

Highlights

Corporate Research and Development

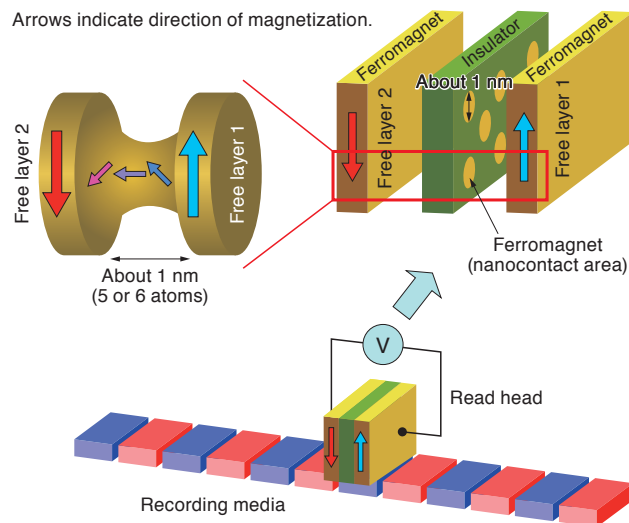
Nanocontact Magnetoresistive Read Head Applicable to Areal Density of 2.5 Tbits/in²

Toshiba has developed a high-sensitivity read head element that can read back the information of hard disk drives (HDDs) with an areal density of 2.5 Tbits/in² for the first time in the world^(*).

The newly developed proprietary process, which allows many nanosized metal areas to connect magnetically and electrically between two magnetic thin films, has made it possible to experimentally produce a high-performance reader based on a new concept called “nanocontact magnetoresistance” (nanocontact MR) with an MR ratio of 30% and a resistance-area product of 0.2 $\Omega\mu\text{m}^2$.

This work was partly supported by the New Energy and Industrial Technology Development Organization (NEDO) under the “Green IT” Project.

(*) As of August 2011, at The 22nd Magnetic Recording Conference 2011 (TMRC 2011) (as researched by Toshiba)



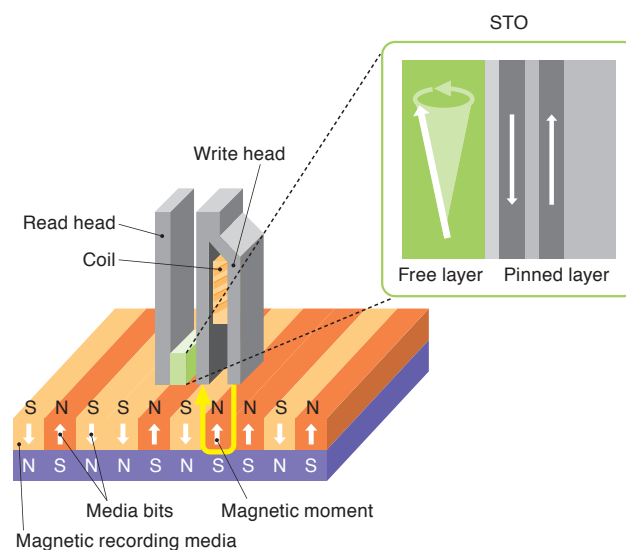
Outline of nanocontact MR read element

Confirmation of Operating Principle of Read Head Incorporating Spin-Torque Oscillator

Toshiba has confirmed the operating principle of a novel read head that realizes high-density HDDs of several Tbits/in².

It is generally considered that the signal-to-noise ratio (SNR) of conventional magnetoresistive heads will greatly decrease in high-density recording beyond 2 Tbits/in² due to the large magnetic noise caused by thermal magnetization fluctuation as well as spin-torque-induced magnetization instability. To overcome these difficulties, we have devised a novel read head incorporating a spin-torque oscillator (STO) and confirmed its operating principle.

The STO type read head senses the media field as a modulation in the frequency, achieving not only a high SNR but also high data-transfer rates beyond those of conventional heads. This technology is expected to realize an STO head with a high data-transfer rate exceeding 5 Gbits/s and a high SNR at a density of 5 Tbits/in².



STO for HDD read heads

Superconducting Filter Unit for Weather Radar Receiver

With the increase in flood disasters caused by local downpours in recent years, the number of high-performance weather radar sites in Japan is increasing to allow precise observation of local downpours. However, the frequencies that can be assigned to 9 GHz-band weather radars are becoming depleted due to the increase in the number of systems installed. A narrowband receiving filter is essential to decrease interference among nearby weather radars. Furthermore, a compact filter unit is required for application to a wide variety of weather radars.

As a solution to these issues, Toshiba has developed the world's smallest^(*) superconducting narrowband filter unit with a volume of 10 L for the receiver of a weather radar with the world's smallest^(*) fractional bandwidth of 0.08%. The narrowband characteristics make it possible to allocate frequencies at double the previous density. Moreover, as this filter unit operates at AC100 V, it can be easily installed anywhere.

We have confirmed that the newly developed filter unit decreases interference by applying it to our current 9 GHz-band solid-state multiparameter radar.

This work was supported by the Ministry of Internal Affairs and Communications (MIC) of Japan.

