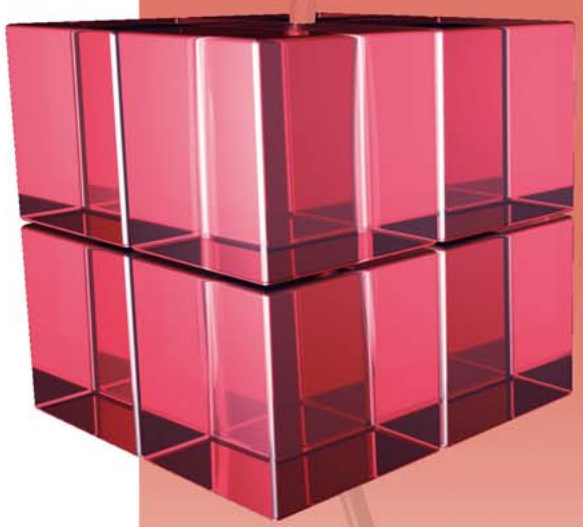
HITACHI TECHNOLOGY
2007-2008

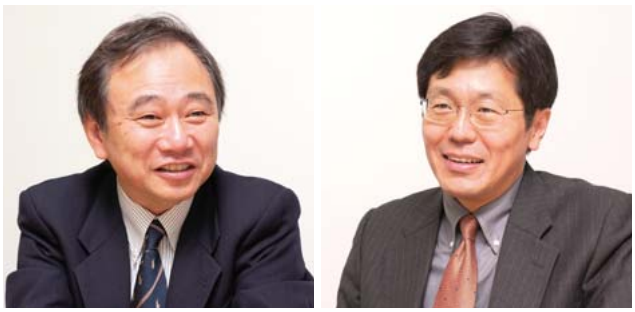
Infrastructure Technology/Products

Hard Disk Drives
Semiconductors
Displays
Materials



Successful Mass Production and Further Evolution of HDDs Using the Perpendicular Magnetic Recording

In today's ubiquitous information society, the recording capacity required of HDDs (hard disk drives) has continuously increased due to the growing amounts of data being handled on PCs (personal computers) and the proliferation of digital image devices. The Hitachi Group has put to practical use the perpendicular magnetic recording, expected to be a next-generation recording method, to achieve greater capacity and has succeeded the mass production of a 2.5-inch HDD model using this recording method. Based on this achievement, Hitachi will now focus on achieving even larger capacity with enhanced reliability.



Dr. Yuzuru Hosoe (left), Chief Researcher, Storage Technology Research Center, Central Research Laboratory, Hitachi, Ltd.; Hisashi Takano (right), Senior Director, World-Wide AdTech Laboratory, Hitachi Global Storage Technologies, Inc.

What is the Perpendicular Magnetic Recording?

Among the magnetic recording technologies typified by the HDD, the horizontal (within the surface) magnetic recording has nearly reached the physical limits of high density. Based on a perception of this situation, Shunichi Iwasaki, honorary professor at Tohoku University (and currently president of Tohoku Institute of Technology) devised the perpendicular magnetic recording in 1975. When information is recorded using this method, the magnetic head magnetizes fine magnetic particles on the recording media in the perpendicular direction so that adjacent magnetic particles do not repel each other and stability is ensured, allowing even higher densities. The Hitachi Group worked on developing practical applications in cooperation with industry and academia, and in July 2006 began mass-producing of a 2.5-inch HDD model using the perpendicular magnetic recording.

What was the Key to Success of Mass Production?

The most important element is the abundant research and development resources possessed by the Hitachi Group. Mass production entails the use of different conventional technologies in every aspect of technological design such as the materials and structures of recording media and magnetic heads. Moreover, production technology requires higher levels of accuracy and reliability than can be provided by conventional technology. The development of these technologies entailed establishing a cooperative organization among the various laboratories involved, which resulted in speedy mass production.

