Components & Materials

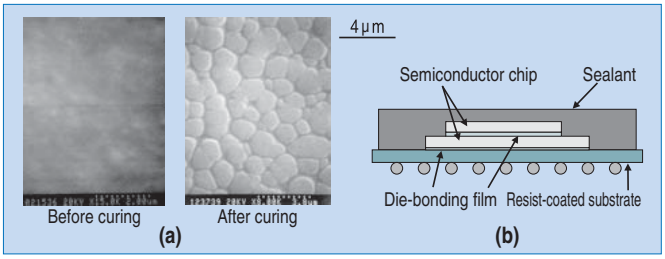
Batteries

Automotive Systems

Materials

Development of Die-bonding Film for Miniaturization and Capacity Enhancement of Electronic Devices

Rapid advances in flash memory capacity in recent years have contributed to improving the functions and performance of electronic devices while also making them smaller. This progress has been underpinned by a die-bonding film for semiconductors developed by Hitachi Chemical Co., Ltd. Along with being thin and flexible, the high level of bonding reliability of this film allows for multilayer mounting of semiconductors, and this is turning the film into the de facto standard for semiconductor layering. In this article, the key people involved in the development and testing of the die-bonding film talk about its characteristics and the development process.



Scanning electron micrographs of epoxy/acrylic polymer alloy (a) and semiconductor package structure (b)

Behind the Scenes Support for Innovation in Electronic Devices

Rapid progress is being achieved in making smartphones and other electronic devices smaller and providing them with higher performance and numerous functions. Major factors behind this are the higher levels of integration and greater capacities being achieved in the flash memories used in these devices. Simultaneously, a die-bonding film developed by Hitachi Chemical Co., Ltd. is providing support for this innovation behind the scenes.

Die-bonding film is a thin film adhesive used to bond semiconductors to circuit boards, other semiconductors, and similar items. While materials like paste were used to bond semiconductors in the past, Hitachi Chemical led the world by developing a polyimide-based die-bonding film in 1995, thereby creating this new field.

Hitachi Chemical then went on to develop a die-bonding film based on reaction-induced phase decomposition using acrylic polymer and epoxy resin in 1998. Using a chemical reaction to cause mixing of different phases resulted in a composite structure in which a curing (thermo-setting) reaction caused the epoxy resin to form particles inside the acrylic polymer. This technique took advantage of the characteristics of both materials, namely the flexibility of the acrylic polymer and the adhesive properties of the epoxy resin.

Opening up Path to Multilayer Mounting of Semiconductors

Since then, developments such as higher mounting densities and thinner semiconductors have increased the performance demands being placed on die-bonding films. Key properties include being easy to handle at room temperature, ease of lamination onto wafers at low temperature (around 60°C) and low pressure, cutting cleanly during dicing, withstanding high temperatures of 260°C or more during soldering, and maintaining reliable adhesion in the finished product. The trade-off between adhesion and heat resistance makes satisfying all of these at the same time a difficult challenge.

In response, working with Professor Takashi Inoue of Yamagata University and utilizing the results of the Project on Nanostructured Polymeric Materials of the New Energy and Industrial Technology Development Organization (NEDO), and also drawing on know-how built up from years of past experience, Hitachi Chemical developed technology for the nano-level control of the phase decomposition structure of the acrylic polymer and epoxy resin. In doing so, it succeeded in developing an even better die-bonding film that is thin, highly flexible, and provides reliable adhesion.

Hitachi Chemical's die-bonding film is becoming a de facto standard in the technology for multilayer mounting of semiconductors, making it an essential component of smartphones, tablets, and other devices. In recognition of this achievement, the product won the Prime Minister's Award, the top prize at the 9th Industry-Academia-Government Collaboration Contribution Awards in September 2011, and also the Award of the Society of Polymer Science, Japan in May 2012.

Combining Development and Testing to Develop Innovative Materials

In the background of these achievements are the accomplishments of Hitachi Chemical's testing and development departments, which have led the world in conducting in-house testing using the same production machinery as its semiconductor manufacturers. In addition to satisfying detailed requirements that differ from customer to customer, this also makes possible the development of more accurate operating procedures. Utilizing this dual capability, which combines both development and testing, Hitachi Chemical will continue to pursue the potential for die-bonding film and other reaction-induced phase decomposition materials.

This current development took on the challenge of utilizing acrylic polymer, a material that in the past was thought to have low reliability for the semiconductor packages, with the basis of its success lying in the use of nano-level structural control of epoxy resin to extract its potential. In the future, Hitachi Chemical intends to continue contributing to society in a variety of different ways by engaging in this sort of innovative material design.

