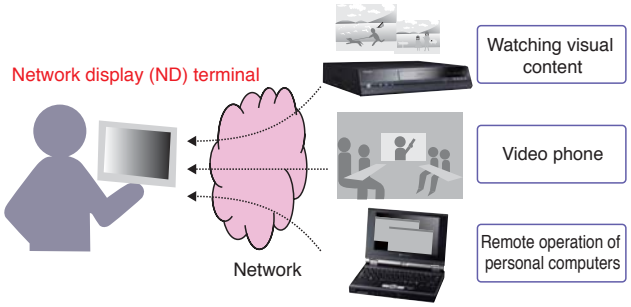
Corporate Research and Development

Toshiba delivers technology and products remarkable for their innovation and artistry — contributing to a safer, more comfortable, more productive life under our new brand tag line, “Leading Innovation”. The R&D division is promoting the creation of new technology such as network display systems technology, enhancement of fundamental technologies and research & development contributing to the business in each field.

Network Display System



Concept of network display system

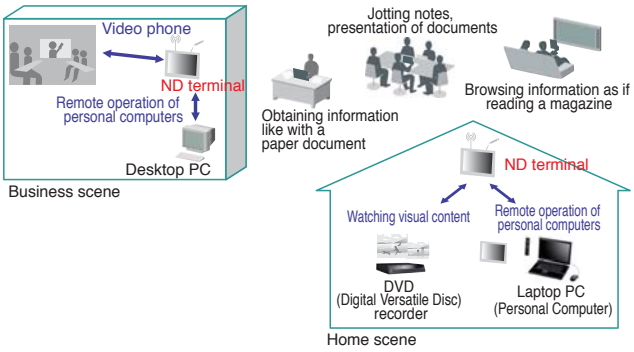
The network display (ND) system is a new system with which anyone can access various services on the network via a display terminal. To realize this system, the display terminal contains only a video/audio processing function and communication function.

The fact that no data information is stored inside the display terminal can prevent information leakage. Furthermore, minimizing the amount of processing at the terminal side can reduce weight and power consumption. These effects will result in a dramatic enhancement of usability.

Toshiba has succeeded in prototyping the display terminal, which can perform three functions, specifically, remote operation of personal computers, acting as a video phone, and playing visual content over the network. Despite having a 12.1-inch screen, the unit weighs just 1.27 lbs. This enables the user to access the high quality services of the various units of equipment on the network.

As an example of usage, in the office, the display terminal can be taken along to a meeting room, you can jot down notes or make a presentation as you would with paper documents. In addition, you can hold a video conference between remote offices. Also in the home, you can easily watch visual content or enjoy web surfing anytime and anywhere.

We aim to improve the usefulness of each feature in this system in our future work.



Uses of network display system

Large-Scale Distributed XML Database

Currently, with the wide spread of the XML (eXtensible Markup Language) format, large-scale XML data, with a size of more than several Tbytes, has appeared in fields such as patent data and gene data.

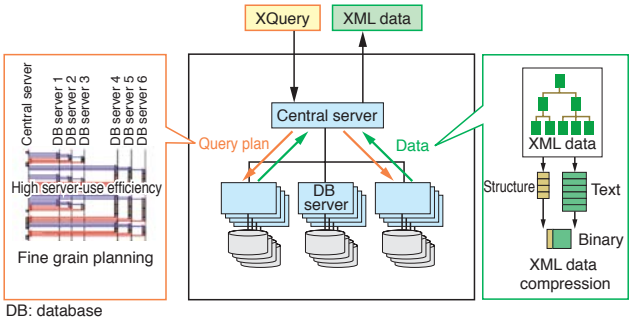
In order to provide reliable and real-time access to large volume XML data, Toshiba has developed a distributed native XML database management system (DBMS) that is a collection of multiple, interrelated databases distributed over a computer network.

A conventional distributed DBMS has a data communication bottleneck between distributed servers and has difficulty in keeping high performance proportionate to the number of servers.

The following are the main technical features.

- Fine grain planning technology
  To improve the usage efficiency of overall server resources, a central server generates query plans in fine-grained codes and controls DB servers.
- XML data compression technology
  To reduce transfer cost, XML elements, constituting XML data, are separately grouped and compressed with suitable compression methods. Our evaluation shows the system can reduce the data communication cost to about 1/9.