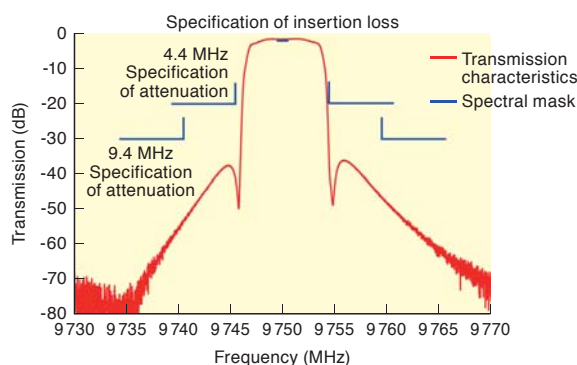
(*) As of October 2011 (as researched by Toshiba)



Compact superconducting filter unit for receiver of 9 GHz-band weather radar



9 GHz-band solid-state multiparameter radar



Result of evaluation of transmission characteristics of superconducting filter unit

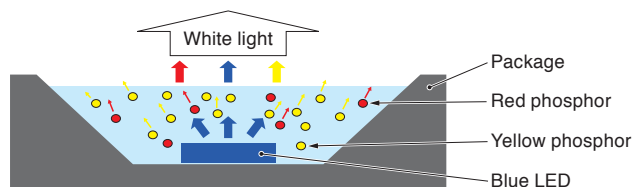
Sr-Containing Sialon Phosphor for White LEDs

Although white light-emitting diodes (LEDs) composed of a blue LED and a yellow-emitting phosphor have been widely used in recent years, they have insufficient color rendering due to a lack of red spectral emission. To realize a warm-white LED with higher color rendering, a red-emitting phosphor that can be excited by blue LED light is required.

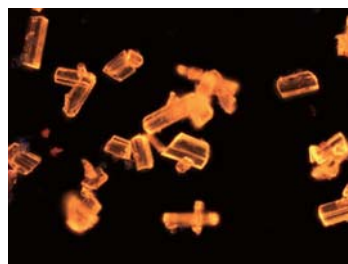
Toshiba has developed a red-emitting phosphor that has a new host material, Sr-containing sialon ($\text{Sr}_2\text{Si}_7\text{Al}_3\text{ON}_{13}:\text{Sr-SiAlON}$), doped with europium ion (Eu^{2+}) as an activator. It achieves both high efficiency and small

thermal quenching under excitation by blue light, which is essential for high-temperature operation. The wavelength of peak emission in the red emission band can be widely shifted from 580 nm to 645 nm by adjusting the crystal composition and the sintering conditions. Furthermore, the efficiency of this phosphor is not significantly decreased with changes in the wavelength of the blue LED or the operating temperature.

These features indicate the high potential of this red-emitting phosphor for application to white LEDs that can transform the cold-bluish-white light of conventional white LEDs into warm-white light suitable for general lighting purposes.



Cross-sectional structure of white LED with high color rendering index



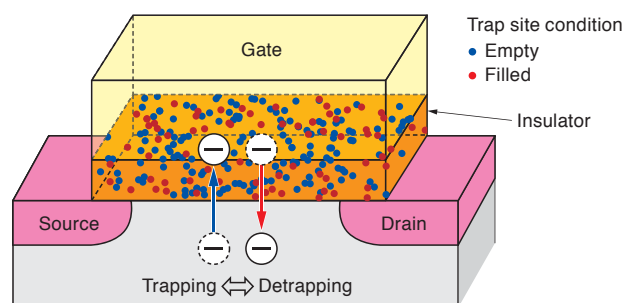
Emission from red-emitting sialon phosphor

3D Random Telegraph Noise Simulator for Development of High-Resolution CMOS Image Sensor

Random telegraph noise (RTN), one of main causes of image degradation in complementary metal-oxide semiconductor (CMOS) image sensors, is caused by current fluctuation originating in charge trapping and de-trapping at the gate insulator of transistors. As conventional device simulators cannot reproduce the dynamic behavior of charge trapping and detrapping at a gate insulator, it is difficult to reduce RTN efficiently.

As a solution to this issue, Toshiba has developed a three-dimensional (3D) device simulator that can predict RTN to improve the resolution of CMOS image sensors through the modeling of trapping and detrapping processes considering traps isolated in the insulator. This simulator makes it possible to predict the noise intensity according to the device structure and bias conditions. Furthermore, it can quantitatively simulate 3D trap site distribution by a comparison of measured and simulated data.

This simulator is expected to reduce the development period for CMOS image sensors by 20% compared with the time required for conventional prototype fabrication.



