HITACHI TECHNOLOGY

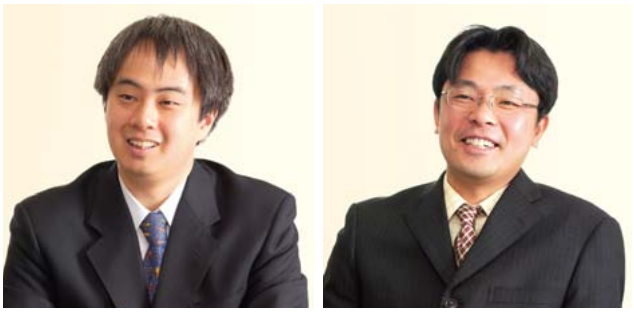
2007-2008

Research & Development

Research & Development

Next-generation Optical Network Technology that can Simultaneously Distribute High-definition Videos to 100 Channels

The integration of network IP (Internet protocol) actually launched the age of broadcasting-communication fusion. The Hitachi Group is developing various types of business related to the fields of communications and video services, including optical access network infrastructure, video distribution systems, and video equipment. With its extensive technological and research & development capabilities, the Hitachi Group has developed next-generation optical network technology that can simultaneously distribute high-definition videos to up to 100 channels. This technology makes it possible to provide new services through a fusion of broadcasting and communication.



Kenichi Sakamoto (left), Senior Researcher; Hiroki Ikeda, Researcher (right), Network System Research Dept., Central Research Laboratory

Background of Development

With the spread of optical access networks, construction of NGN (next generation network) which integrates telephone communication and broadcasting into IP, in addition to conventional data communications, has already begun in many countries around the world. We believe that HD (high definition) broadcasting will soon be distributed in the form of IP, and initiated development of this technology in the fall of 2004. We began with the development of GPON (gigabit passive optical network) to provide a technology platform which would enable even faster optical communications, and achieved for the first time in the world, a practical GPON system featuring a communication speed of 2.4 Gbit/s. Further by taking advantage of its features of high-speed performance and functions suitable for video transmission, we developed technology enabling the simultaneous distribution of up to 100 channels of HD video. Another feature is that, unlike on-demand video distributions systems, channel changes can be conducted quickly through equipment in the home, thus allowing users to change channels without any stress.

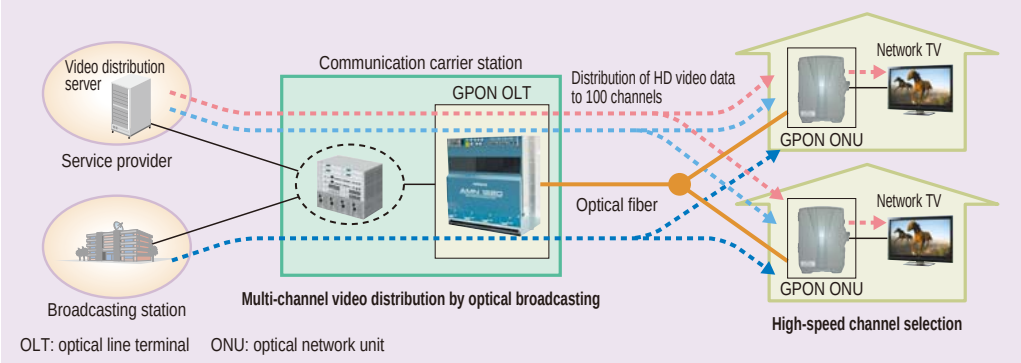
Points of Successful Development

Development of an optical network system entails the use of a wide range of technology, including optics, electrical signal processing, LSI (large scale integration) development, etc. The Hitachi Group, with the Central Research Laboratory of Hitachi, Ltd. at its core, possesses all the necessary technology, as well business in home appliances. This sort of collective strength and cooperation within the Group is leading to the development of next generation network technology.

The GPON system is also a product of this collective knowledge and cooperation. The product development team from Hitachi Communication Technologies, Ltd., which has extensive experience in communication infrastructure technologies, has been involved in the project from LSI development, a key component in the system. Also, early on in development, we encountered LSI failure trouble, but were able to resolve the problem again thanks to cooperation such as advice from computer technology experts at the Central Research Laboratory, and the efforts of many young researchers in debugging.

Future View

The next technical goal is to implement network technology which enables the simultaneous distribution of up to 1,000 channels of HD video at a communication speed of 10 Gbit/s. The Central Research Laboratory has formed a project team covering several technical fields to focus on its development. With regard to applications, we intend to propose novel ways to enjoy video such as simultaneous multi-channel recording which takes advantage of a feature of IP broadcasting which does not require a tuner. Further, we are also considering a system which not only broadcasts video information to users, but can also gather from users, for applications such as video monitor based security systems or *n*-to-*n* bi-directional video communication. We will continue to develop solutions taking advantage of features of high-speed large-capacity networks and the IP form, and pioneer new ways to using information.