Even with large XML data of more than 1 Tbyte, Toshiba’s new distributed DBMS has realized quick access response and server scalability.



DB: database
XQuery: Query language designed specifically for XML data access.

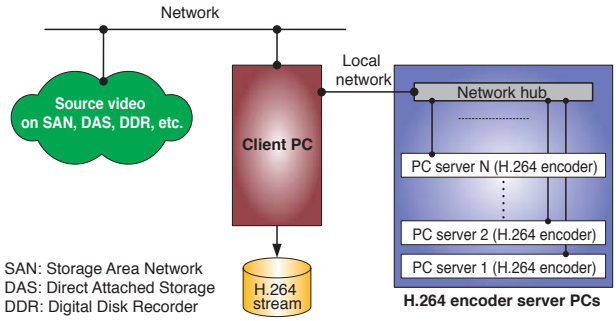
Conceptual image of distributed native extensible markup language (XML) database

H.264 Video Encoder for HD DVD Title Creation

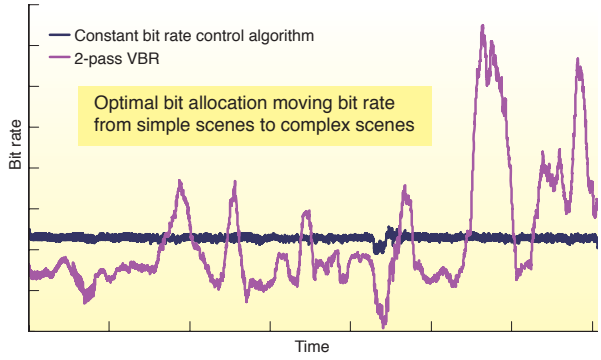
Toshiba has developed an H.264 video encoder that helps to efficiently create HD DVD-Video titles with high picture quality.

The developed encoder adopts a 2-pass variable bit rate control algorithm (2-pass VBR). 2-pass VBR is a bit rate allocation and control method according to the encoding complexity of the scene, which has been used for the DVD title creation for more than 10 years. Since H.264 has coding technology at least twice as efficient as MPEG-2 (Moving Picture Experts Group-phase 2), the adoption of 2-pass VBR in the encoder achieves high picture quality encoding for high definition video. This enables the storage of more than 4 hours of high quality and high definition video on a dual-layer single-sided HD DVD-ROM disc.

In addition, a fast encoding algorithm has been newly developed and implemented by software. The algorithm reduces the computational burden significantly while maintaining the high picture quality encoding. The software can run in parallel on personal computers connected via the network and encode full-HD video in real time.



Configuration of H.264 video encoder system



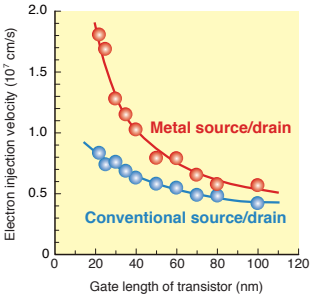
Example of bit rate allocation using 2-pass VBR

Metal Source/Drain Electrode Technology for Realizing Ultrahigh-Performance MOSFETs

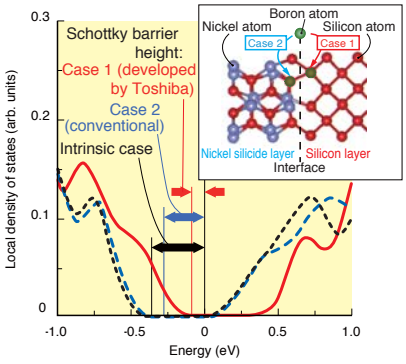
Downscaling of LSIs, the key devices underpinning the progress of IT, continues to progress. In order to further enhance LSI performance, it is necessary to tackle new research themes. In this context, reducing electrode resistance is one of the most important new themes. In order to achieve it, Toshiba has developed metal sources/drain electrode technology.