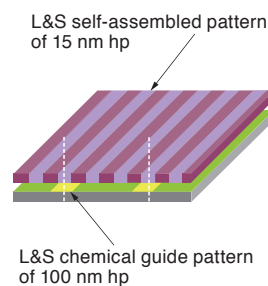
Outline of RTN simulation

Pattern Orientation Control for Directed Self-Assembly Lithography

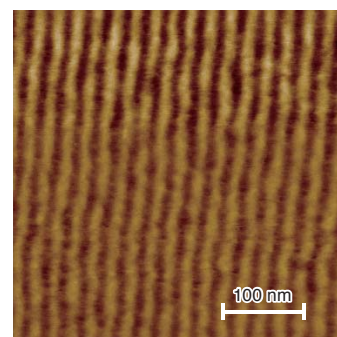
A block copolymer consisting of two segregated polymer blocks linked by a chemically covalent bond forms self-assembled nanometer-scale patterns, whose size does not depend on a lithographic exposure tool but on the molecular weight. This nanofabrication technique is referred to as directed self-assembly (DSA) lithography. It can be applied to the fabrication of semiconductor devices such as NAND flash memories. However, as the block copolymer naturally forms a nanostructure that is randomly aligned like a fingerprint, it is necessary to control the alignment of the self-assembled patterns.

Toshiba has developed a method of controlling pattern orientation using chemical modification of the surface of the silicon substrate as a pattern guide. We have fabricated a line-and-space (L&S) self-assembled pattern of 15 nm half-pitch (hp) directed on a 100 nm hp L&S pattern of a chemical guide.

We are aiming to develop DSA lithography with high reproducibility by optimizing the materials and processes.



L&S patterns formed by DSA

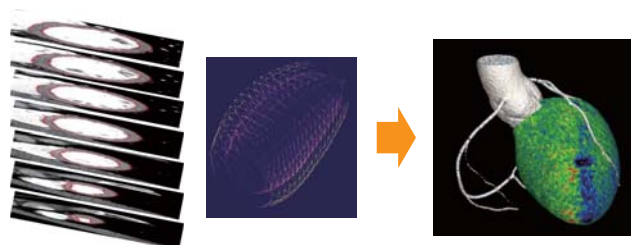


Myocardial Contour Detection and Cardiac Slice-Alignment Methods for Medical Image Processing

For the accurate evaluation of myocardial perfusion on computed tomography (CT) images, Toshiba has developed a myocardial contour detection method based on an active shape model with highly accurate left ventricle coordinate system estimation. This method eliminates the variations of heart position, rotation, and scale in volume, and thus achieves accurate and fast myocardial contour detection sufficient for myocardial perfusion examination.

This technology has been incorporated into the Aquilion ONE™ whole-body X-ray CT scanner produced by Toshiba Medical Systems Corporation since July 2011.

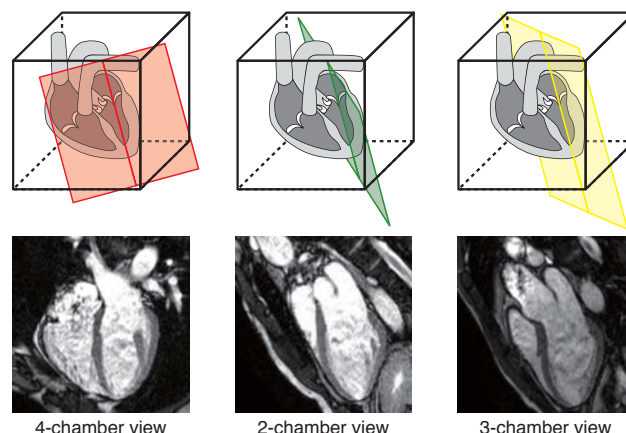
In order to simplify cardiac scan planning, we have also developed a sophisticated slice-alignment method for cardiac magnetic resonance imaging (MRI) systems. This method employs knowledge-



Automatically extracted contour of myocardium of left ventricle (left) and result of myocardial perfusion (right)

based recognition technologies combined with image processing technologies, making it possible to detect the cardiac planes more quickly and accurately than with the conventional method. It is also more robust with respect to data from a variety of ethnic groups, achieving highly efficient slice alignment.

We presented a paper on this method at the 28th Annual Scientific Meeting of the European Society for Magnetic Resonance in Medicine and Biology (ESMRMB) in October 2011.

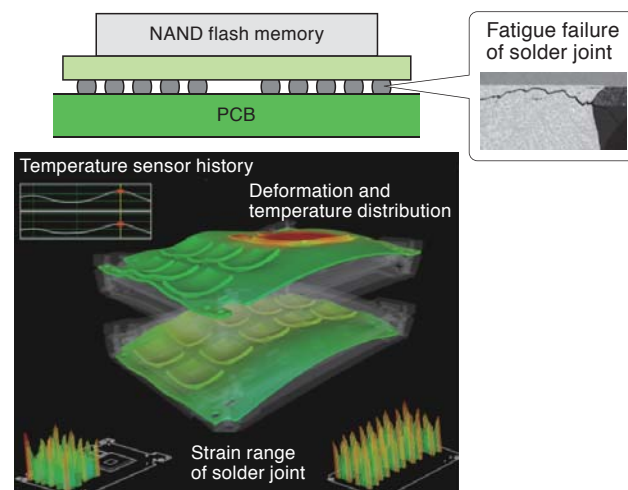


Automatic slice alignment for cardiac MRI

Fatigue Life Prediction Method for SSD Printed Circuit Boards Based on Canary Circuit

With the progressive increases in capacity and miniaturization of solid-state drives (SSDs), demand has been growing for high-density packaging of NAND flash memories assembled on printed circuit boards (PCBs). However, high-density packaging leads to increased fatigue failure risk of the solder joints due to lowering of the reliability margin for stress.