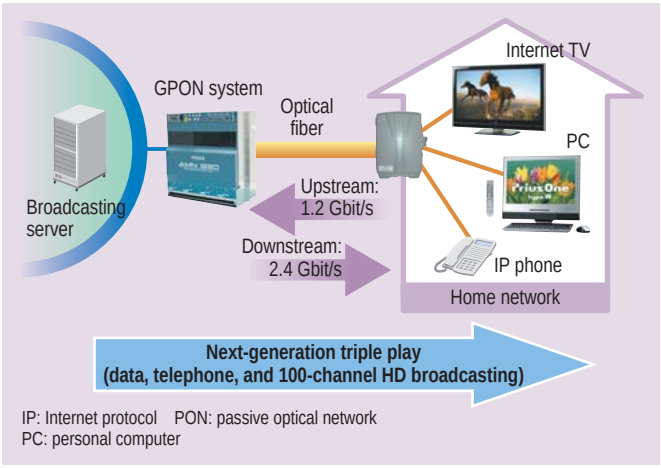


Configuration example of IP broadcasting system to distribute HD video to 100 channels

IP Broadcasting Using GPON System

Hitachi has developed an optical access system [GPON (gigabit passive optical network)] that enables broadband access from home and the office to networks. The system's transmission speeds are 2.4 Gbit/s downstream and 1.2 Gbit/s upstream, and up to 32 users can share the bandwidth. The system can provide triple-play services, video streaming, telephone, and data communications. This system began service in Bandon, Oregon, USA, in June 2007, and is the world's first GPON commercial service.

IP (Internet protocol) broadcasting technology using this system has been developed at the Central Research Laboratory. Current access systems such as the ADSL (asymmetric digital subscriber line) lack sufficient bandwidth for multi-channel video streams, and since network systems must respond to each user's request for video service, the channel-switching time is rather slow. In the GPON system, downstream data is transmitted very fast (at 2.4 Gbit/s) from a telephone office to all users. Given its advantageous features, this system can send multi-channel video streams to users all the time, and an IP multicast function for selecting channels is implemented in the ONU (optical network unit) on the user side. As a result, this system quickly responds to user-requested channels (in less than one second) so that the user can enjoy channel zapping and searching for video programs. The system can also provide more than 100-channel HDTV (high-definition television) streams.



Broadcasting and communication fusion and collaboration platform

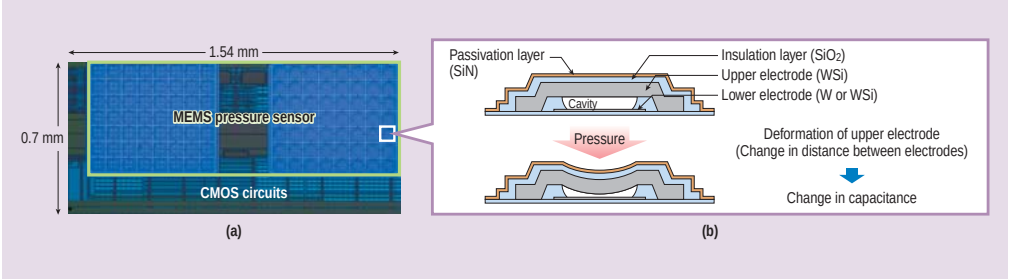
MEMS Pressure Sensor Integrated with CMOS LSI

Hitachi developed a MEMS (micro-electromechanical system) pressure sensor that can be integrated on CMOS (complementary metal-oxide semiconductor) LSI (large-scale integration). The pressure sensor is small (approx. 1 mm^2) and has a low power consumption of 0.6 mA. As compared to conventional planar structures where the MEMS is fabricated adjacent to the LSI, the chip size was reduced to 1/10 and the power consumption was reduced by more than 1/2. This was achieved by developing a MEMS fabrication technique that uses conventional wiring materials and low temperature BEOL (back-end of line) processes.

The MEMS pressure sensor consists of MEMS capacitors, which have cavities between the upper and lower electrodes, analog sensing circuits, and digital control circuits. The capacitance of the MEMS capacitor was changed by applying different pressures, and the capacitance was measured by using a capacitance-to-voltage (C-V) conversion circuit that amplifies and adjusts the offset and span.

This BEOL MEMS fabrication technique may be applied to the monolithic integration of various MEMS sensor types with advanced CMOS LSIs to achieve a compact, low power, and high performance 1 chip multi sensor.

This work was supported by the New Energy and Industrial Technology Development Organization.



Prototype MEMS pressure sensor LSI (a), and cross-section and operating principle (b)

Electroluminescence from Single Crystal Ultra-thin Silicon for On-chip Optical Interconnection

A low-dimensional nanostructured silicon emits light due to the quantum mechanical confinement effects, even though bulk silicon is an in-direct band gap semiconductor. However, conventional structures, such as nano-dots or nano-wire silicon, are covered with a silicon-dioxide insulator, resulting in poor carrier injection efficiency.