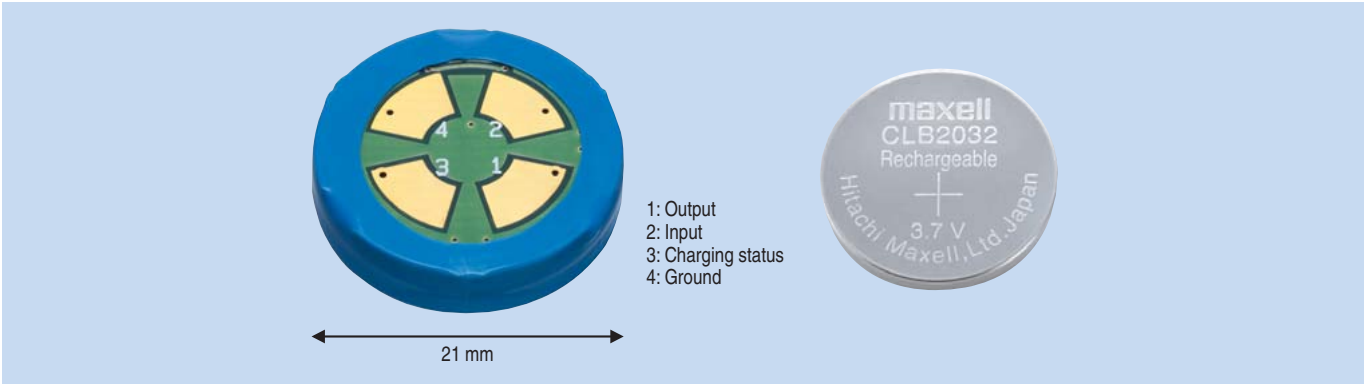
Keiichi Hatakeyama (left), Senior Researcher; Tetsuro Iwakura (middle), Staff Researcher, Telecommunication Materials Development Center; Teiichi Inada (right), Chief Researcher, Fundamental Technology Development Center, Power Electronics Materials Group, Tsukuba Research Laboratory, Hitachi Chemical Co., Ltd.

Coin-type Lithium Rechargeable Battery Unit

Special power sources are needed in various applications, such as electrocardiographs; medical measurement instruments for brain waves, heartbeat, body motion, body temperature, and breathing; wearable devices such as pulse sensors; multifunctional watches; rechargeable hearing aids; headsets; and various sensor networks.

These applications require small, long-life rechargeable batteries that can deliver power at heavy currents.

Hitachi has released a new coin-sized lithium secondary battery that provides a discharge capability of 100 mA in a small and safe battery unit (ϕ21×5 mm).
(Hitachi Maxell Energy, Ltd.)



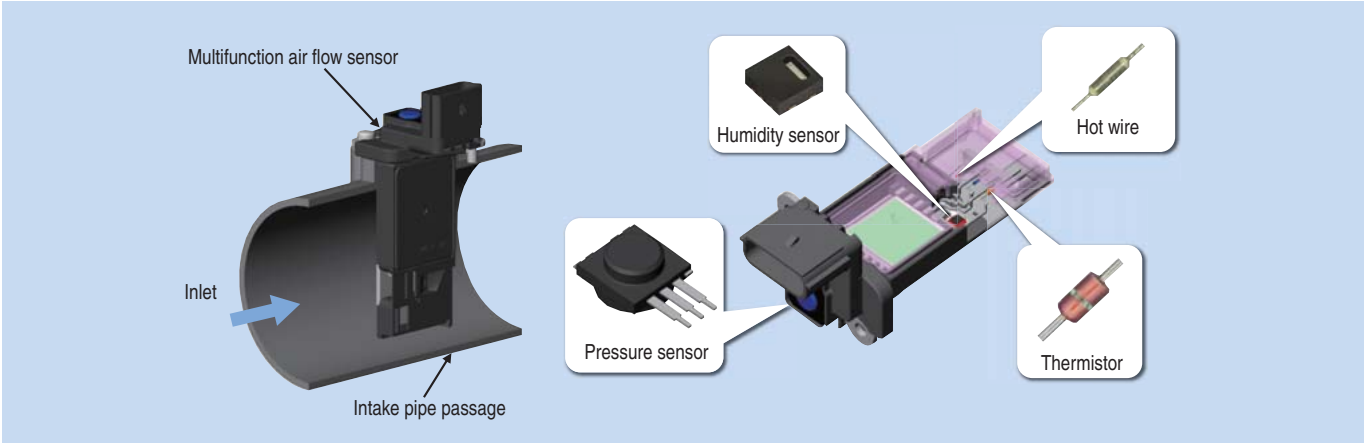
Coin-type lithium rechargeable battery unit (left) and the battery (right)

Multifunction Air Flow Sensor

With increasing concerns over environmental issues and depletion of fossil fuels, regulation has been intensified regarding control of automotive gases and reduction of fuel consumption. To support these regulations, in addition to measuring the air flow taken into the engine, and its temperature, based on the information on humidity and pressure measurements, study has advanced to make the ignition timing of the engine highly precise, and optimize engine torque control.

Hitachi has integrated these detection functions, and has developed a multifunction air flow sensor. The multifunction air flow sensor has a humidity sensor installed in the bypass passage of a hot wire flow meter, which has ample market performance and is reliable; both assuring precise humidity measurement and fouling resistance. In addition, a thermistor type temperature sensor has been integrated with a miniature pressure sensor, integrating various functions for intake air detection into a single product, achieving both miniaturization and high reliability.