More specifically, the key technologies involve the properties of resistance to external magnetic fields and corrosion. In the perpendicular magnetic recording, magnetization is simplified by employing dual recording media where the soft magnetic underlayer that attracts the magnetic field from the magnetic head is positioned under the recording layer to enhance the recording property. Although this soft magnetic underlayer posed a problem of being sensitive to external magnetic fields, optimizing the magnetic head structure improved the property of resistance against external magnetic fields. Moreover, since rust tends to form faster under higher magnetism, elements to be added were elaborately chosen in order to improve corrosion resistance.

Before starting mass production, we mounted a number of proto-drives on notebook PCs and conducted field tests since December 2004. The results of these tests were reflected in subsequent mass production to ensure reliability equivalent to or better than that conventionally possible. Since then the drives have passed strict examinations by major customers and been implemented in a number of products.

HDD implemented with the perpendicular magnetic recording method

What Activities are Needed for Further Evolution?

A recording density of 345 Gbits per square inch (equivalent to 2 Tbytes on a 3.5-inch HDD) was achieved at the laboratory level in September 2006 and a 3.5-inch HDD with 1-Tbyte capacity will be commercialized in 2007. Even higher densification requires technologies for stable recording even with limited magnetic field intensity. Therefore, a structure for easy recording is being developed using heat to set a smaller distance between the magnetic head and recording media. Moreover, since control in this technical field already requires a factor of nanometers, the production technology must further evolve. In perceiving the future, research on innovative development is now underway to further miniaturize the bits of information with a fine patterning of media or heating an extremely small region by optical spotting. We will continue contributing to the ubiquitous information society by achieving even larger capacity and higher reliability of HDDs utilizing the Hitachi Group's broad organizational establishment for research work.

The achievement described above was made possible through research and development conducted at ASET (Association of Super-Advanced Electronics Technologies) as part of a super-advanced electronic technology development promotion project undertaken by the Ministry of Economy, Trade and Industry in Japan and NEDO (New Energy and Industrial Technology Development Organization) during fiscal years 1995 to 2001, and through further research and development conducted by Hitachi Global Storage Technologies.

One-terabyte Hard Disk Drive

Hitachi Global Storage Technologies (Hitachi GST) announced the industry's first 1-terabyte HDD (hard disk drive) in January 2007. Hitachi's terabyte HDD targets three distinct application areas: The Deskstar 7K1000 is targeted towards gaming and high-performance PCs (personal computers), external storage devices, and PC upgrades; the CinemaStar 7K1000 is used to optimize set-top box and digital video recording applications; and finally, the new Ultrastar A7K1000 was developed for lower duty cycle enterprise applications. The 7K1000 hard drive is the next generation of its successor, the Deskstar 7K500, which remains a highly successful and popular product with customers. The 7K1000 series of products features a 3.0-Gbit/s serial-ATA interface and a 32-MB data buffer to deliver high performance for a wide variety of target applications.

The Deskstar, CinemaStar, and Ultrastar terabyte HDDs are built using the industry's most reliable PMR (perpendicular magnetic recording) technology, which delivers higher recording densities than normal. The products' features include reduced air turbulence for extremely accurate positioning, low power, low acoustic noise, and best-in-class RV (rotational vibration) robustness. As capacity is increased, the recording density must be also increased. This higher density requires a more robust design, and these three technologies are the key to supporting a 1-terabyte HDD.

Hitachi GST's second-generation PMR technology provides more improved magnetic stability than the first generation and, thus, contributes to higher recording densities, higher performance on data transfer rates, and greater reliability. The 7K1000 series of HDDs also incorporates a TMR (tunneling magneto resistance) read sensor that is highly sensitive to the disk magnetic field. The incorporation of a TMR head allows the drive to achieve an extremely low error rate, which significantly improves the overall reliability. With PMR technology, the 7K1000 hard drives have a 38% larger track density than the previous generation of products.