Hitachi developed a novel device structure that has an optically active layer consisting of ultra-thin silicon crystals. The structure also has carriers that are laterally injected from highly doped thick silicon electrodes that are directly connected to the ultra-thin silicon layer. Strong photoluminescence and electroluminescence have been confirmed.

The device was fabricated by using conventional silicon processing techniques involving silicon-on-insulator substrates. The device operates as a light-emitting field-effect transistor in which the optical intensity can be controlled by applying bias to the substrate. This also enables a number of small optical switches to be integrated on a single silicon chip. Optical interconnection was demonstrated and an electrical signal was transferred by light and detected on the same silicon chip as photocurrents when the device was operated.

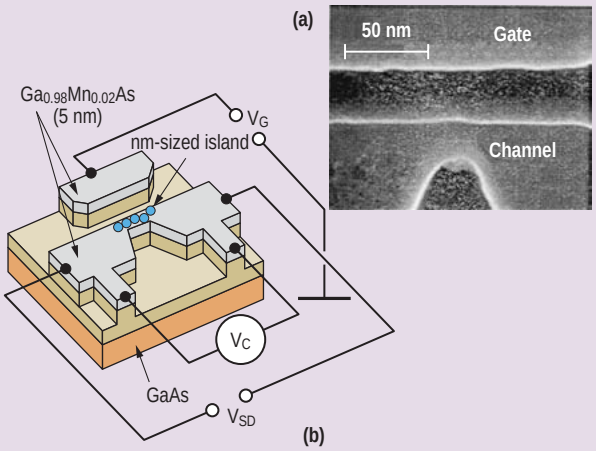
This device might be introduced as a light source to send optical signals to the silicon chips and/or between chips. Next-generation devices will use photonic and electronic devices to manipulate information.

Red region represents strong optical emissions. Wavelength is in infrared range, and actual light cannot be seen by naked eyes.

Electroluminescence from ultra-thin silicon

A Gallium-manganes-arsenide Single Electron Transistors with Proven Controllable Magnetoresistance that Changes Electric Resistance More than 1000-fold

The Hitachi Cambridge laboratory of Hitachi Europe Ltd. joined forces with the University of Cambridge (United Kingdom), the Institute of Physics ASCR (Academy of Science of the Czech Republic) and the University of Nottingham successfully developed a ferromagnetic single electron transistor of gallium-manganes-arsenide. They then found that this transistor exhibits a novel magnetoresistance effect and named it CBAMR (coulomb blockade magnetoresistance), which can change the electric device resistance more than 1000 fold. Strikingly, size and even sign of this large magneto-resistance effect can be electrostatically controlled by a small gate voltage. They observed such very large effects at low temperatures of 4.2˚K (–296.8˚C). This extraordinary large resistance variation depends on the magnetization orientation which can be changed at low magnetic fields of the order of 10 milli-Tesla.



Prototype gallium-manganes-arsenide single electron transistor (a), and its components (b)

This very large magnetoresistance effect at low magnetic fields obtained in the present project dramatically increases magnetic detection sensitivity. It could pave a way for high sensitivity in magnetic head technology to be adopted in hard disk drives having a capacity of more than one Tbit per square inch.

Moreover, CBAMR transistor devices also combine nonvolatile memory and conventional transistor functionalities in a single nanoscale device and could be core-elements of future nonvolatile programmable logic applications.

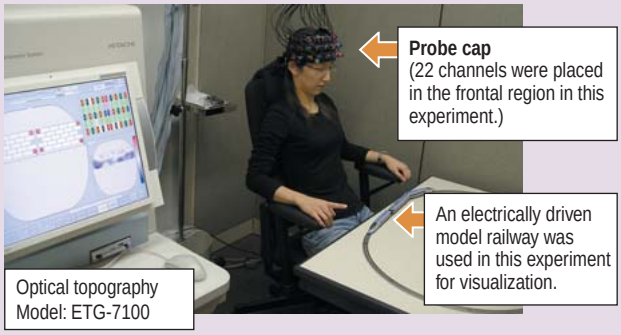
Optical Brain-machine Interface for a Practical Non-invasive Brain Switch

Optical topography is a neuro-imaging method based on NIRS (near-infrared spectroscopy). A brain-machine interface application using this technology [Optical-BMI (brain-machine interface)] was announced by Hitachi and provides a practical unrestrictive non-invasive brain-switch that does not require large equipment.

This developed prototype system allows an operator to manipulate in real-time, electrically-controlled equipment in the external environment without actual physical contact by measuring spatiotemporal changes in the hemoglobin concentration at 22 points in the prefrontal cortex. Each point consists of a pair of infrared light source and detector. These sensors are arranged on a "probe cap" that the operator wears.