With future progress in high performance and high integration, Hitachi will develop the product so that it can support various intensified regulations.
(Hitachi Automotive Systems, Ltd.)



Mounting structure and internal structure of intake pipe passage of multifunction air flow sensor

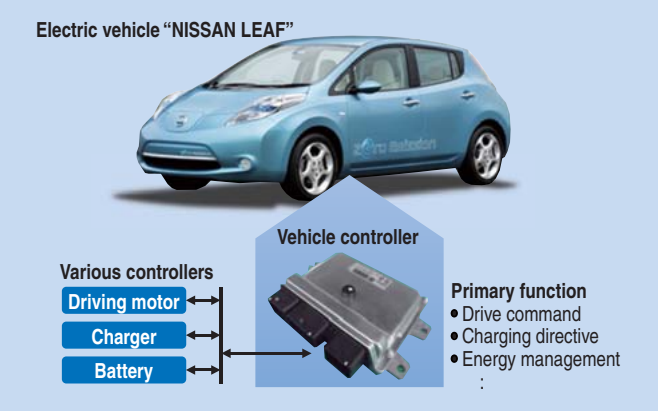
Vehicle Controller for EV

NISSAN MOTOR CO., LTD. developed the NISSAN LEAF* electric vehicle (EV) to help prevent global warming. The car is powered by electricity, which can also be generated from renewable energy, and therefore emits no carbon dioxide (CO_2) during its operation.

Hitachi has developed a vehicle controller for the NISSAN LEAF. The controller controls the EV by outputting driving commands to the drive motor in response to accelerator and gear-shift operations and the state of the battery. Hitachi has drawn on its experience with controllers for gasoline vehicles, which control the engine in response to accelerator operation, and this technology has allowed the new controller to be developed in a short period of time.

The controller also includes a timer charging function (something not applicable to gasoline vehicle systems) and a diagnostic function for testing the timer charging function. The system also uses dual in-vehicle networks. One is the same network used in gasoline vehicles and the other is specific to EVs. An interconnection between the two networks allows units connected to the EV network to be diagnosed using diagnostic devices connected to the gasoline vehicle network.

In the future, Hitachi intends to standardize these technologies to allow their use in a wider range of vehicles.
(Hitachi Automotive Systems, Ltd.)



Vehicle Controller for EV

* See "Trademarks" on page 91.

Fuel Efficient Engine Simulation Technology

Automotive engine fuel consumption and emission regulations have intensified year by year. The systems are increasingly complex, and the increase in the control parameters is accelerating.

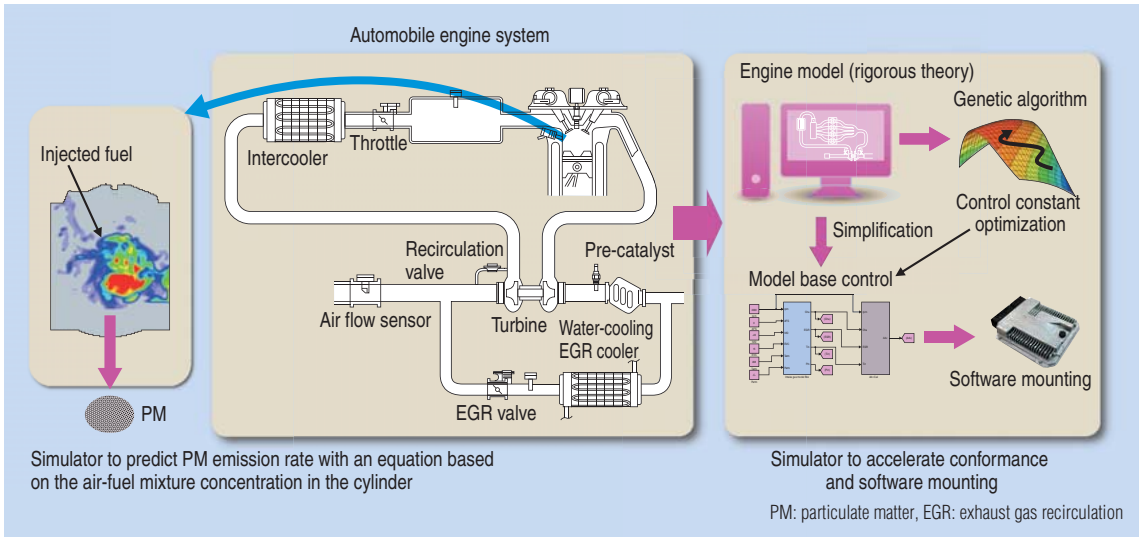
As a response to the advancing engine systems, Hitachi has developed a fuel efficient engine simulation that allows integrated development of combustion improvement technology aiming at enhancing performance (fuel efficiency) as well as model base control technology for it.

It consists of the two major points below.