Toshiba has developed a failure precursor detection technology based on a fatigue life prediction method under usage conditions. In this method, the lifetime of actual circuits can be predicted using disconnection detection of a canary circuit (dummy daisy-chained solder joints). The canary circuit is designed to fail earlier than actual circuits due to the same failure mechanism by the use of large-scale stress simulation and accelerated reliability tests.



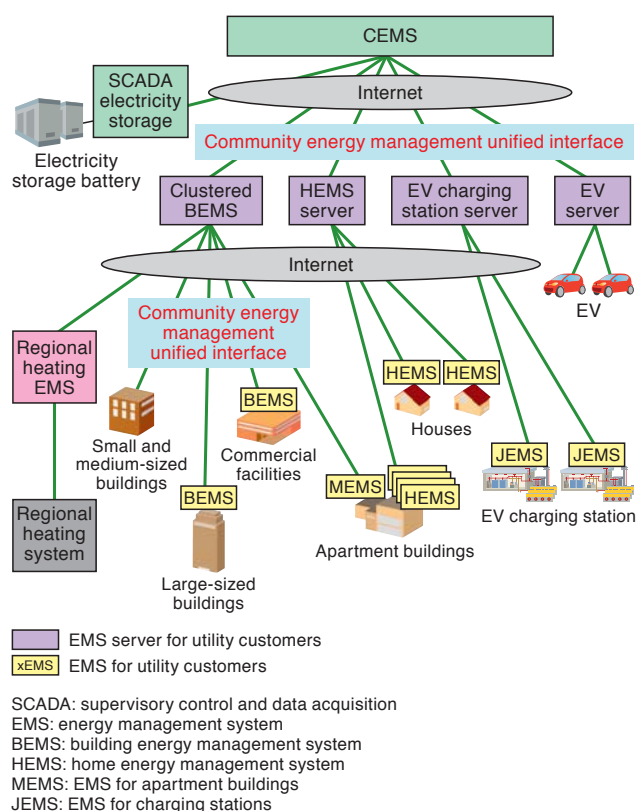
Large-scale stress simulation of SSD

Development of Community Energy Management System

Toshiba has developed a community energy management system (CEMS) using a newly developed community energy management unified interface connecting utility customers to realize demand response based on global-standard Web service technologies. The uniformity and loose coupling of this interface facilitate easy connectivity between the CEMS and diverse utility customers, and contribute to the dissemination of the CEMS.

The CEMS will be used in the Yokohama Smart City Project (YSCP), a large-scale smart grid verification project involving about 4 000 households and 2 000 electric vehicles (EVs). We are planning to verify the demand response function of the CEMS using this interface in the project.

This work was partly supported by the Ministry of Economy, Trade and Industry (METI) under the “Project for the development of community energy management systems” in fiscal year 2010.



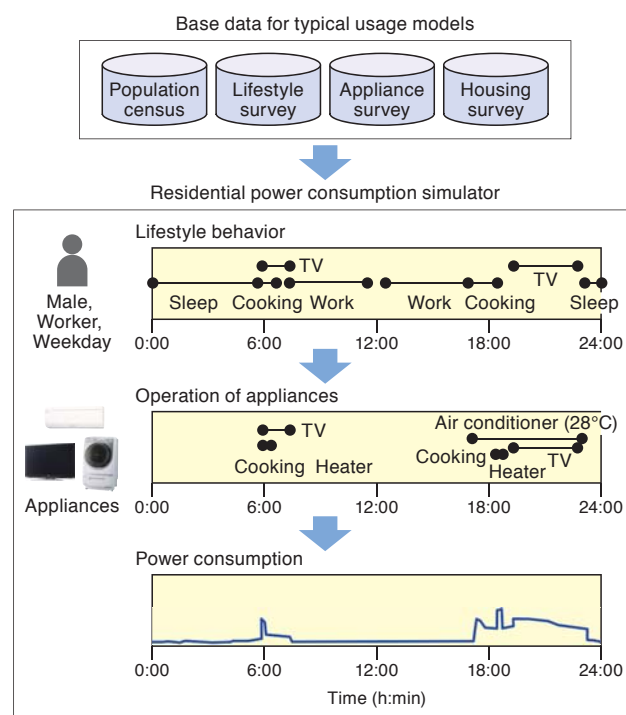
Configuration of CEMS demonstration system for YSCP

Model-Based Simulation Technology for Estimation of Residential Power Consumption

Toshiba has developed a new model-based simulation technology for estimation of the power consumption of residences in a given region. This technology incorporates typical usage models expressing the relationship between the behavior of the residents and power consumption, whose parameters can be set for each house depending on the lifestyle of the residents and specifications of appliances.

By means of these usage models, the behaviors of the residents during a one-day period are determined so as to estimate power consumption. These usage models have been developed based on statistical surveys on the regional characteristics of various lifestyles. The regional power consumption can be easily simulated by stochastically adjusting the parameters of the usage models to the regional characteristics of lifestyles. Based on the simulation results, we can provide predictions of regional power consumption to utilities in the case of changing the settings of appliances, and can also provide recommendations to residents regarding the replacement of appliances or changes in lifestyle to reduce energy consumption. This technology is available for regional energy-saving simulations and prior evaluations of smart communities.