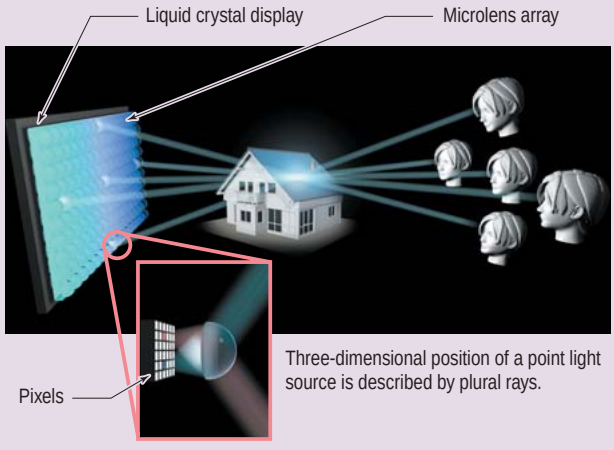
To generate optimal measurement parameters for the operator, the activity patterns specific to the individual are measured during the performance of pre-determined tasks (e.g. mental arithmetic, word recall, short term memory recall) in a "calibration mode." In the "operation mode," the operator repeats the pre-determined task internally over a few seconds to control, in the case of this experiment, the speed and movement of a model railway train.

Possible applications envisioned for this technology are its use as a support device (e.g. communication, equipment manipulation, and rehabilitation) for people with severe neuromuscular disorders or an entertaining educational tool.



Experimental set-up

Autostereoscopic Display for Natural 3D Visual Perception



Principle of integral videography

Despite recent developments in autostereoscopic displays, one of the most important problems that occurs is eye strain. This problem is caused by differences from natural three-dimensional perceptions, such as the discrepancy between the eye's convergence and accommodation, when a user watches an autostereoscopic display.

Therefore, Hitachi developed an autostereoscopic display using what is called integral videography, method to produce autostereoscopic displays that portrays three-dimensional information as naturally as possible. Three-dimensional images can be viewed without the need for special eyewear by controlling the direction of light rays from the display using a microlens array which is an array of a number of small convex lenses. With this structure, vertical and horizontal disparities can be expressed and almost natural three-dimensional ray information can be produced, a unique feature of this system. Rendering movie content in real-time is difficult because integral videography needs large amounts of ray information. However, Hitachi developed a system that can create interactive content by dividing the rendering process into pre-processing and real-time processing. Hitachi is continuing to research and develop a total system, including content, hardware and envisions this technology being used in fields ranging from education and entertainment to medicine and other public applications.

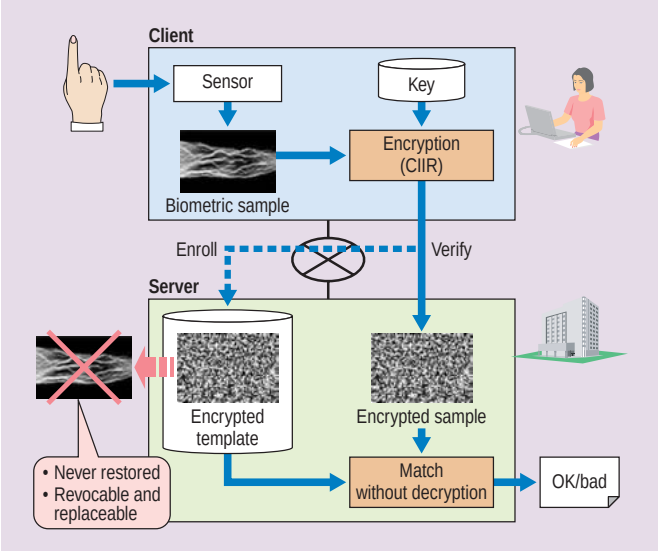
Template Encrypted Biometric Verification

Due to the demands for high security and convenience, biometric authentication is used in access control, ATMs (automated teller machines) and many different identity-verification systems. However, biometric data, such as fingerprints and vein patterns, is a permanent feature that cannot be changed like passwords, and so must be protected securely. The finger-vein authentication systems used in ATMs address this problem using a match-on-card technique in which the biometric template is stored and matched inside a tamper-proof chip on the card.

However, this technique cannot be used to protect biometric data in a remote authentication system in which the template is stored and matched in a remote server.

To protect biometric data in such systems, Hitachi has developed a technique called template encrypted biometric verification. This technique keeps the data secret by using a particular encryption algorithm (correlation-invariant image randomization or CIIR) and matches the encrypted data to an encrypted template without decrypting the data.

By using this technology, biometric data is kept secret from not only eavesdroppers but also from the administrator of the server in a remote biometric system. Additionally, even if the stored data is compromised, it can be canceled and replaced by simply changing the encryption key. This will reduce the risk of biometric compromise and enable a much more secure biometric authentication system.