By applying Toshiba's original technique to the metal electrodes, which makes it possible to segregate dopants on the silicon side at the Schottky (silicide/silicon) interface of the electrodes, Toshiba has observed a 50% improvement in the drive current of the transistors. These experimental results suggest a 40% reduction of the electrode resistance and an increase to double the injection velocity for an electron from the source electrode.

In addition, as a result of first-principles calculations, Toshiba found that the Schottky barrier height, which indicates the degree of interface resistance, can be reduced at least 0.3 eV by controlling the distribution of boron atoms in the vicinity of the nickel silicide/silicon interface of the source/drain electrode. It should be noted that this effect is attributable to dipoles generated around boron atoms. This result indicates the possibility of realizing the source/drain electrode resistance required for LSIs of sub-22 nm generations. Also, based on the new principle, Toshiba intends to examine processes for ultra-precision control of impurity atom distribution.



Effect of gate length on electron velocity



Calculated local density of states for nickel silicide/silicon interface

New Magnetoresistance Effect in Nickel-Iron Film with Nanoscale Point-Contact

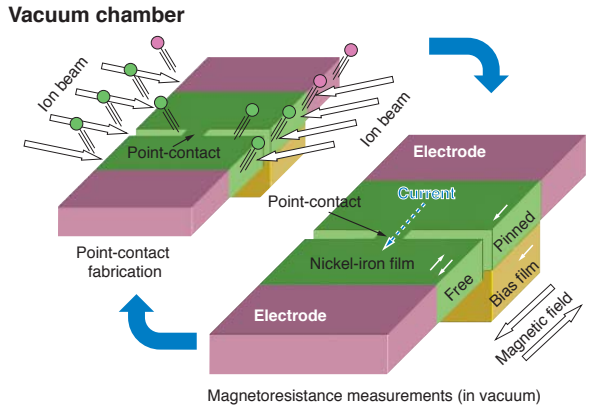
A test element with a nanoscale point-contact fabricated by a dry process in nickel-iron film showed a magneto-resistance (MR) ratio of as large as about 20%. This value is much larger than that which has been reported in point-contacts fabricated with dry processes.

The new principle MR due to abrupt domain wall was observed experimentally first in a point-contact of broken-junction in nickel wire with an MR ratio of larger than 200%(*). However, because of lithography limitations, such a large MR ratio has not been observed in point-contacts fabricated with dry processes which are necessary for reading-device manufacture. Furthermore, the point-contact is so susceptible to oxidization that MR measurements in air become unstable immediately.

Toshiba has developed a unique point-contact fabrication and MR measurement method, that is, the point-contact shrinking method, with the horizontal incidence ion beam process and successive MR measurements in vacuum. This method is capable of performing point-contact size fabrication beyond the lithography limit and oxidation-robust measurement. Using this unique method we have succeeded in observing large MR ratios of about 20% in point-contact fabricated with the dry process in nickel-iron film. This could be a first large step toward realization of reading heads in hard disc drives (HDDs) based on the new principle.

The IT programs of Research Revolution 2002 of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan provided financial support for this work.

(*) N. Garcia, et al., Phys. Rev. Lett., 82, 1999, p.2923.



Point-contact fabrication and MR measurements

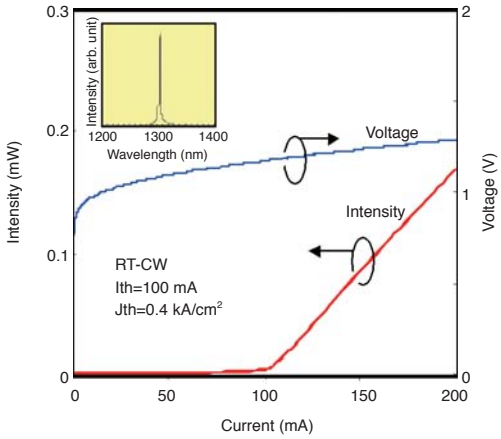
Semiconductor Quantum Dot Lasers for High-Speed and Low-Cost Optical Data Communication Systems

Semiconductor quantum dot (QD) laser diodes have been developed for low cost short distance optical fiber communication systems in the wavelength range of 1.3 μm.