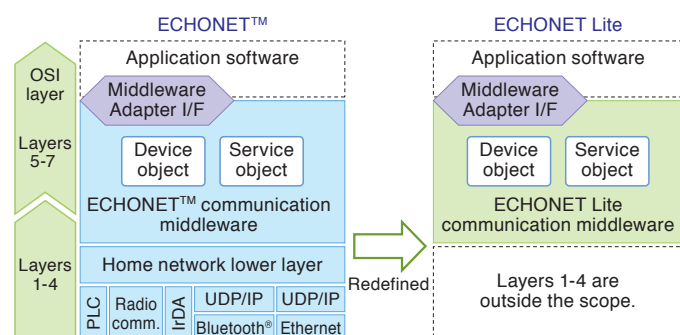
This work was supported by NEDO.



Processing flow of residential power consumption simulator

HEMS Communication Based on ECHONET Lite

The ECHONET™ Consortium, which discusses specifications for home networks in terms of smart appliances, has now released the specification for ECHONET Lite Ver.1.00. This allows the implementation of its communication stack and the installation of embedded devices to be easily performed due to the simplification of existing ECHONET™ specifications in view of the trends in home networks.



(Adapted from ECHONET™ Consortium site)

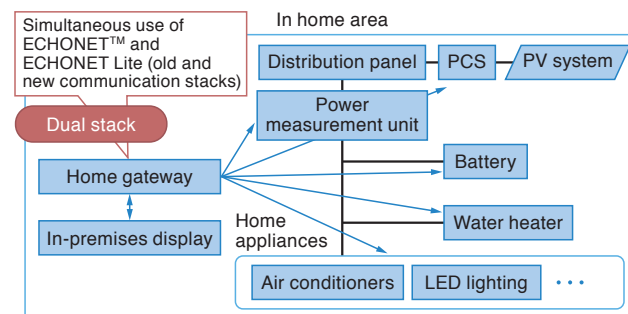
The Bluetooth word mark and logos are owned by Bluetooth SIG, Inc. and any use of such marks by Toshiba is under license.

OSI: open systems interconnection Radio comm.: low-power radio communication
I/F: Interface IrDA: Infrared Data Association
PLC: power-line carrier UDP: User Datagram Protocol

Comparison of architectures of ECHONET™ and ECHONET Lite

Toshiba has been participating in the relevant international standardization activities, and has contributed to the adoption of the related security specifications based on Internet Protocol (IP) technologies as well as to the expansion of the ECHONET™ specifications corresponding to smart energy devices. We have already released IP-based “ECHONET™-Ready” appliances. We have now developed prototype virtual ECHONET Lite devices, and confirmed the effectiveness of efficient energy cooperative control in a home energy management system (HEMS) integrating energy-creating, energy-storage, and energy-saving functions.

ECHONET is a trademark of the ECHONET Consortium.



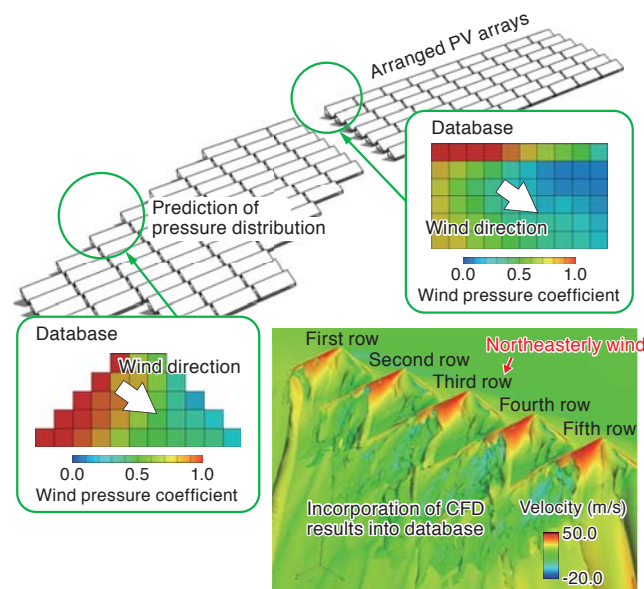
PCS: power conditioning subsystem PV: photovoltaic

System designed to optimally control energy use in homes

Construction of Wind Pressure Database for Various Arranged Photovoltaic Arrays

Toshiba has developed a method to predict wind pressure distribution, which is expected to contribute to the construction of a reliable large-scale photovoltaic (PV) power generation plant that can withstand strong winds. This method can be applied to variously arranged PV arrays to realize cost-effective design of the array arrangement.

In order to design an array arrangement in a short period, a wind pressure distribution database has been constructed on the basis of precise computational fluid dynamics (CFD) analysis for several probable array arrangements. Through the selection and interpolation of pre-analysis results, the database makes it possible to obtain the wind pressure distribution of a specified array arrangement without the need for time-consuming and costly large-scale analysis.