(1) The combustion simulator in the direct injection engine to predict the emission rate of the exhaust particulates based on the concentration of the air-fuel mixture inside the cylinder.
(2) The engine cycle simulator that can theoretically determine the control model to be mounted on the engine control unit and the control constants, based on a unique model that introduces a genetic algorithm into the rigorous theory.

Using this simulator, parts specification of an engine fuel system and ignition system aiming at environmental protection, and the high precision control model for them can be developed in a short period of time.

In the future, while enhancing development cost competitiveness using the technology, Hitachi will seek to shorten the development cycle for novel fuel efficiency enhancement technology.
(Hitachi Automotive Systems, Ltd.)

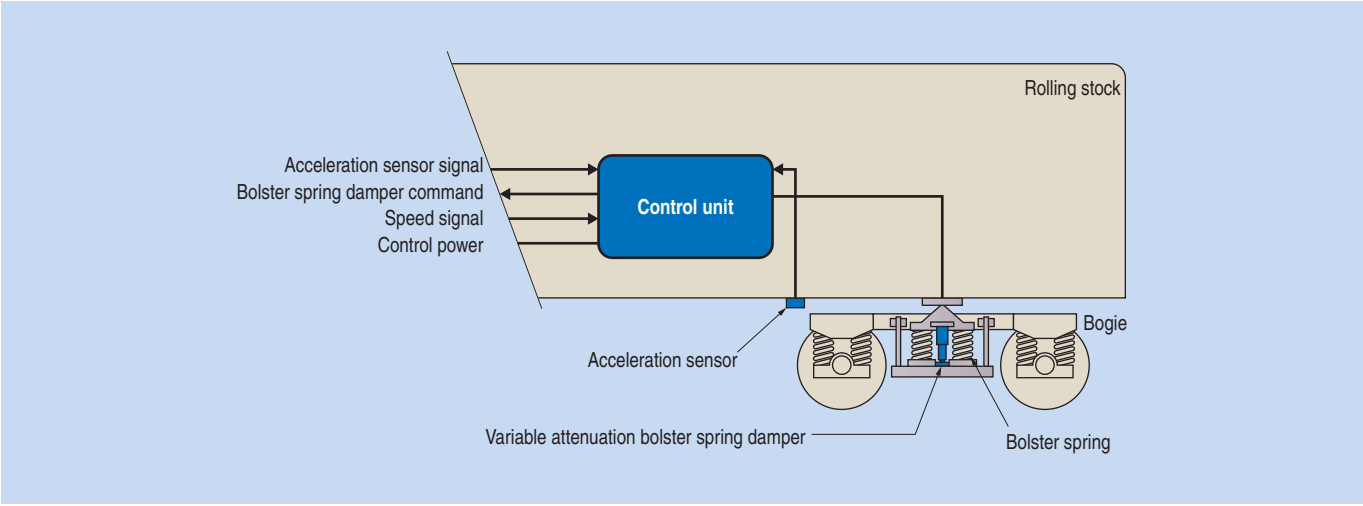


Integrated simulation of engine combustion (PM emission rate) and engine control

Variable Damping Force Damper System for Rolling Stock

A variable damping force damper system is a system that carries a damper in which damping force can be varied continuously to achieve enhanced ride comfort at a low cost. The vibration control system, co-developed with the Railway Technical Research Institute, reduces the vertical vibration of the vehicle by controlling the damping force of the damper. For the first time in the world, this newly developed system has been mounted on railway rolling stocks for practical use.

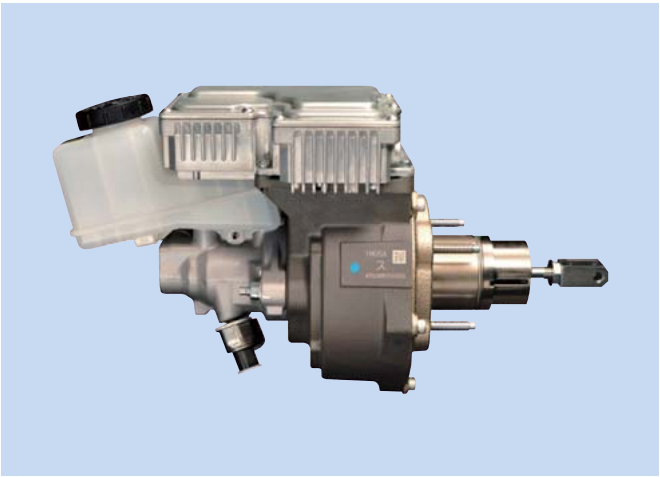
This system has been mounted on a tourist express of the Kyushu Railway Company named "Ibusuki no Tamatebako" (treasure chest in Ibusuki) (between Kagoshima-chuo and Ibusuki of the Ibusuki-Makurazaki Line) and has started commercial operation in March 2011. The new damper system is contributing to greater ride comfort on tourist express trains, and Hitachi is working toward having the damper system adopted on a wider range of rolling stock in the future, including on local lines.
(Hitachi Automotive Systems, Ltd.)



Variable damping force damper system for rolling stock

Electrically-assisted Actuation

Hitachi has developed electrically-assisted actuation that coordinates regenerative braking with the drive motor of hybrid electric vehicles and electric vehicles to assure the requisite braking force with a natural pedal feel.