QD laser diodes on a GaAs substrate have temperature stability superior to the conventional laser diodes on an InP substrate. Therefore we can eliminate the temperature stabilizer, which is the dominating factor in terms of size, cost and power consumption of a laser module.

These laser diodes were fabricated by using a newly developed structure consisting of a GaInNAs covering layer over InAs QDs to improve the size uniformity of QDs. The continuous wave operation of QD laser diodes on a GaAs substrate was realized in a wide wavelength range of 1.26 μm to 1.33 μm for the first time by using metal organic chemical vapor deposition (MOCVD) technology, which is preferable for mass production.

The results were obtained through cooperative research with Prof. Y. Arakawa of the University of Tokyo supported by the IT programs of Research Revolution 2002 of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

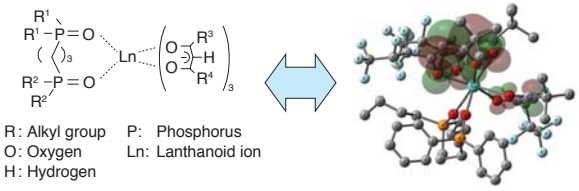


Characteristics of the QD laser diode. The inset shows the spectrum.

Development of Novel Rare-Earth Complexes through Collaboration between Molecular Design Methods and Computational Chemistry

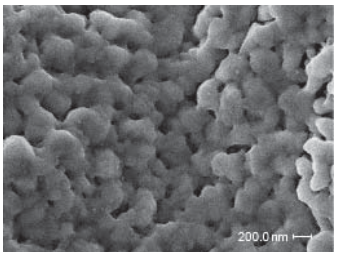
Rare-earth organic luminescent compounds dissolved in polymer are colorless and transparent under room light, but exhibit strong emission under ultraviolet-light shown in the figure. They are attracting much attention. In particular, the pure color emission derived from the rare-earth ions is suitable for interior illuminations, displays and various other applications. However, time-consuming trial and error is necessary to develop the luminescent compounds which will fulfill the requirements of excellent solubility, emission intensity and durability.

To discover more suitable molecular structures within a reasonable term, Toshiba is promoting collaboration between our original molecular design methods and computational chemistry capable of predicting the durability and absorption coefficients. By integrating these two approaches, we have developed novel luminescent compounds applicable in various types of electronic devices. For example, new white LEDs, which can vividly reproduce fresh color tones, have been realized with the novel Eu(Ⅲ) complexes. We expect lighting for various kinds of daily-life situations to be realized using these materials, and that our inventions will contribute to the popularization of white LEDs, whose load on the global environment is far smaller than that of traditional fluorescent lamps.



Development of novel rare-earth complexes and their application

New High Temperature Lead-Free Bonding

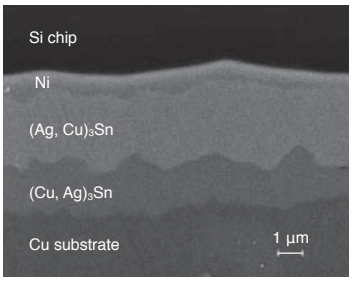


SEM image of the surface of the evaporated film

At present although high-melting-point solder containing more than 85 mass % of lead applied to power devices such as power transistors and thyristors is not restricted by the RoHS Directive(*), an alternative lead-free solder will be indispensable in the near future.

To form intermetallic compounds that have a high melting point, interactions of AgSnCu layer deposited by vacuum evaporation were examined. The evaporated film consisting of AgSnCu was prepared by depositing Ag, Sn and Cu on a Si wafer with sputtered film of Ti/Ni/Au. The total thickness of the evaporated film was 5.0 μm. The figure above shows an SEM (Scanning Electron Microscope) image of the surface of the evaporated film. The evaporated film was composed of particles of about 200 nm in diameter. This structure activates the interaction of the AgSnCu layer during joining because the dissolution rate of Ag and Cu in molten Sn increases. Joining of Si chip to Cu substrate can be performed at lower temperature and in shorter time than joining with AgSnCu solders of the same composition in a bulk state. The figure below shows an SEM image of the joining part, which has a two-layer structure. The upper layer was $(Ag, Cu)_3Sn$ that was based on Ag_3Sn, and the lower layer was $(Cu, Ag)_3Sn$ that was based on Cu_3Sn. The melting points of Ag_3Sn and Cu_3Sn are 753 K and 949 K, respectively. Since their temperatures are much higher than the heat resistance temperature, 543 K, which is required for the high-melting-point solder, this joint part has good heat resistance. The shear strength of this joint part at 543 K showed 16.6 MPa, which is higher than that of Pb based joint parts.