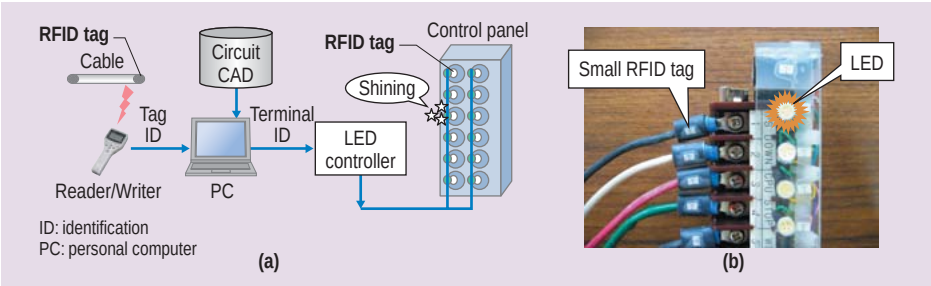


Template encrypted biometric verification system

Application of RFID Technology to Construction of Plants

Hitachi has started developing RFID (radio frequency identification)-applied construction technologies to create highly reliable power plants. A control panel in such an environment requires many cables to be connected to the control panel terminal blocks. As a result, construction workers will carefully have to compare design data to make sure they have properly connected the actual cables. Hitachi focused on using RFID to ensure correct matching between the design data and real objects and to avoid human errors.

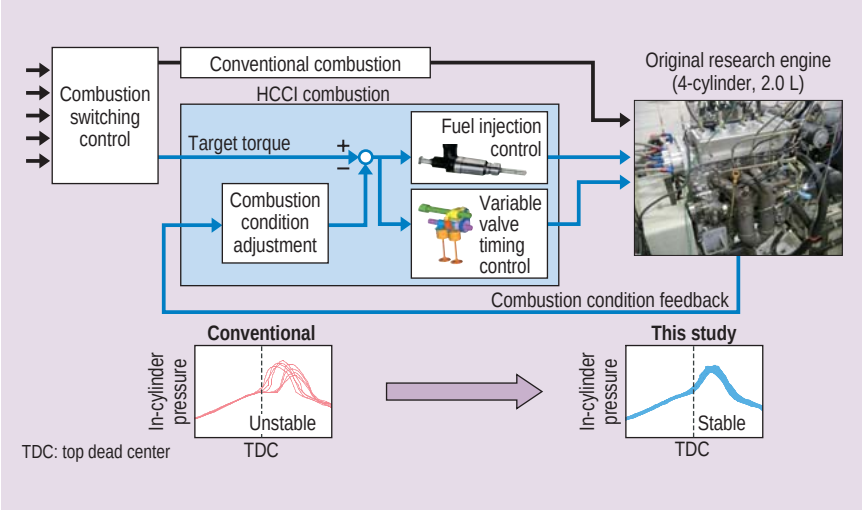
A wiring-navigation system—which automatically assists a worker in joining electric cables to terminals on the control panel—is presently under development. The configuration of this system is shown schematically in Figure (a). The RFID tags in this system are attached to the terminal side and the wiring side. This set-up enables users to determine whether a butt connection is correct and to confirm the wiring condition used in the circuit design drawing. The system imports circuit CAD (computer-aided design) data upstream of the design and the terminal number required for the wiring work, and then displays the center-wire number of the cable by an LED (light-emitting diode).



Application of RFID technology for wire-connection work
(a) Configuration of wire-connection navigation system
(b) Small RFID tags and LED navigation plate

Development of Gasoline HCCI Engine Control Systems

Hitachi is researching and developing gasoline HCCI (homogeneous charge compression ignition) engine systems, which have the possibility to reduce fuel consumption by 20% as compared to conventional gasoline engines. The main focus in this research has been the development of method to control HCCI combustion because this combustion occurs by self-ignition without a spark being ignited. A precise HCCI control method was developed based on controlling the feedback in combustion conditions using in-cylinder pressure sensors and optimizing the variable valve timing controller and fuel injection. Hitachi demonstrated the effectiveness of this method by using its original research engine equipped with VEL (variable valve event and lift) and direct cylinder fuel injectors. This research will focus on developing the world's best and first practical gasoline HCCI engine.