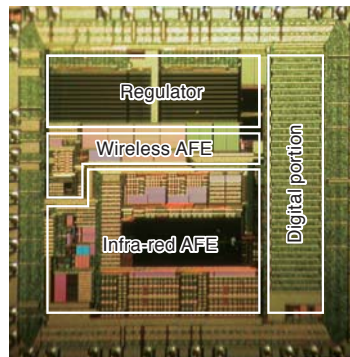


Visualization of forces applied to PV arrays using wind pressure database

ecochip™ Achieving Almost 0 W Standby Power Consumption for Home Appliances

Toshiba has developed the ecochip™, a low-power receiver chip for remote-control systems, incorporating an analog front-end (AFE) circuit and signal detection/relay switch controlling schemes in the digital domain. Using these functions, the ecochip™ makes it possible to reduce the standby power consumption of home appliances to almost 0 W by turning off the relay switch connected to the power line in the standby state. When the chip receives a wakeup signal it turns on the relay switch, even when the power line is disconnected. We have developed a mixed-signal processing technology for filtering and other functions by optimizing the partition between the analog and digital blocks, and a digitally assisted calibration scheme for process variations of analog circuits in order to attain a total power consumption of only 150 μ W.

The ecochip™ incorporates both infrared and wireless remote-control systems. The infrared version of the ecochip™ remote-control system has been adopted for the REGZA 32BE3 liquid crystal display (LCD) TV launched on the market in December 2011. The standby power consumption of the 32BE3 is about 1/1 000 that of conventional TVs, which means almost 0 W. The wireless version of the ecochip™ remote-control system has been applied to an experimental wakeup system for



ecochip™ low-power receiver chip



REGZA 32BE3 equipped with ecochip™

remote-controlled network equipment. Experiments on the wireless version of the ecochip™ confirmed that it achieves successful performance in contributing to the reduction of power consumption.

This work was partly supported by MIC of Japan.

High-Quality Image Creation for Glasses-Free 3D Displays

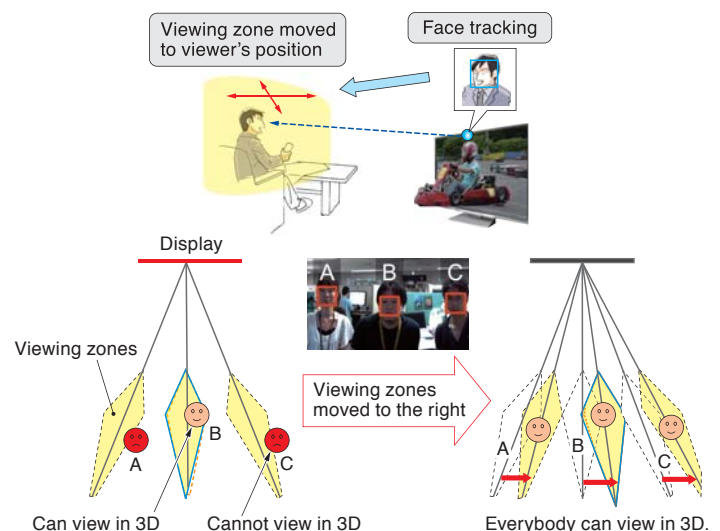
Toshiba has developed technologies to ensure high-quality image creation for glasses-free 3D displays.

We have achieved a moiré-free panel design by applying our accurate moiré simulation technology to the prediction of moiré fringe caused by interference of a slanted lens-array and panel pixels.

We have also developed a face tracking technology that automatically makes adjustments of the viewing area according to the individual positions of multiple viewers, enabling all of the viewers to watch high-quality 3D images.

These technologies have been applied to the REGZA 55X3, the world's first(*) 55-inch glasses-free 3D LCD TV with quad full high-definition (QFHD) resolution.

(*) As of October 2011 (as researched by Toshiba)



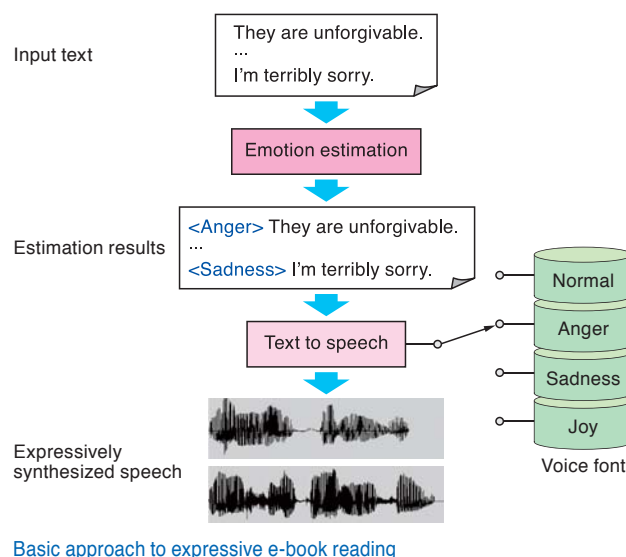
Viewing zone control using multiple face tracking for glasses-free display

Expressive Text-to-Speech Synthesis for e-Book Reading

To provide new and enjoyable experiences for e-book readers, Toshiba has been developing expressive technologies related to e-book reading. We have now developed a technology that automatically estimates implicit emotions from the dialogues of an e-book.

