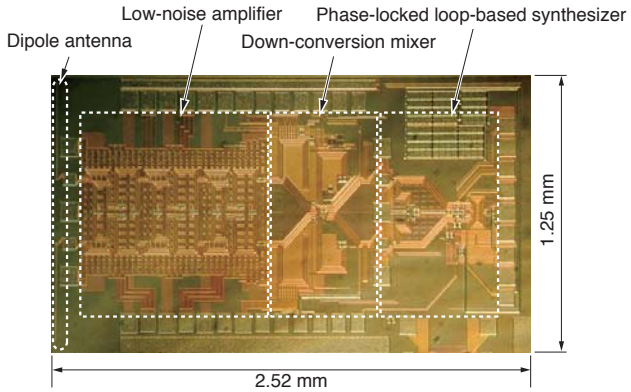
Beam splitter (top) and architecture of newly developed LED (bottom)

CMOS Receiver Front-end and Loop Antenna for Wireless Personal Area Networks in 60-GHz Band

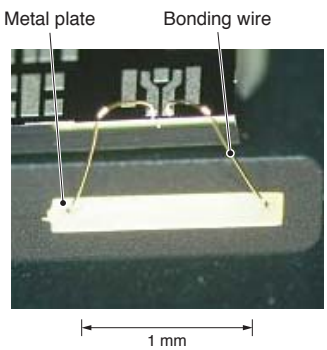
Toshiba has developed a receiver front-end chip adopting a 90-nm CMOS process for wireless personal area networks in the 60-GHz band.

The 1.25 mm× 2.52 mm chip integrates an on-chip dipole antenna, a low-noise amplifier, a down-conversion mixer and a phase-locked loop-based synthesizer. The fully-differential circuit configuration and optimized device structure as well as transmission-line structure have achieved stable receiving operations in the 60-GHz band.

A solid loop antenna built into an IC package has also been developed. This antenna connects each end of a wide metal plate mounted on the interposer in the IC package to one of the differential feed points on the IC chip, using two bonding wires. Since the metal plate requires no additional area in the conventional IC package, use of the loop antenna increases the gain by 5 dB to 8 dB without changing the size of the IC module compared with the case of using the on-chip dipole antenna.



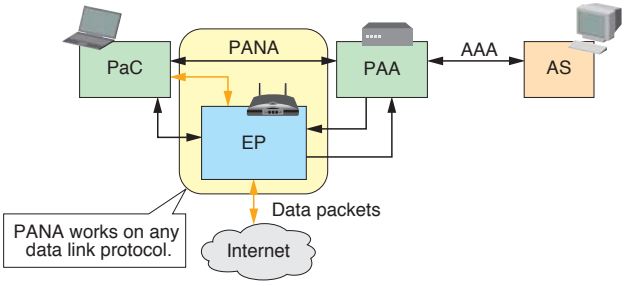
CMOS receiver IC for 60-GHz band



Bonding wire antenna

Protocol for Carrying Authentication for Network Access (PANA)

Toshiba has been taking the initiative in standardizing the Protocol for carrying Authentication for Network Access (PANA), a next-generation network access authentication protocol, whose specifications are available as a proposed standard request for comment (RFC) 5191. The PANA is designed to operate on arbitrary data link protocols, and has high expandability achieved by functionally separating the authentication agent and network access enforcement point, thus enabling secure network access control for various types of networks including corporate, public and residential networks. Toshiba will provide networking and mobile business solutions, capitalizing on the features of the PANA.



PaC : PANA Client
PAA : PANA Authentication Agent
AAA : Authentication, Authorization and Accounting
AS : Authentication Server
EP : Enforcement Point

Access network architecture based on PANA

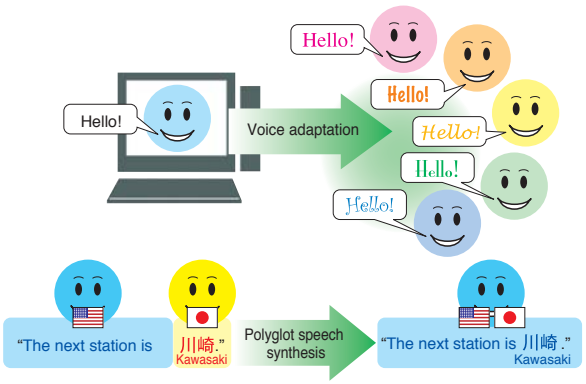
Technologies of Improving Multiplicity of Speech Synthesis

Toshiba has developed a voice adaptation technology and a polyglot speech synthesis technology for a high quality text-to-speech (TTS) system to increase the variation of speakers, speaking styles and languages.