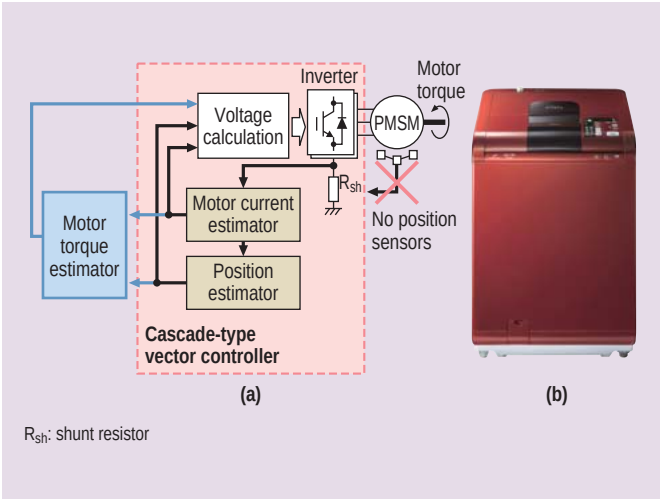
Gasoline HCCI engine control system

Sensorless Drive Technique of PMSMs for Washer-dryers

Hitachi developed the sensorless drive technique of PMSMs (permanent magnet synchronous motors) optimized for washer-dryers. To drive PMSMs, information of the motor rotational position and the motor current are needed. Position sensors are usually used for washer-dryer drives, because high torque is required from low-speed region. However, if the position sensors are attached incorrectly, current distortion and mechanical noise might occur. Therefore, sensorless drive technique for washer-dryers has been desired.

Applying the sensorless drive technique to washer-dryers was big challenge, because washer-dryers have various operation modes and load torque changes quite widely. In order to solve these difficulties, Hitachi developed two original solutions, an accurate torque control and a motor torque estimation method. Accurate torque control is realized by using a novel vector control method named cascade-type vector control. The motor output torque is controlled precisely in extensive motor speed range. The torque estimation method detects the difference of laundry quantity and enables the motor to start-up smoothly. These techniques enable the sensorless drive technique to apply to washer-dryers.

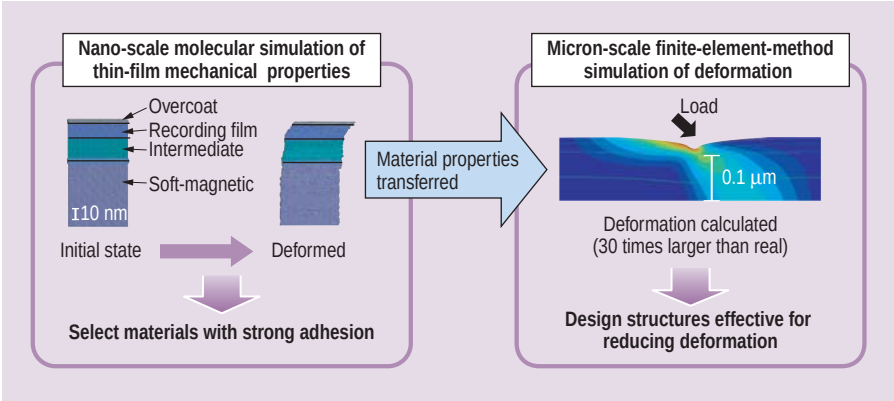
Hitachi continues to expand the application field of the sensorless drive technique.



Block diagram of developed sensorless drive technique (a), and combined washer-dryer model BW-D9GV (b).

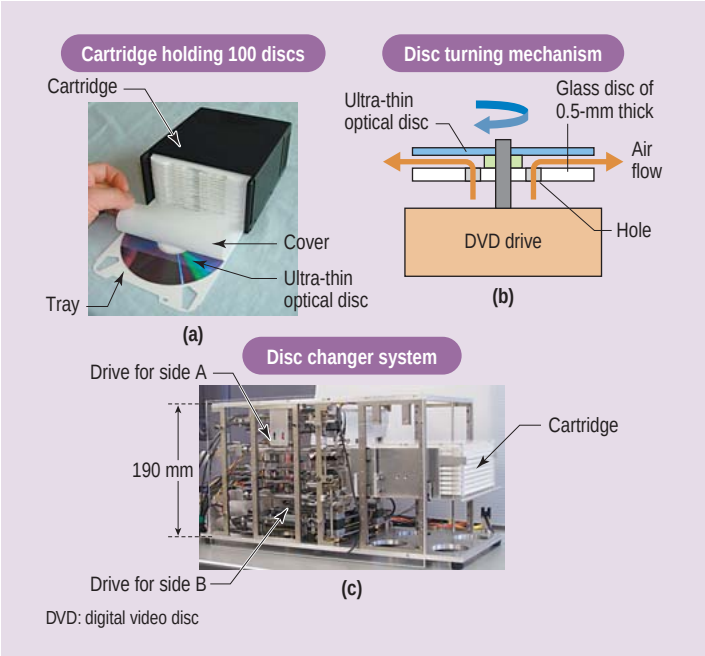
Multiscale Simulation for Nanotechnology Devices

A multi-scale simulation technique was developed that calculates the deformation and stress of nano-scale-film layered structures in nanotechnology devices such as magnetic recording media. This technique consists of a nano-scale molecular simulation that calculates a nano-scale-film's mechanical properties and a micron-scale finite-element-method simulation that calculates deformation and stress. The nano-scale-film properties obtained from the molecular simulation are used as input parameters in the finite-element-method simulation. This technique enables us to investigate multilayer structures of nano-scale-film alloys whose properties and crystal structures cannot be experimentally measured. This work will help to increase mechanical strength and to reduce deformation and stress in various nanotechnology devices such as next-generation magnetic recording media and magnetoresistive heads, and semiconductor devices.