Based on previously learned pairwise data composed of large volumes of sentence examples and emotion labels such as “joy,” “anger,” and “sadness,” this technology assigns emotion labels to the text data by means of a complementary naïve Bayes-based method, and classifies unlabeled data by integrating this method with an expectation-maximization (EM) algorithm. The estimation results allow a text-to-speech system to actualize the expressive reading of dialogues through the selection of a voice font or a prosodic parameter associated with the emotion.

We are promoting the development of a product module with a reading function in which this technology is embedded, as well as the application of this technology to voice content authoring tools.



Basic approach to expressive e-book reading

Application of Software Platform Construction Technology

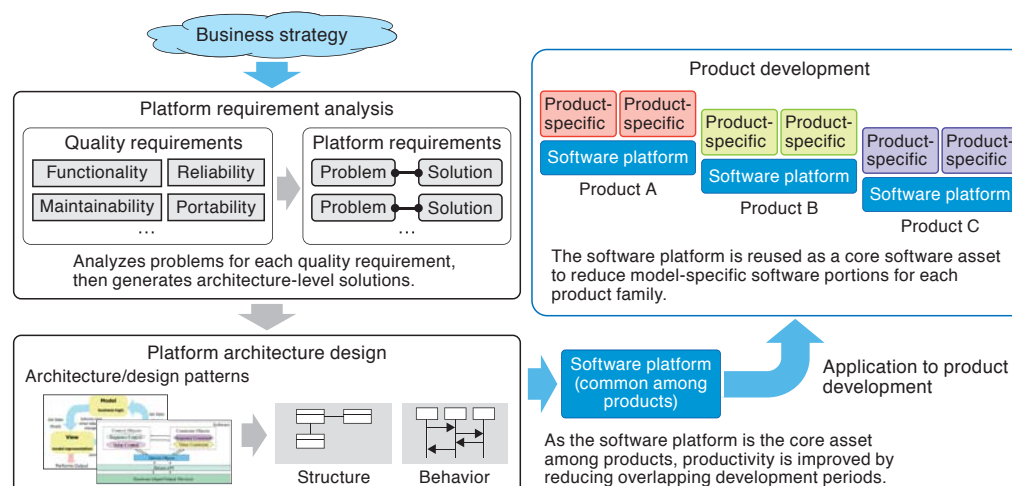
In recent years, software products have shown a trend of increasing diversity while the software life cycle has become shorter. It is therefore necessary to tackle the challenges of achieving software development within a short period and satisfying market demand in a timely manner. To solve these issues, two key techniques

are essential: the production of common software shared among different products, and the systematic implementation of business strategies as software products.

Toshiba has been developing a software platform construction technology that realizes these techniques

by two methods: a platform requirements analysis method that systematically organizes a business strategy into sets of problems and their solutions for each quality requirement, and a platform architecture design method that implements the solutions into structures and behaviors of a software product.

We have applied this technology to the development of glasses-free 3D REGZA models and achieved improvements in value, quality, and productivity.

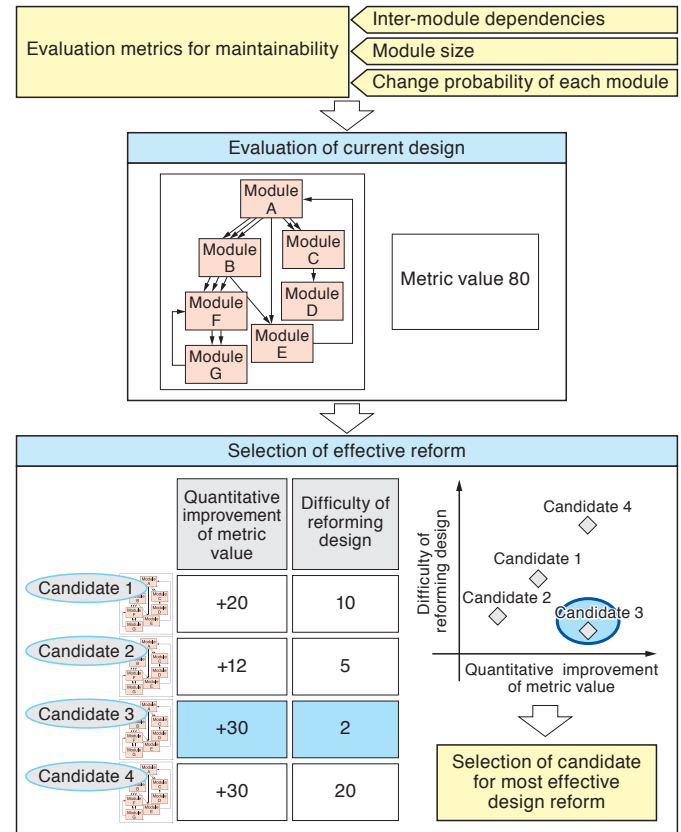


Configuration of software platform construction technology

Evaluation and Improvement Technologies for Software Architecture Maintainability

Software architecture maintainability is essential for the efficient development of software product lines, including reuse and customization. In order to improve software architecture maintainability, Toshiba has developed a new method to narrow down problems in existing software architecture, leading to improved maintainability.