Electrically-assisted actuation

Instead of the conventional vacuum booster, it utilizes a simple system to produce master cylinder hydraulic pressure with a hollow motor and its internal ball screw as actuator, therefore it is relatively easy to replace conventional braking systems, if by any chance electric power is not supplied at all, it can assure braking power as a friction brake by means of pedal force from the pedal (the motor is made by Hitachi Car Engineering Co., Ltd.). In addition, due to its advanced hydraulic controllability, it is scalable to the intelligent transport systems (ITS) function. This product is utilized in Nissan Motor Co., Ltd.'s "FUGA HYBRID" and "Nissan LEAF."

Promoting the spread of this technology by means of further cost reduction and miniaturization, Hitachi will contribute to reduced automotive fuel costs and cleaner emissions.
(Hitachi Automotive Systems, Ltd.)
(Start of mass production: October, 2010)

Navigation Application for Smart Devices

Hitachi has developed a software navigation application for smartphones, tablets, and other smart devices that makes it easy to modify, customize, and optimize navigation functions in response to changing business needs.

Its features include functions for displaying points of interest (POI) or spot information on the navigation map screen based on its location. This includes various information on road conditions, such as hazards, that has been collected by companies that operate commercial vehicles, and specified as company-defined POI. The navigation application also includes functions for performing route searches and generating route guidance using these company-defined POI and road conditions as well as predefined POIs.

Traditional navigation systems have had a number of problems, especially when used in commercial vehicles. These include a lack of flexibility, making it difficult to customize their user interfaces to suit specific user requirements, and also a lack of hardware flexibility due to the fact that, once purchased, the hardware is often not replaced for five to 10 years. This makes it difficult for the systems to keep pace with advances in information and communication technology (ICT).

The new navigation application incorporates the following features to overcome these problems:

(1) Architecture supports flexible customization

Based on the popular Android framework for smart devices, Hitachi has designed and implemented a navigation application program interface (API) that allows business applications to invoke navigation functions and implement required functions with flexibility, while keeping pace with advances in hardware, communications, and other technologies.

(2) Customization of HMI

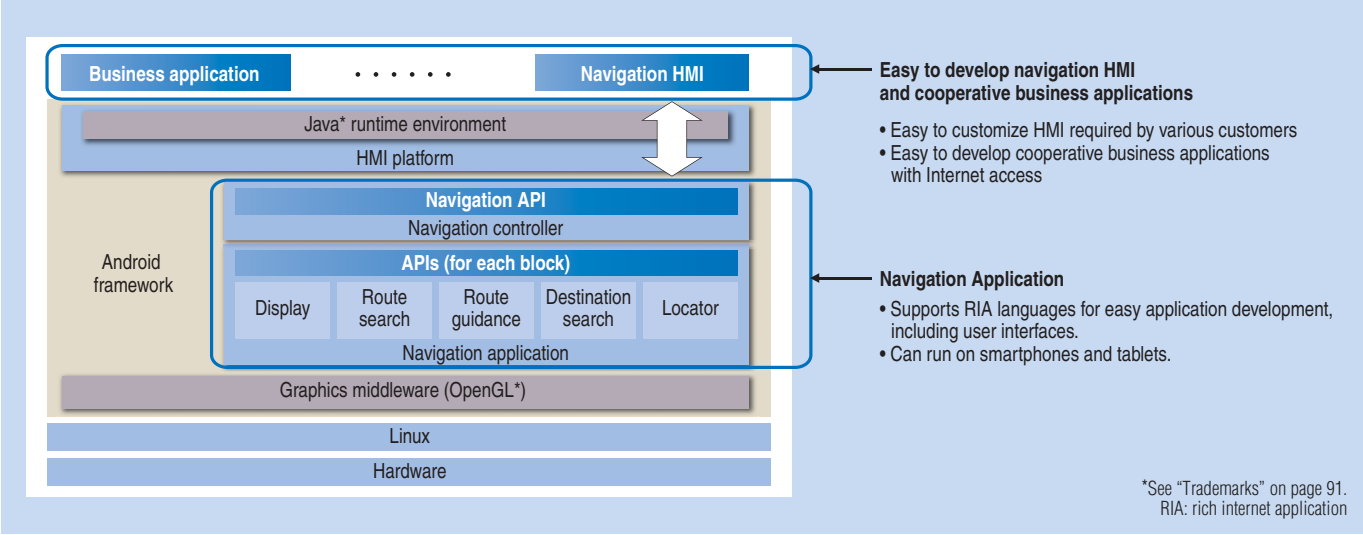
As the navigation API, navigation human-machine interface (HMI), and business applications are kept independent, it is easy for an application programmer to invoke appropriate navigation functions and customize the HMI as required, even if they are not a navigation system developer.

(3) Integration with business systems

Functions such as receiving and updating information, or sending probe data, can operate in realtime via the Internet connection that is a standard feature of the Android framework. Also, highly flexible and useful business applications can be implemented easily using a media player function and other standard functions.