Multiscale deformation simulation of thin-film layered structures

Tbyte-class Ultra-thin Optical Disc Storage Device SVOD

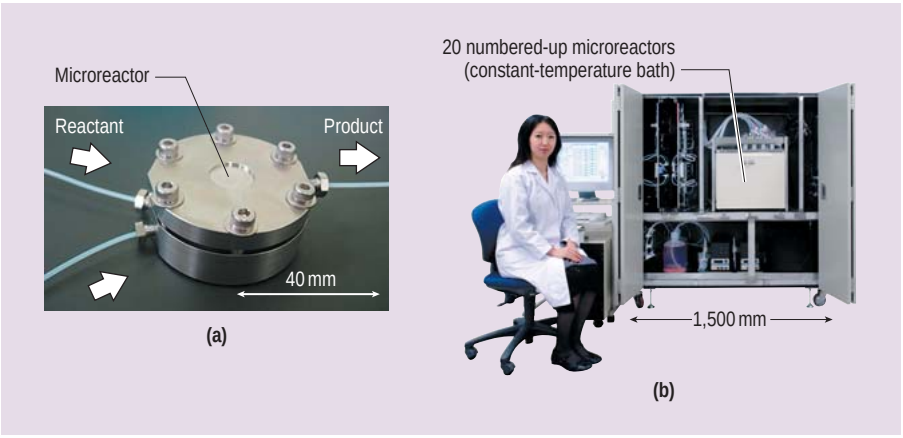


Cartridge holding 100 discs (a), disc turning mechanism (b), and disc changer system (c)

Hitachi, Ltd. and Hitachi Maxell, Ltd. developed an ultra-thin optical disc storage device SVOD (stacked volumetric optical disc) using discs with a thickness of only 0.098 mm.
The 0.94-Tbyte storage capacity of the SVOD is made possible by stacking 100 ultra-thin optical discs in a dedicated cartridge.
Each optical disc is produced using a thin polycarbonate sheet. The land and groove pattern on the discs' surface is precisely formed by using a nanoimprinting technique.
The mechanism to turn the optical disc stably at high speed uses air flow, and enables commercially available optical disc storage devices to read/write on SVODs.
SVOD is targeted for small, large-capacity archives and back-up storage devices.

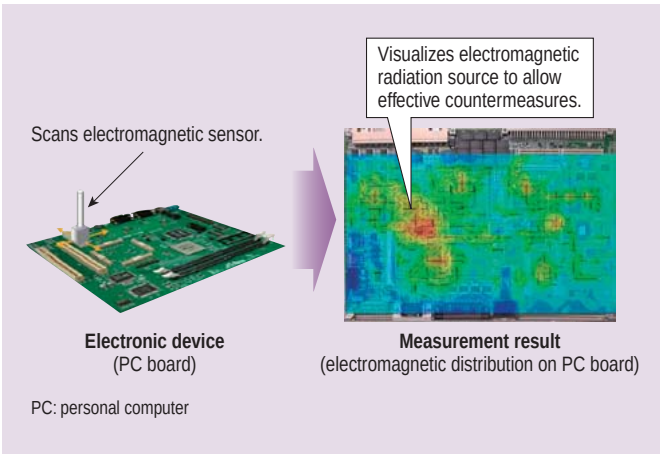
Highly Efficient Control of Chemical Reactions by Using a Pilot Plant with Numbered-up Microreactors

Hitachi developed a micro device, microreactor, for chemical reaction that has a minimum channel width of 25 µm and is made by MEMS (micro-electro-mechanical systems) technology. The yield of the bromination reaction using the microreactor was increased by 40% as compared to a conventional batch method. Moreover, a pilot plant with 20 numbered-up microreactors was developed, and the synthesis of a chemical solution for a maximum of 72 t per year was enabled. The pilot plant does not use a conventional scale-up method but a numbering-up method to increase the number of microreactors. Therefore, the transition from laboratory experiments to production is much quicker. In the future, Hitachi will promote the practical use of pilot plants with microreactors in the manufacture of chemical products and pharmaceutical products.