A high amount of air turbulence degrades not only the position accuracy, but also the drive's power consumption due to increased loads to the motor current and acoustic noise. The 7K1000 incorporates a new feature in the mechanical design that reduces air turbulence. With a narrower gap between the disk and base-plate and the newly designed air spoiler, the air turbulence is significantly reduced. As a result, the 7K1000 series has a 6.2% lower power consumption and a 6.5% lower acoustic noise than the previous generation.

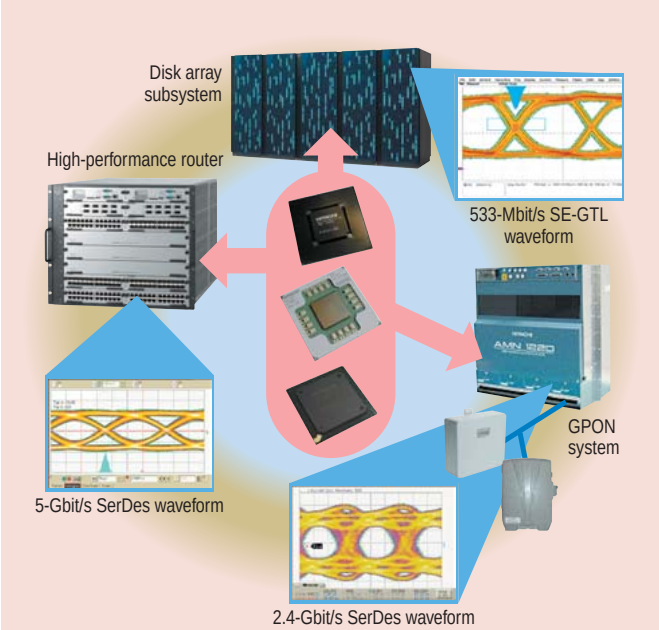
Storage systems that incorporate multiple HDDs require robust rotational vibration safeguard technology. Rotational vibration comes from the motion of neighboring HDDs in a system, and the resulting motions affect read/write performance. The previous generation Deskstar 7K500 series of products used a digital filter as a rotational vibration safeguard. However, the effective frequency band was narrow, and, therefore, the effectiveness was dependent upon the mechanical structure of storage system. A new analog filter used in the 7K1000 series has a wide frequency band, and this improved the rotational vibration robustness. When this new functionality was compared, performance degradation was reduced by 50% with equivalent RV levels.

(Hitachi Global Storage Technologies)

One-terabyte hard disk drive

CMOS ASIC with High-performance Serial Interface for Information Systems

Hitachi has successfully commercialized a group of CMOS (complementary metal-oxide semiconductor) ASIC (application specific integrated circuits) LSI (large scale integration circuit) based on 140-nm node and 110-nm node technologies, and provided with a high-speed serial transmission interface for information processing systems. In the ASIC system, the CBIC (cell based integrated circuit) or EA (embedded gate array) can be selected according to use of the application system. To achieve large-capacity packet transfer processing in the gigabit router unit, 48 channels are mounted for the SerDes (serialization/de-serialization) interface, with each channel operating at 5 Gbit/s. The SerDes interface can cope with transmission speed switching in the range of 1.25 to 5.0 Gbit/s. The GPON (gigabit passive optical network) unit is miniaturized thanks to a 1.2/2.4-Gbit/s SerDes interface provided for burst bit synchronous transfer. These SerDes interfaces are also equipped with an automatic cable slip-off detecting function and a BIST (built-in self-test) function to ensure reliability. The large-capacity RAID (redundant arrays of independent disks) storage unit is provided with a 533-Mbit/s SE-GTL (single end gunning transceiver logic) interface to significantly improve throughput. In the future, Hitachi intends to adopt an ASIC of 90-nm node to support SerDes interfaces operating up to 10 Gbit/s.