(*) The RoHS Directive (2002/95/EC) stands for "the restriction of the use of certain hazardous substances in electrical and electronic equipment".



SEM image of the joint part

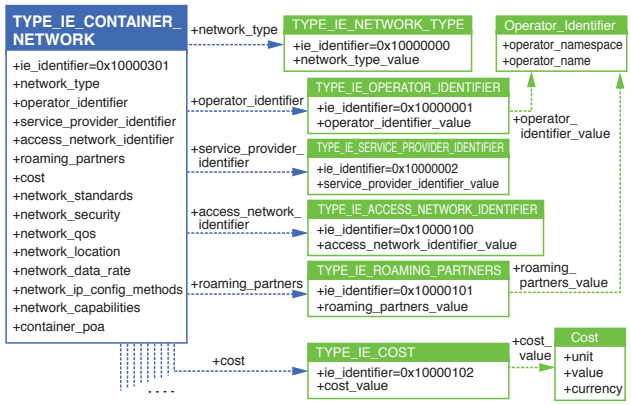
Seamless Proactive Handover across Heterogeneous Access Networks

Toshiba America Research, Inc. has developed AIS (Application-layer mechanism for Information Service) and MPA (Media-independent Pre-Authentication), two handover signaling components for realizing seamless handover across multiple different wireless technologies without disrupting mid-session applications. AIS and MPA are based on proactively performing most of the higher-layer handover operations before the occurrence of any link-layer handover.

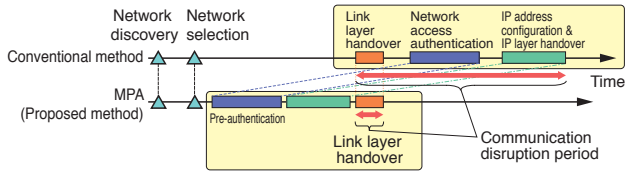
AIS provides a flexible and extensible framework for a mobile device to query information on neighboring networks with use of RDF (Resource Description Framework) and XML (eXtensible Markup Language). AIS defines the following two types of RDF schemas. The basic schema defines information common to any link-layer technology to provide basic interoperability and the extended schema defines any other type of information to provide extensibility. AIS has been adopted to IEEE 802.21, a specification on media-independent handover.

MPA provides a mechanism for a mobile node to authenticate itself to the target network through the serving network, obtain an IP (Internet Protocol) address from the target network and perform higher-layer handover operations, before the occurrence of a link-layer handover.

IEEE: Institute of Electrical and Electronic Engineers



Basic schema for IEEE 802.21 information service



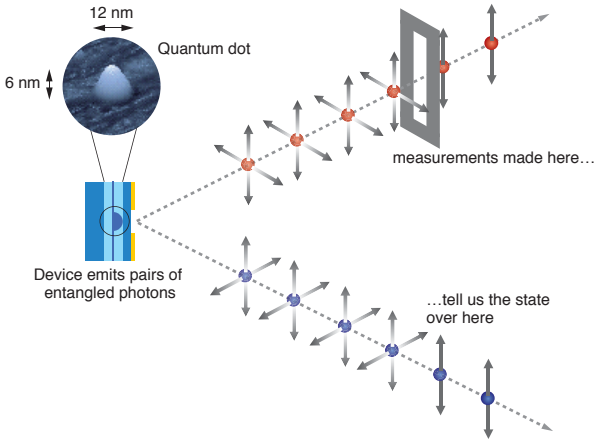
Comparison of MPA with conventional method

Generating Entangled Light with a Semiconductor Nanostructure

Entangled photon pairs have interconnected properties, such that measuring changes in one photon tells us the state of the other instantaneously. This unusual property makes entangled light a key resource for exciting new applications in quantum information. For example, entangled photons form a critical part of a quantum repeater, which can extend the distance over which quantum communication can operate. They are also required in the implementation of a scalable optical quantum computer.