For this method, we have defined a new metric called “influence.” In each module of the software architecture, this metric is calculated as lines of software source code that will be influenced when a certain code is changed in the module based on inter-module dependencies. For the overall architecture, it is calculated as a weighted average by the change probability for each module. This feature makes it possible to achieve more accurate evaluation of maintainability for a software product line. Using this metric, our new method indicates a way to reform design to improve maintainability effectively. For various design reform candidates, the quantitative improvements of metric values and associated difficulty in reforming the design are calculated. Through the evaluation of these two factors, the most effective reform of the design can be identified.

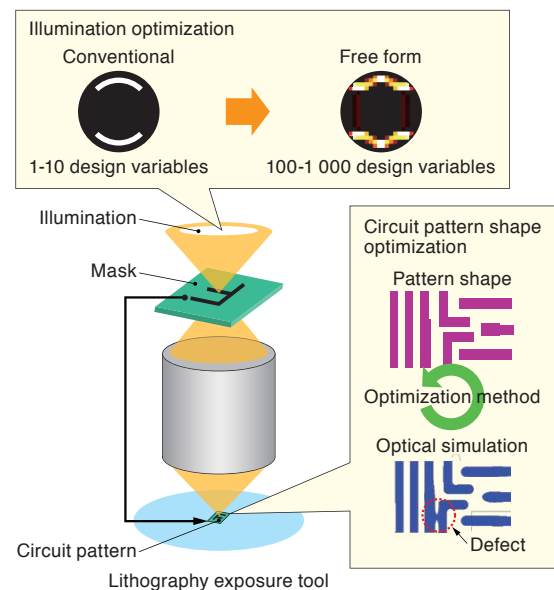


Outline of software structure improvement using evaluation metrics

Optical Design for Lithography to Shrink Semiconductor Feature Size

As semiconductor feature sizes have been shrinking rapidly, it is necessary for optical lithography to manage extremely fine-tuned optical element designs such as photomask layouts and illumination shapes in order to maximize the performance capability of current-generation exposure tools.

Toshiba has developed two computerized design methods based on numerical optimization techniques: (1) a fast illumination optimization method focused on the recent very complex free-form illuminations that have 100 times or more design variables compared with the conventional method, and (2) a wafer pattern optimization method to make circuit shapes that have sufficient robustness for manufacturing. The robust circuit shapes are automatically derived by optimization combined with optical simulation to predict defects. These methods provide solutions for the patterning of feature sizes very close to the resolution limit of exposure tools.



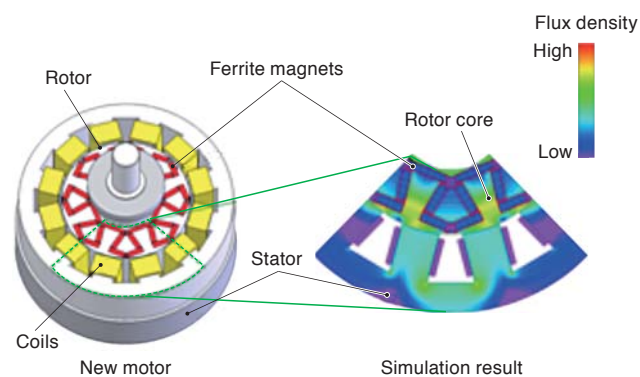
Optical design technologies to maximize lithography equipment performance

Motor with Higher Power Using Ferrite Magnets without Rare-Earth Metals

The price of neodymium magnets is soaring, having tripled in 2011 alone, and the adoption of cheap alternative magnets is desired for high-output motors. However, the residual magnetic flux density of a ferrite magnet is about 33% that of a neodymium magnet, and the lower magnetic flux inevitably degrades efficiency.

As a solution to this issue, Toshiba has developed a new structure in which ferrite magnets are embedded in the rotor core, and improved the magnetic flux by optimizing the number and arrangement of the magnets. As a result, we have achieved 68% of the magnetic flux of neodymium magnets by using five magnets per magnetic pole and arranging them in a concave shape when viewed from the magnetic pole side.

We are now aiming at the broadening of applications to household appliances, automobiles, etc.



Structure and result of magnetic field analysis of motor without rare-earth metals

High-Throughput Single-Wafer Wet Etching Equipment



High-throughput single-wafer wet etching equipment

Demand for high-throughput equipment is growing in the field of semiconductor device manufacturing to reduce costs. In response to this situation, Toshiba has developed single-wafer wet etching equipment that precisely etches a fine pattern at high speed.

The features of this equipment are as follows:

- Etching can be performed at high speed by raising the temperature of the chemical solution.
- The equipment is fitted with special chemical discharge nozzles offering improved performance.
- The atmosphere and air current in the chamber are optimized.

This newly developed equipment can etch the entire surface of a wafer uniformly at high speed, realizing high productivity with an approximately 50% shortening of the process time compared with conventional equipment.

This equipment is manufactured by Shibaura Mechatronics Corporation and has been operating at the Toshiba Yokkaichi Operations facility.