CMOS ASIC with high-performance serial interface for information systems

VGA Resolution IPS Low-temperature Polysilicon TFT LCD for Digital Still Cameras

2.98-inch VGA IPS-Pro

The performance of DSC (digital still camera) is constantly improving, especially increases in the number of CCD (charge coupled device) pixels (now over 10 M pixels has been launched). The demand for high resolution affects LCD (liquid crystal display). The VGA (video graphics array) resolution LCD requires a dot number four times that of currently available products. To meet market demand, Hitachi developed a VGA LCD based on low temperature polycrystalline TFT (thin film transistor) technology and its active size is 7.6 cm in diagonal. The display has high performance color reproductivity based on IPS (in-plane switching) optical technology and of good readability under the sun based on tiny reflective technology.

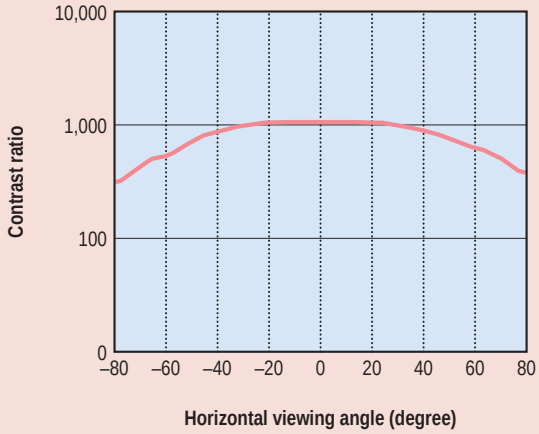
[Main features]

(1) Dot number: 640 (H) × 480 (V)
(2) Active size: 7.6 cm (2.98 inches)
(3) Viewing angle: over 170°
(4) Color gamut: 50% (NTSC)
(5) Interface: RGB 24 bits digital interface

(Hitachi Displays, Ltd.)

A 37-inch Diagonal LC Module for LCD TVs

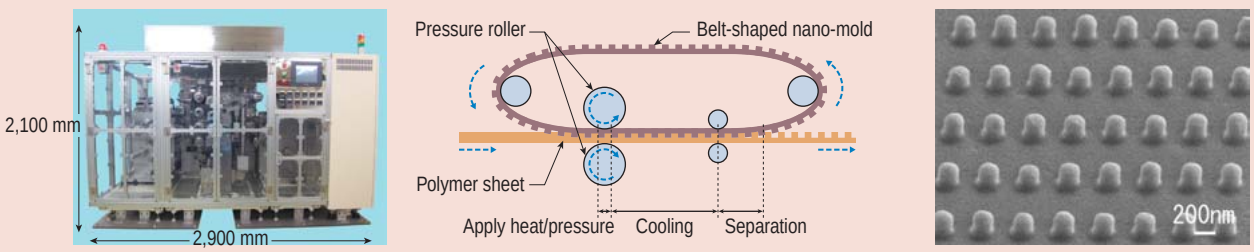
IPS (in-plane switching) is a horizontal electric-field type liquid crystal mode that provides superior super-wide viewing angle for users. The technology was first announced by Hitachi in 1995, and the following year the company used this technology in its actual products. This technology has also been used in LCD (liquid crystal display) -TVs, including the 26-, 32-, and 37-inch diagonal models, in IPS Alpha Technology, Ltd. products since May 2006. The company has developed products at the 6th generation line with a mother glass of 1,500 × 1,850 mm squares.
A 37-inch TFT (thin film transistor) -LCD module has been developed that has a viewing angle contrast ratio over 300:1 within 160 degrees. This module also has an improved front view contrast ratio from 850:1 to over 1,000:1. Furthermore, the blurred moving performance has been reduced to 50% by increasing the frame rate frequency from 60 to 120 Hz.
(IPS Alpha Technology, Ltd.)