Toshiba Research Europe Limited in Cambridge, UK, has developed the first semiconductor source of triggered entangled photons. This result was first reported by Toshiba in the prestigious research journal Nature. The device, shown schematically below, is based upon light emission from a single semiconductor quantum dot nanostructure. The tiny quantum dot can only hold a small amount of charge, enough to emit just a single pair of photons each cycle. Careful optimization of the size and shape of the dot by control of growth parameters enables the emitted photon pairs to be entangled.

The device is tested by comparing the polarizations of the two emitted photons for different polarization directions. This has revealed that, provided that the size and shape of the quantum dots is carefully controlled, the majority of the emitted photons are entangled. Once integrated into a simple LED-like design, the Toshiba entangled light source could help bring quantum information applications into mainstream technology.



Device generates photons with entangled properties

Circuit Compatible Device Models of Carbon Nanotube and Nanowire FETs

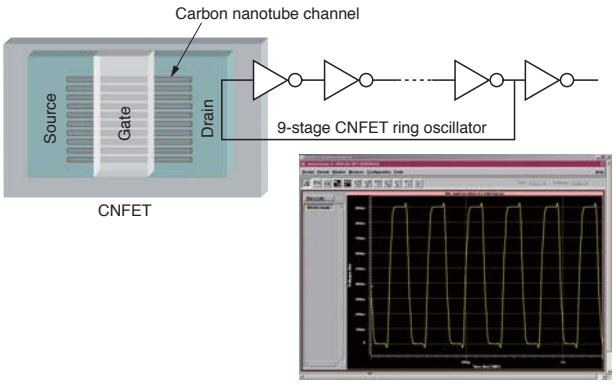
Toshiba America Research, Inc. (TARI) has developed circuit compatible analytical device models of carbon nanotube and nanowire field effect transistors (FETs). These models can be efficiently used in design and analysis of circuits and systems using these devices.

Carbon nanotube and nanowire FETs are being explored as potential alternatives to Si technology for VLSI applications and traditionally device modeling forms an integral part of any such effort. The developed models thus significantly advance the investigation by enabling existing design and analysis tools such as SPICE to provide a fast and accurate estimation of the realistic performance of circuits and systems.

The models were obtained by analytically solving device equations with appropriate approximations and were extensively verified with other established numerical models and experimentally measured current-voltage characteristics. The figure below shows an example of simulation result of a 9-stage carbon nanotube FET (CNFET) ring oscillator using the developed model with 25 nanotubes in the channel of each transistor.

The potential of these models has also been demonstrated to analyze the performance of these devices under stochastic process parameter variation. Further, the usefulness of these models will be invaluable for design and synthesis of circuits and systems when these devices are finally put to work in VLSI applications.

SPICE: Simulation Program with Integrated Circuit Emphasis



Schematic of a CNFET and simulation result of a 9-stage CNFET ring oscillator using the developed model

Text Input System Using Online Overlapped Handwriting Recognition for Mobile Devices

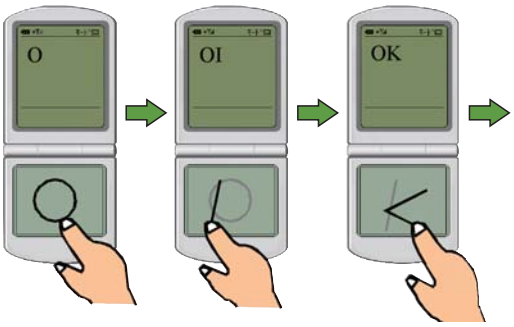
Toshiba has developed a novel online overlapped handwriting recognition system for mobile devices such as cellular phones and portable music players.

For conventional Japanese systems, it is common to employ a multi-box writing interface, where users write a character in each box one after another. Handwriting in a box is recognized as a character after the stylus is moved to the next box. However, the size of each box must of necessity be rather small because the overall writing area is limited on small devices. It is uncomfortable for users to write small characters in these small boxes, particularly when writing with a finger.