In general, adding a new voice for a TTS system is a time-consuming and expensive process. The voice adaptation technology, which requires only a small amount of voice data from a new target speaker to approximate the synthetic voice of an existing speaker to that of the target speaker, allows TTS systems of various speakers to be developed in a short time and at low cost.

The polyglot speech synthesis technology can improve the quality of synthetic speech containing multiple languages in one text. It is difficult to generate fluent synthetic speech by the conventional method, which concatenates synthetic speech portions of each language. The newly developed technology can generate synthetic speech having the same voice quality, natural rhythm and intonation, regardless of the language.

We are now developing TTS middleware incorporating both technologies in order to expand the applications of our TTS system to a broad range of fields.



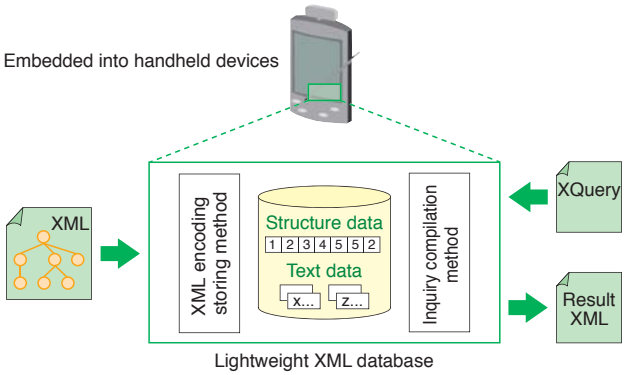
Voice adaptation technology and polyglot speech synthesis technology

Lightweight XML Database

There is a growing need for XML (eXtensible Markup Language) data management in small information appliances such as smart phones and handheld devices. In order to manage XML data in such devices, Toshiba has developed an embedded XML database management system (DBMS) with superior performance and low-resource consumption.

In low-resource environments, conventional XML databases offer poor performance in update and retrieval tasks. To overcome the problem, we have developed an XML encoding/storing method which encodes structure elements of XML data into a compressed one-dimensional array. This method decreases the structure data size to 1/50 or less. We have also developed an inquiry compilation method which translates a query written in XQuery language into efficient internal code.

Results of XML database benchmarking show that our system runs more than 10 times faster than conventional native XML databases under the conditions of a few Mbyte usage.



Conceptual outline of lightweight XML database

Novel Chemical-Reuse Environment-Conscious Semiconductor Resist Stripping Technology

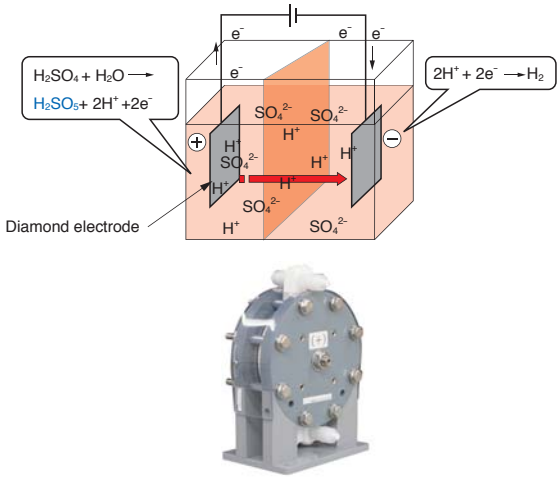
Toshiba has developed an electrolyzed sulfuric acid single-wafer resist-stripping system that will be integrated into the semiconductor manufacturing process in collaboration with Shibaura Mechatronics Corporation and Chlorine Engineers Corp., Ltd. This is the first time that electrolyzed sulfuric acid has been applied to the resist-stripping system for mass-operation.

Resist is a masking material used in the etching process for forming semiconductor circuit patterns. In the conventional approach, resist is stripped after etching with peroxymonosulfuric acid which is produced by mixing sulfuric acid with hydrogen peroxide solution. However, since hydrogen peroxide solution contains not less than 65 wt% of water, the sulfuric acid is diluted drastically, which makes it difficult to recycle the sulfuric acid.

The new technology using newly developed diamond electrodes allows generation of peroxymonosulfuric acid by electrolyzing sulfuric acid instead of adding hydrogen peroxide solution. This enables sulfuric acid to be recycled after stripping the resists. Furthermore, it is possible to control the oxidizing chemicals by optimizing the electrolysis parameters according to the properties of various resists.

From an environmental perspective, the electrolyzed sulfuric acid system not only allows recycled sulfuric acid to be used for other applications but also eliminates the energy required for producing hydrogen peroxide since our system does not employ hydrogen peroxide.

This system is now being evaluated using equipment which is ready for mass production at Toshiba's Yokkaichi Operations.