Horizontal viewing angle performance of 37-inch diagonal IPS LC (liquid crystal) module

Enhanced Nano-scale Productivity Using Sheet Nanoimprint Technology

Hitachi, Ltd., in cooperation with Ikegami Mold Engineering Co., Ltd. and Hitachi Plant Technologies, Ltd. developed sheet nanoimprint technology that enables 100 times greater productivity of nano-scale patterns (internal comparison) than conventional technology. This increased productivity is enabled by continuous processing of heating, pressing, cooling and separating using a belt-shaped nano-mold.
Sheet nanoimprint technology is expected to enable significant breakthroughs in the nano-fabrication field for IT (information technology)/electronics, bio/life sciences and energy/environment industries.
This work was conducted as part of a NEDO (New Energy and Industrial Technology Development Organization), Japan, project that involves the R&D of practical applications for nanotechnology and advanced materials.

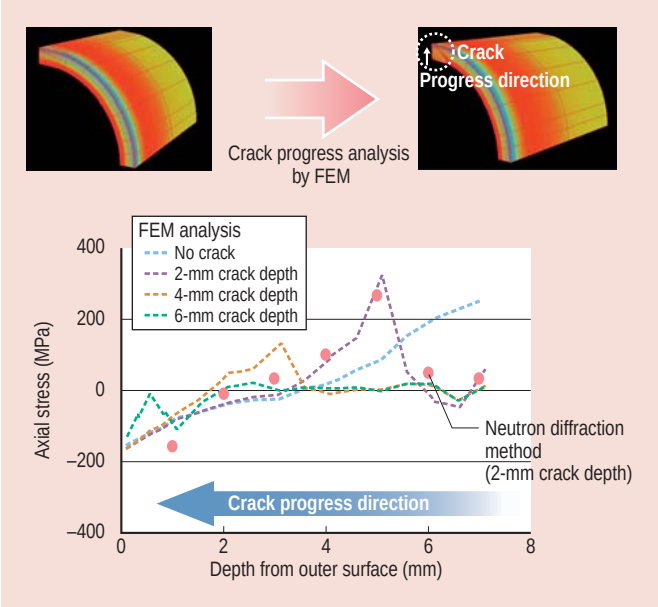


(a) Appearance and schematic diagram of developed sheet nanoimprint equipment —continuous process of heating, pressing, cooling and parallel separation—

(b) Example of imprinted high aspect ratio pattern (scanning electron microscopy)

100 times enhanced nanoimprint productivity using reel-to-reel system

Evaluating Residual Stress Redistribution Behavior on Butt-weld Pipe with Crack Extension Using Neutron Diffraction Method



Overview of evaluating residual stress redistribution behavior on butt-weld pipe with crack extension by using neutron diffraction method and FEM analysis

Rationalization of power plant operations while maintaining safety is required from an economic standpoint as the cost for supplying power becomes more competitive. Therefore, a standard code for conservation has started to be accepted in the field of nuclear power plant and is being improved by societies and national agencies to fit plant operation.

The neutron diffraction method developed by the Japan Atomic Energy Agency and Hitachi enables users to measure the internal residual stresses of materials that had only been evaluated by using the FEM (finite element method). These are the first results in Japan in which the residual stress distribution of butt-weld tubes and the redistribution behavior of residual stress around a crack tip with crack extension were measured and quantitatively evaluated by using the neutron diffraction method. These results contribute to the data being collected for a standard code and rationalizing the maintenance of nuclear power plant components.

These techniques will enable Hitachi to produce high quality and reliable products and contribute to the development of improved manufacturing techniques.