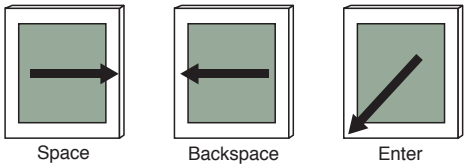
In order to solve this problem, we have realized a new handwriting recognition system, which interprets the stroke and updates the recognition results every time a stroke is written.

As shown in the figures below, users can input characters continuously without pauses on a single writing area while confirming the most up-to-date recognition results. It enables users not only to input characters but also to conduct basic operations directly by inputting certain handwritten gestures.

Users can perform all operations for text entry in a single small area with minimum finger movement. It enables users to input characters without having to watch what their fingers are doing. We have realized a new handwriting interface similar in appearance to a touch-typing interface.



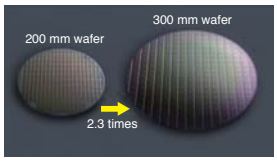
Continuously overwriting character input and recognition results



Three basic gestures

Automation System for 300 mm Wafer Processing in Clean Room for More Effective Operation

The size of silicon wafers in semiconductor processing is shifting from 200 mm to 300 mm in order to enhance productivity of devices such as memory and logic ICs.



□ffect of □□□mm wafer
□□□mm wafer efficiently allows us to make □□□ times as many chips as previously□

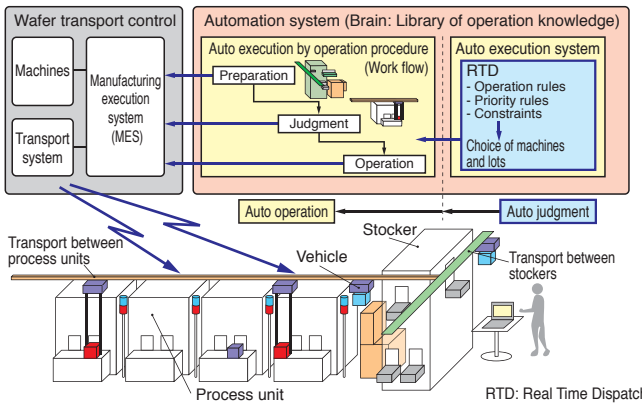
Because of their weight, 300 mm wafers are not transported manually, but carried by vehicles, which run on rails built above the process units.

Toshiba has developed an automation control system for 300 mm wafer processing. This system not only automates wafer transportation, but also automates operator's work and decision-making in the clean room.

Previously, the issue of manufacturing orders depended on the decision of an operator. For this automation system, decision making rules were created by clarifying the operator's knowledge based on their experience, such as selecting a process unit capable of processing as required, selecting wafers to be processed, assigning wafers to the process unit and determining the time to start process.

The developed system automatically calculates the wafer processing priority, and issues transportation orders and/or processing orders for the wafers. By making decision rules given in the plug-in library format newly developed, decision rules can be added or revised without halting the operation of the system. Moreover, this system can be easily applied in other semi-conductor facilities.

□utomated system for transporting wafers between process units
The new facility is e□uipped with the most advanced automatic material handling system□



Configuration of automatic 300 mm wafer processing system in clean room

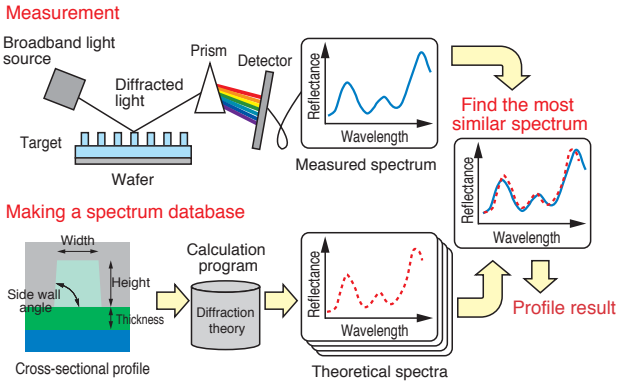
Application of Scatterometry to Photoresist Dimension Monitoring in Flash Memory Production

Toshiba applied scatterometry technology in photoresist dimension monitoring for mass production of NAND flash memory. The advantages of this technology are higher throughput, higher repeatability, and less damage to the target compared to scanning electron microscopy.