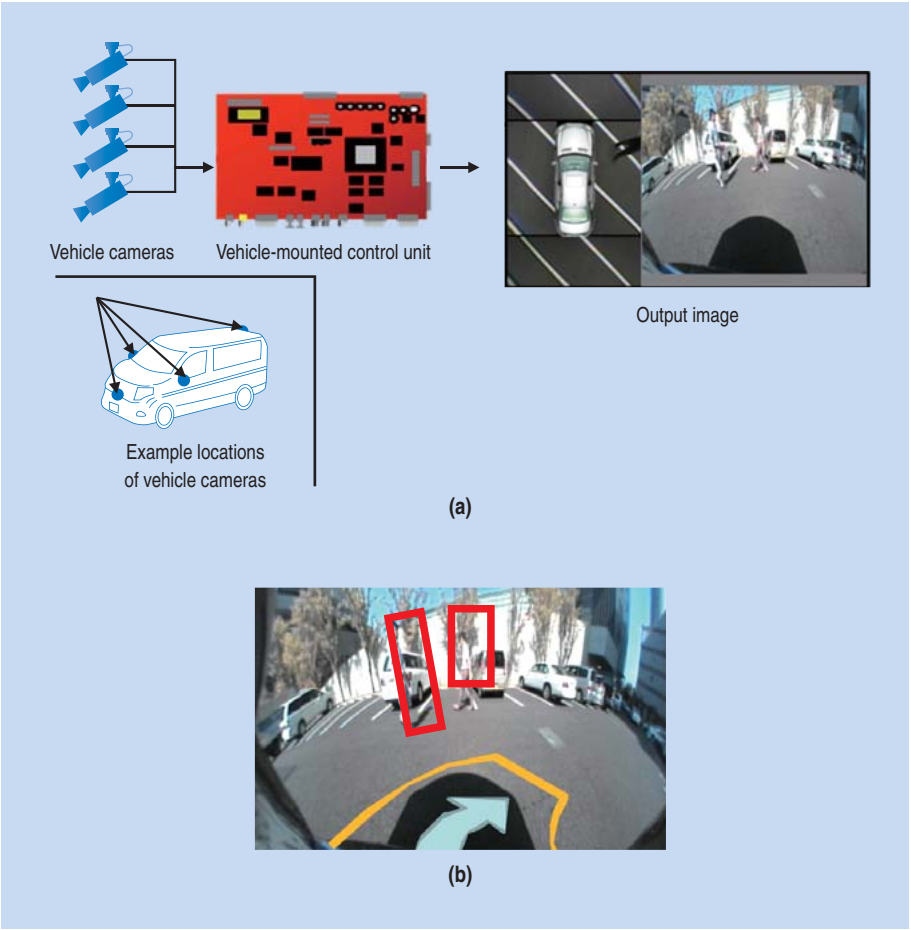
To harmonize and enhance convenience for users of commercial vehicles, Hitachi has integrated the navigation application with a telematics service and location based service for commercial vehicles provided by Hitachi Solutions, Ltd.

(Hitachi Automotive Systems, Ltd.)



Structure of navigation application

Application of Image Recognition to Vehicle Periphery Monitor System



Cameras and overhead view (a), and detection of moving objects in rearview image (b)

The overhead view monitor (OVM), vehicle periphery monitor system, uses cameras to monitor the surroundings of a vehicle during parking and improves safety by minimizing blind spots. The system also incorporates image recognition to prevent accidents by warning of any pedestrians or other moving objects around the vehicle that the driver may have failed to notice. In addition to the immediate vicinity of the vehicle, the recognition function can also extend its range for detecting moving objects using the forward or rear images based on the vehicle's direction of movement.

The OVM system synthesizes a bird's eye overview image. As any people projected onto the overview image appear distorted, use of pattern recognition to detect them is difficult. The way the image recognition technique used in this system works is to calculate the enlargement ratio of the image field and the multiresolution optical flow. This allows it to detect any pedestrians in the vicinity of the vehicle, or walking into its path, while the vehicle is still moving at low speed.
(Clarion Co., Ltd.)

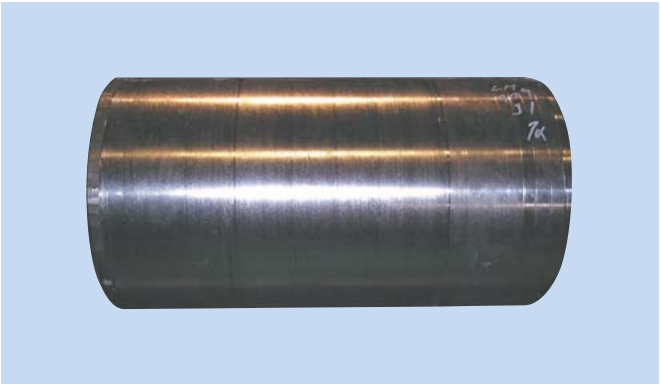
High-temperature Ni-based Superalloy for Stream Turbines

To improve the thermal efficiency of coal-fired power plants, Hitachi has developed a new nickel (Ni) superalloy for use in advanced ultra-supercritical (A-USC) steam turbines.