High Performance Cold Work Tool Steel, SLD-MAGIC

A new cold work tool steel was developed that has higher wear resistance and much better machinability than conventional steel type. The figure shows the relationship between the wear resistance and machinability of conventional steels and the developed steel, SLD-MAGIC. A trade-off exists between wear resistance and machinability in conventional steels, such as AISI D2, A2 and S7. However, these properties are improved in SLD-MAGIC. Material characteristics of SLD-MAGIC as compared to AISI D2 are as follows:

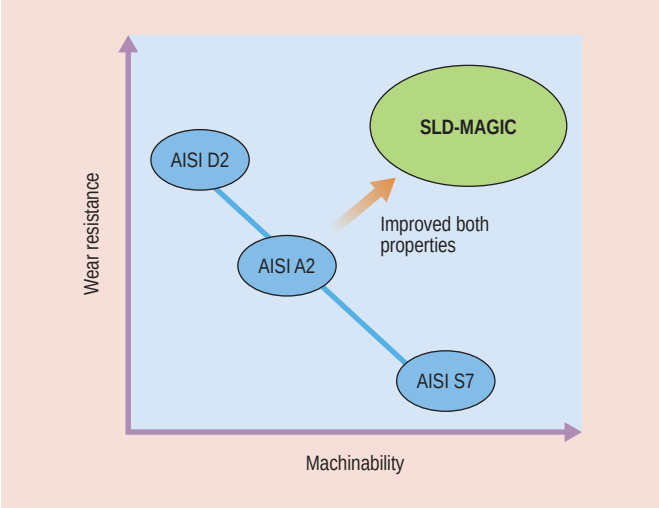
(1) Much better machinability in annealed conditions and greater wear-resistance after hardening

(2) Greater dimension stability at hardening and at the same level of hardness

(3) Stronger cohesion of chemical carbide coating and PVD (physical vapor deposition) coating

(4) Greater toughness and better weldability

The life span of dies and molds manufactured using SLD-MAGIC increased by about double to 100 times. In a part of these cases, works are high tensile strength steel plates with a grade of 490 to 980 MPa, which are used in the frames or bodies of cars. The fabrication costs of dies and molds decreased by about 10 to 40% because of better machinability and greater dimension stability. (Hitachi Metals, Ltd.)



Schematic relationship between wear resistance and machinability

Ferritic Heat-resistant Steel Cast for Exhaust Components of Diesel Engine

Growing concern for the earth's environment has led to strict government regulations to control exhaust gas emissions and reduce fuel consumption. Meeting these new regulations now requires the use of high performance engines that can produce exhaust gas temperatures of 1,000°C. Hitachi Metals, Ltd. has developed the HERCUNITE series of heat resistant materials for use in exhaust components of these new high performance engines. Possible applications of the HERCUNITE series of heat resistant materials are explained in Fig. (a).

HERCUNITE-F5N (F5N) is a material especially suited to high-performance diesel engines due to its outstanding resistance to oxidation and thermal fatigue cracking.

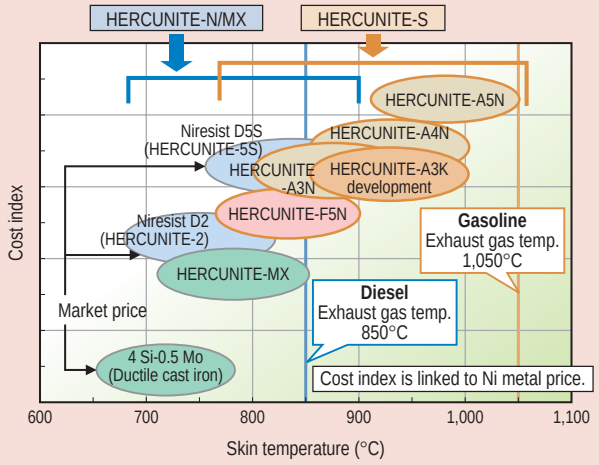
As shown in Fig. (b), the oxidation resistance of F5N is twice as effective as that of Niresist D5S austenitic heat resistant cast iron. Since F5N has a quick diffusion speed of Cr, it forms a precise and firm Cr oxide film layer on the outer surface.