Novel method: Electrolysis of sulfuric acid

System for Debugging Equipment Control Software without Using Hardware

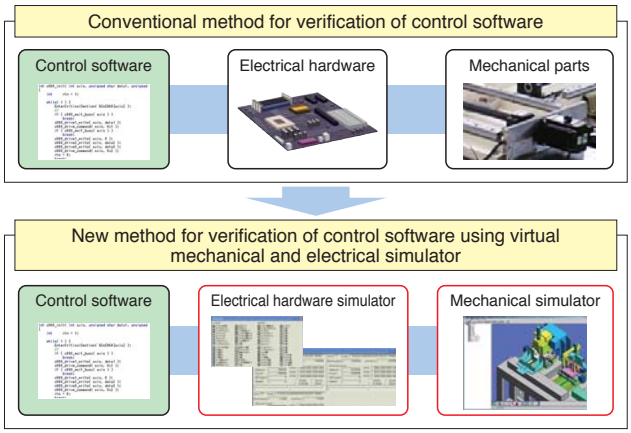
To launch a new product in the market quickly, it is necessary to develop manufacturing equipment in a short term. Toshiba has therefore established a verification environment for manufacturing equipment control software using a virtual mechanical and electrical simulator. This system shortens the development period of manufacturing equipment.

Previously, it was necessary to complete the hardware of equipment before starting to debug the control software since the control software is designed to operate with the hardware.

However, if control software could be debugged before producing equipment, the development period could be shortened. To achieve this, we established virtual hardware by using mechanical and electrical simulators. In this virtual hardware, the mechanical simulator was created using 3D CAD data, while the electrical hardware simulator was made by developing special software. This special software consists of function modules so that the software can be reconfigured to simulate different structures of electric hardware.

This system has already been used for certain equipment and reduced the software verification period by 60%.

CAD: Computer Aided Design

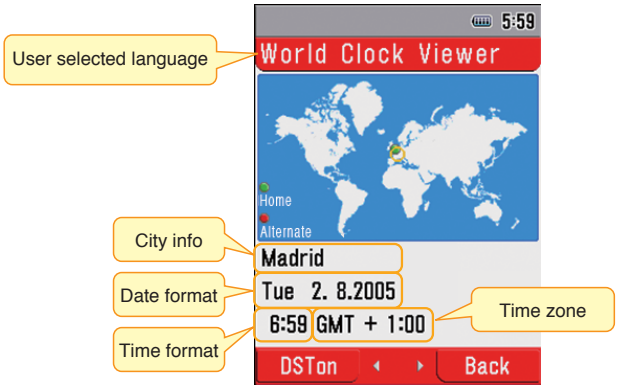


System for debugging equipment control software without using hardware

Multilingual Framework for Cellular Phone

Toshiba has developed a multilingual framework for cellular phones to enable efficient development of cellular phones for overseas markets.

This framework supports internationalization and multilingualization features. The internationalization feature in software means that people in different countries or regions can use the same software. The multilingualization feature enables the user to use the language and script of his/her choice. Because the framework handles the resources that are different among cultures or languages, such as the date format and time zone, each application is not required to take care of these issues individually. Thus, we are able to develop more reliable multilingual cellular phones in a shorter time.



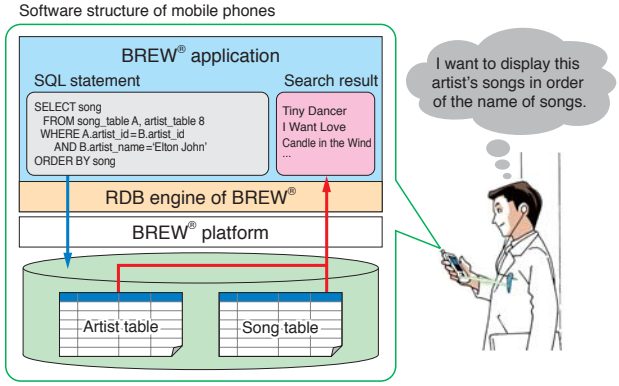
Example of multilingual cellular phone display

Embedded Relational Database Engine on BREW® Platform

Toshiba has developed an embedded relational database (RDB) engine on a BREW® application platform for mobile phones. BREW® developed by Qualcomm is the software runtime environment for the chipset in mobile phones. Toshiba modified an open source embedded RDB engine largely under the restriction of BREW® in order to execute the RDB engine on the BREW® platform, thus enabling an RDB engine to be used on BREW® unlike before. Furthermore, the RDB engine on BREW® improves the efficiency of application development and performance such as quick searches of various data in mobile phones.

Toshiba believes that mobile phones will continue to require more advanced functions yet at a lower price to remain competitive in the market, and that the RDB engine on BREW® is necessary to achieve this.

BREW: Binary Runtime Environment for Wireless



SQL: Structured Query Language

System architecture of embedded relational database for BREW®