Microreactor (a), and pilot plant (b)

Electromagnetic Compatibility Techniques for Electronic Equipment



Overview of electromagnetic radiation source visualization technique

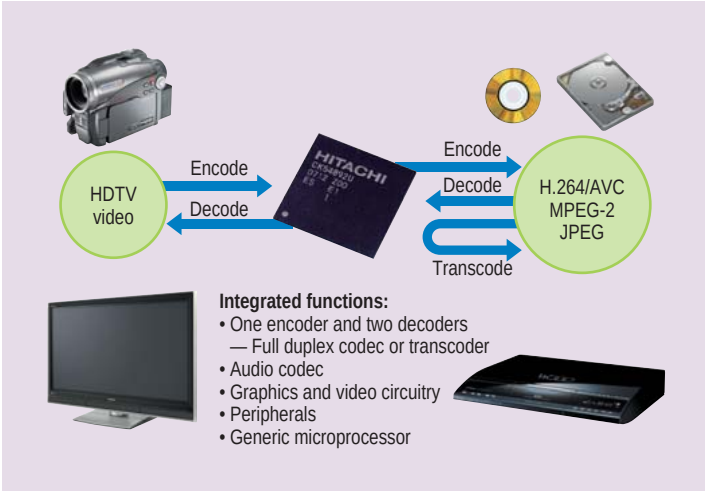
The following two EMC (electromagnetic compatibility) techniques have been developed to suppress electromagnetic radiation emitted from electronic equipment.
(1) A recently developed measurement technique can be used to visualize areas that emit electromagnetic radiation in the product prototyping phase. This will ensure more efficient identification of problem areas and development of appropriate countermeasures.
(2) Design guidelines for circuit designs that are less likely to emit electromagnetic radiation are now available in a database. This tool is intended to improve reliability in the design phase, thereby reducing costs.
This technology will help create environmentally-sensitive products free of electromagnetic emissions.

Single-chip H.264/AVC HDTV Encoder/Decoder System LSI

Hitachi has developed a single-chip HDTV (high-definition television) encoder/decoder system LSI (large-scale integration) that supports multiple video compression formats including H.264/AVC (advanced video coding).

This LSI is targeting digital consumer applications. As HDTV becomes more popular, the demand for H.264 support will increase for the next-generation recording media. Decoding capability and encoding functions are necessary for consumer storage devices, such as PVRs (personal video recorders). Transcoding capability is very useful for converting hours of video data originally encoded in the conventional MPEG (Moving Picture Experts Group) -2 to the more efficient H.264/AVC format.

This is the first HDTV H.264 system LSI that also supports conventional video compression formats, including MPEG-2 and JPEG (Joint Photographic Experts Group). The system includes an encoder core and two decoder cores. These processing cores can work either independently or cooperatively; this means that the chip can support full duplex codec and can act as a transcoder while still allowing the other decoder to decode another bitstream. The LSI also integrates almost all the necessary functions for digital consumer applications, including an audio codec, graphics and video circuitry, peripherals, and a generic microprocessor to control the entire system.

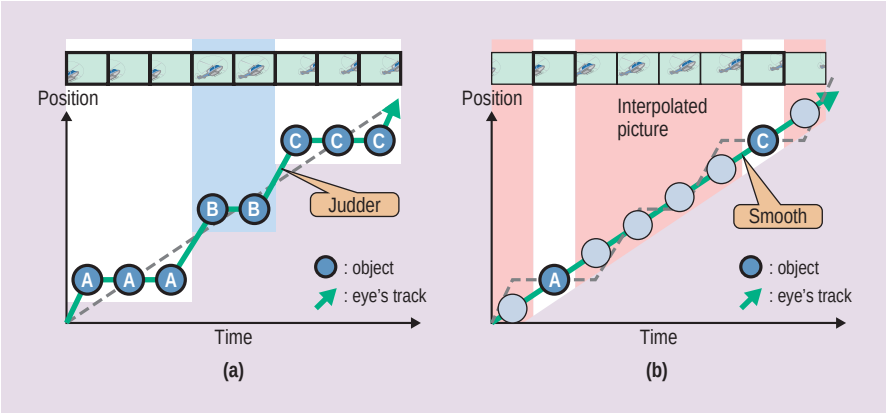


Integrated functions of H.264/AVC HDTV encoder/decoder system LSI

Picture Improvement Technology for FPD TVs

Picture improvement technologies were developed for an FPD (flat panel display) HDTV (high-definition television) that displays cinema content by eliminating motion judder.

Video signals of cinema content from a broadcaster currently transmitting or a DVD (digital versatile disc) player repeat the same frame two or three times to adjust the 24 fps (frames per second) of cinema content to the 60 fps required for TV. Therefore, motion judder caused by the motion errors is sometimes observed. To compensate these errors, interpolated pictures were created from the original cinema frames by using new motion estimation and motion compensation technologies. The interpolated pictures were positioned based on the motion direction of the original cinema picture. Therefore, an FPD TV that has these new technologies can produce an excellent smooth cinema picture without motion judder.



An object position at each frame in cinema content: conventional (a) and newly developed (b)