The high-temperature (700°C) strength of the new Ni-based alloy is more than twice that of conventional superalloys, allowing it to be used at temperatures up to 800°C. Meanwhile, a technique for control of precipitation volume gives the material an excellent balance between high-temperature strength and manufacturability.

While the production of large forgings made of high-strength, Ni-based superalloy is known to be difficult, Hitachi successfully forged a large ingot of the new Ni-based superalloy with a weight of 3 t, a diameter of 800 mm, and high quality.

This research was funded by the New Energy and Industrial Technology Development Organization (NEDO).



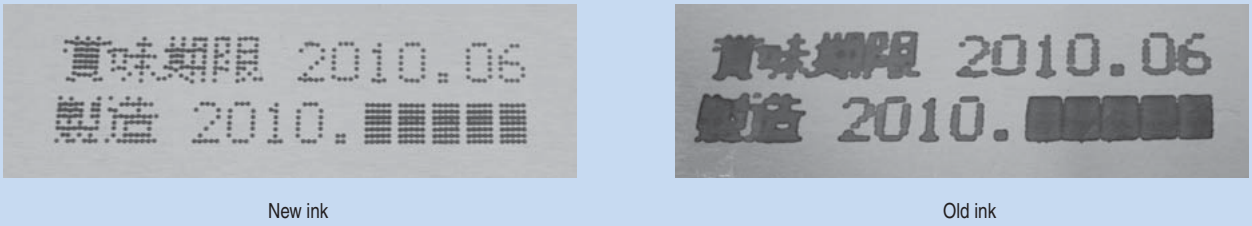
800-mm large-diameter ingot

Ethanol Ink for Industrial Inkjet Printers

Industrial inkjet printers are used in a variety of industries, including the food industry. While methyl ethyl ketone, which has excellent fast drying properties, is widely used as the solvent component of ink, there are calls for its replacement with ethanol, a solvent that places less of a burden on the environment.

By analyzing the molecular structure of inks and how they spread when applied during printing, Hitachi has now developed an ink with excellent legibility that is less prone to smudging than previous inks that used ethanol as a solvent. Hitachi Industrial Equipment Systems Co., Ltd. has released a new industrial inkjet printer that uses this ink and that has been taking orders since September 2011 in Japan.

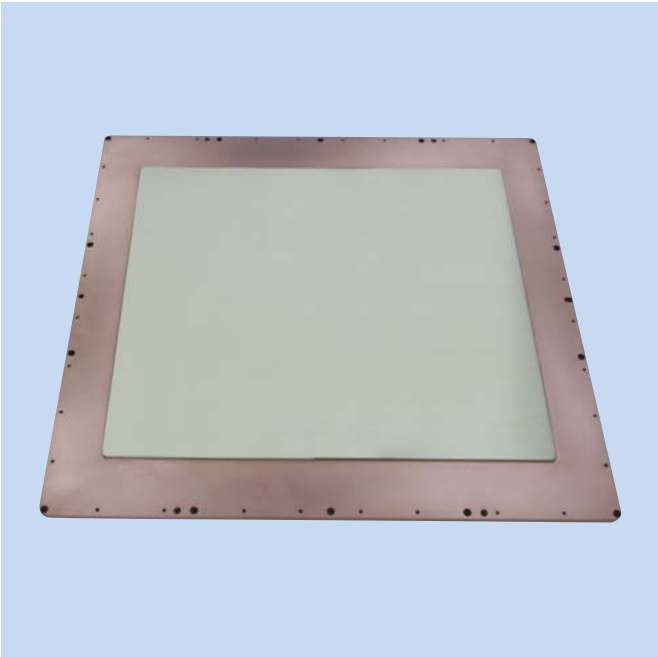
Hitachi intends to market the new printer to a range of industries, including for use on aluminum cans in the beverage industry.