Scatterometry technology is based on the principle that the spectrum of the diffracted light from the target changes depending on the cross-sectional profile of the target. Profile dimensions of the target can be estimated by finding the most similar spectrum from the theoretical spectrum database prepared in advance. In making the spectrum database, the variation of profile due to process fluctuations is taken into consideration in order to increase estimation reliability.

Through utilizing this technology, high throughput, high precision and damage-less photoresisit monitoring have been realized. Furthermore, precise control in photolithography processing has become possible using the monitored results.

NAND: Negative AND circuit



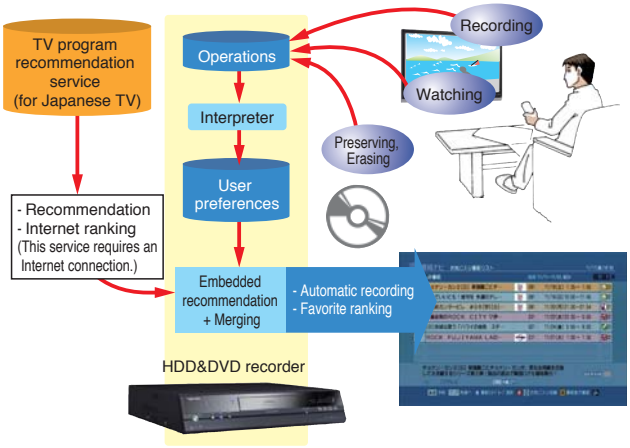
Measurement principle of scatterometry

Automatic TV Program Selection and Recoding in Personal Video Recorder by Recommendation Technology

Toshiba has developed a TV program recommendation system as embedded software for home audio visual products such as personal video recorders.

This system is an application of a probabilistic reasoning, which can determine a user's preferences from the history of operations performed on personal video recorders. After the recorder has acquired sufficient user preferences, the user may find TV programs automatically recorded that they are likely to enjoy, just by following their recording habits.

Moreover, this system can cooperate with Toshiba's internet TV program recommendation service, which is based on a collaborative filtering algorithm. Users of a Toshiba recorder connected to the Internet service might find potentially enjoyable TV programs, which they do not normally watch, but that are often recorded by users with interests or favorites similar to their own. Both the embedded recommendation function and the Internet service function will be available for models in Japan.



Assistance and recommendation functions for program selection

Linux Development for Cell Embedded Devices

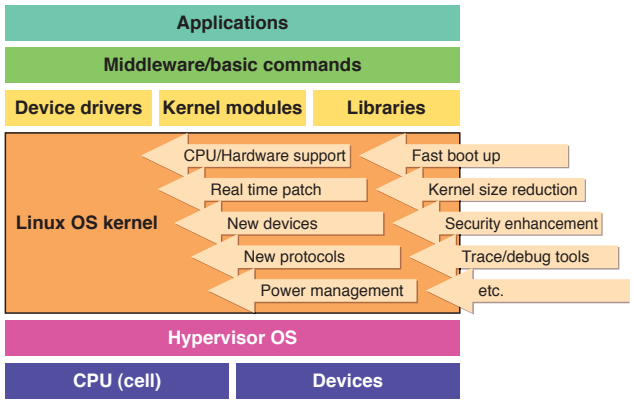
As embedded devices have become ever more complicated in recent years, it has become necessary for operating systems to have various functions and capabilities. On the other hand there are too few engineers to develop sufficient capabilities in each corporation.

The Linux operating system is renowned as a successful scheme to involve engineers in the industry to resolve this situation.

Toshiba has implemented Linux in the Cell Reference Set, which is an original device consisting of a Cell Broadband Engine (CBE) and peripherals, and enhanced the real-time function of Linux on it. The code developed was submitted to the Linux community to contribute to its progress. The code for the Cell Reference Set will be merged into the Linux kernel tree.

We will continue to investigate and develop Linux and its functions for various embedded devices.

"Linux" is a registered trademark of Linus Torvalds in the United States and other countries.



OS: Operating System

Enhanced modules of Linux for embedded systems