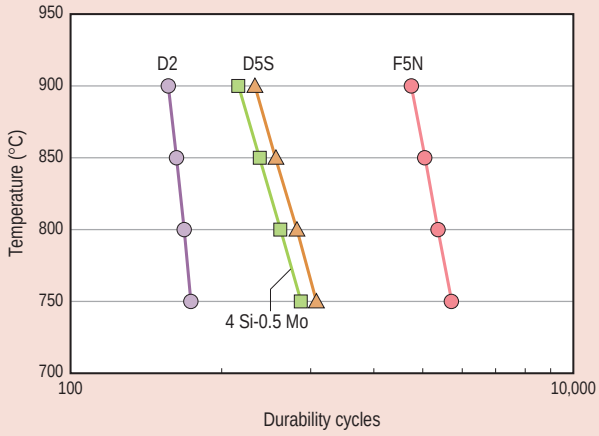
Moreover, F5N has a thermal fatigue life that is three times longer than that of conventional materials at a temperature of 800°C [see Fig.(c)].

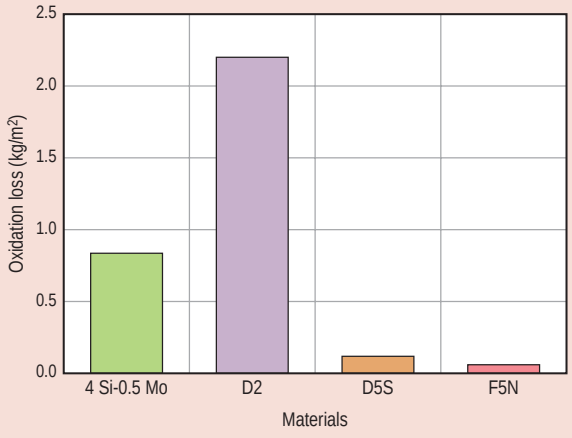
Although D5S has conventionally been used in the exhaust components in diesel engines, this material is approaching its limit due to increases of exhaust gas temperature and longer life requirements. Furthermore, large price increases in nickel have reduced the cost effectiveness of D5S (D5S contains 35% nickel). Therefore, the demand for a much more cost efficient alternative material has been increasing in recent years.

In direct response to this increased demand, F5N has been successfully launched for use in exhaust manifolds and turbine housings. F5N is a ferritic heat-resistant steel casting material that has excellent oxidation resistance and thermal fatigue life properties. Fig. (d) shows examples of exhaust manifold used in diesel engines made from F5N ferritic heat-resistant steel castings. Currently, F5N is mainly used in diesel engine vehicles in the European market. However, the market for F5N parts is expected to develop all over the world from now on.

(Hitachi Metals, Ltd.)



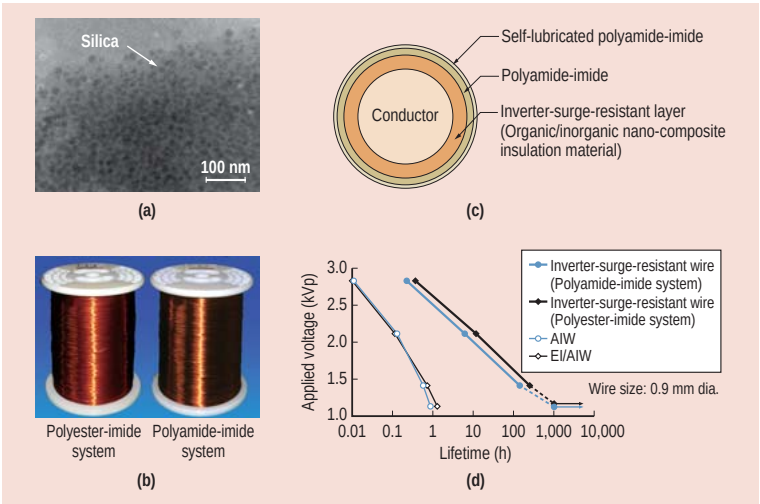




Examples of application of HERCUNITE materials (a), comparing oxidation losses of main heat-resistant materials (800°C and 200 hours) (b), comparing skin temperature and thermal fatigue life of each heat-resistant material and a thermal fatigue life ($\eta = 0.25$) (c), and examples of exhaust manifold used in diesel engines made from F5N ferritic heat resistant steel castings (d)