New ink　　Old ink

Comparison of new and old inks

CuGa Target Material for CIGS Solar Cells



Cu30Ga (at%) target material

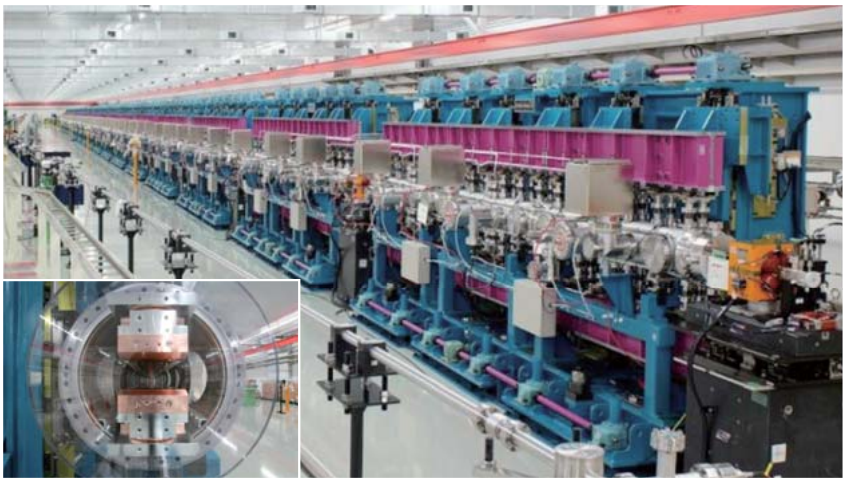
Although crystalline silicon (Si) solar cells are the mainstream at present, due to silicon supply shortages, high prices, and other problems, thin-film solar cells have been drawing attention due to their ability to hold down manufacturing costs. Of these thin-film solar cells, those that use a compound of copper (Cu), indium (In), gallium (Ga), and selenium (Se) known as "CIGS" [Cu (In, Ga) Se_2] instead of silicon provide a high level of conversion efficiency when compared to other thin-film solar cells, and are expected to experience rapid market growth. Hitachi has developed a CuGa target material that can be used in a uniformly fine CIGS layer (light absorption layer) for these products, and which is characterized by both high density (with a relative density of 99% or higher), and high purity (with a purity level of 99.99% or higher).

Hitachi is expanding sales both in Japan as well as in other countries, and has plans to start mass production.
(Hitachi Metals, Ltd.)

In-vacuum Undulators for XFEL

The SACLA, x-ray free electron laser (XFEL) facility in Japan, began operations on March 7th, 2012. NEOMAX ENGINEERING Co., Ltd. manufactured the undulators that serve as the heart of this facility.

An undulator is a device comprised of multiple magnets arranged in a line, in such a way as to create an alternating magnetic field. Electrons that have been accelerated to almost the speed of light pass through the alternating magnetic field of the undulators, causing them to follow a sinusoidal path and generate synchrotron radiation. The XFEL uses resonance to increase the strength of this synchrotron radiation even further, thereby creating an x-ray laser beam that enables tasks such as the analysis of material structure at a more advanced level.



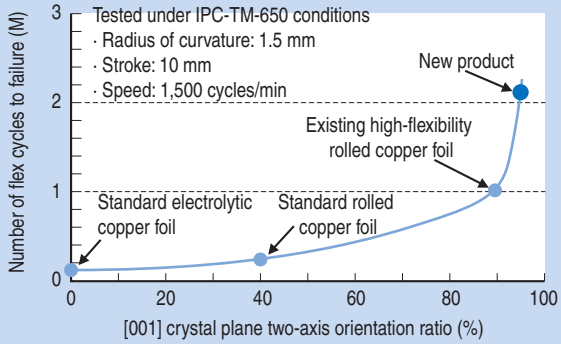
XFEL in-vacuum undulators and magnetic circuit parts (bottom left)

Hitachi's undulators, which made this XFEL possible, are in-vacuum undulators that send electron beams over a series of magnets enclosed within a vacuum chamber. This enables a reduction in the size of gaps between magnets, which in turn makes it possible to generate a magnetic field with the short period length and high magnetic flux density necessary to produce a short-wavelength laser. By using an array of 18 undulators with a high-precision magnetic field distribution, a period length of 18 mm, a peak magnetic flux density of 1.3 T, and a magnetic circuit length of 5 m, SACLA has succeeded in generating an XFEL pulse as short as 10 trillionths of a second at 0.063 nm, the shortest wavelength in the world.

Hitachi's undulator manufacturing technology is widely praised both in Japan as well as in other countries, and has been adopted for use in synchrotron radiation facilities around the world.
(NEOMAX ENGINEERING Co., Ltd.)

Ultra-flexible Rolled Copper Foil

Rolled copper foil for FPCs (thickness: 12 μm)



Rolled copper foil for FPCs (top) and graph of relationship between [001] plane two-axis orientation ratio and number of flex cycles to failure (bottom)

A high degree of flexing characteristics is demanded in applications such as the repeatedly movable parts of the hinge in a mobile phone or the flexible printed circuit (FPC) boards used to fit into the small spaces inside a smartphone. Making FPCs more flexible requires greater flexibility in the copper foil used as a conductor and the rapid shift to smaller and slimmer designs in recent electronic devices has seen this demand become progressively more stringent with each passing year.

To satisfy this demand, Hitachi has developed an ultra-flexible rolled copper foil with even greater flexibility than existing high-flexibility rolled copper foil. The new product achieves approximately twice the flexibility of existing high-flexibility rolled copper foil by using a high degree of two-axis orientation control of the [001] crystal plane (this is equivalent to approximately 10 times the flexibility of standard rolled copper foil and 20 times that of standard electrolytic copper foil). Also, because the addition of minute quantities of alloying elements maintains this flexibility despite heat treatments over a wide range of temperatures, a variety of different temperature patterns can be used during the FPC's copper-clad laminate process.

Hitachi intends to proceed with commercializing this new copper foil and utilize it in a wide range of applications.
(Hitachi Cable, Ltd.)