Inverter-surge-resistant Nano-composite Enameled Wire

In response to global environmental protection shared by people all throughout the world, energy saving has become actively promoted and inverter-fed-motors have become mainstream. Insulation systems for motors are essential because inverter outputs have an overlapping surge (high steep pulse) voltage. High voltage is observed between individual wires in windings when a surge occurs. Therefore, to solve this problem, an inverter-surge-resistant enameled wire is necessary. Hitachi has developed an inverter-surge-resistant enameled wire and used it in organic/inorganic nano-composite insulation material. These materials exhibited good voltage endurance and good general properties. Presently, this type of wire is mainly used in industrial machinery. However, Hitachi intends to extend the applications of these wires to include EVs/HEVs (electric vehicles/hybrid electric vehicles) driving system, whose demand is expected to increase in the near future.

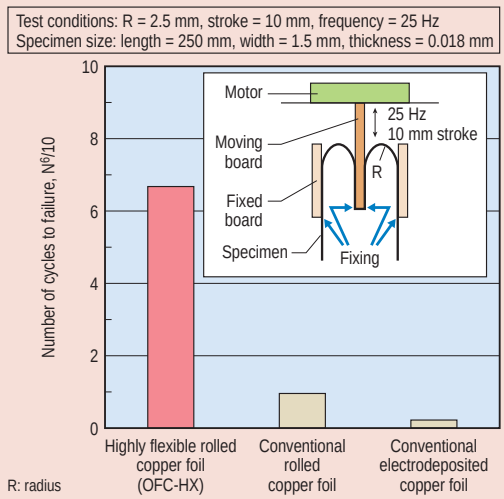


TEM (transmission electron microscope) image of nano-composite insulation material (a), appearance of inverter-surge-resistant enameled wire series (b), structure of inverter-surge-resistant enameled wire series (c), and voltage endurance (10-kHz sine wave) (d)

[Major characteristics]
(1) Voltage endurance: These wires have a life time 1,000 times greater than that of conventional enameled wires when they are used at voltages approximately the same as that of a typical inverter surge voltage (at 1.1 kVp). (2) Flexibility and scrape resistance: These wires have almost the same general properties as conventional enameled wires. (3) Lineup of inverter surge resistant enameled wire series: (a) Polyester-imide system: 200-˚C class and (b) Polyamide-imide system: 220-˚C class
(Hitachi Magnet Wire Corp.)

Highly Flexible Rolled Copper Foil for FPC

An FPC (flexible printed circuit) requires a significant increase in its flexible fatigue property. This circuit also requires a reduced size, a greater density mounting, and better performing of electronic equipment. Since the flexible fatigue property of an FPC depends on the copper foil being used, it is necessary to improve the property of the copper foil.
To meet this demand, Hitachi Cable, Ltd. has developed a highly flexible rolled copper foil (OFC-HX). This copper foil has a fatigue life (number of cycles to failure) six times longer than that of a conventional rolled foil and 30 times longer than that of a conventional electrodeposited copper foil. Hitachi developed a fabrication process with a high rolling rate using suitable heat-resistance, which was controlled by using OFC with a purity higher than that of TPC (tough pitch copper) and adding a small amount of an element. As a result, the flexible fatigue property excels extremely by controlling crystalline texture. Since OFC-HX has the same softening property as that of conventional foils, it can be used in a conventional FPC process without the need to change the processing conditions, such as heat treatment.
(Hitachi Cable, Ltd.)



Flexible fatigue property of OFC-HX compared with conventional rolled copper foil and conventional electrodeposited copper foil [IPC (Institute for Interconnecting and Packaging Electronics Circuits) -based fatigue test].