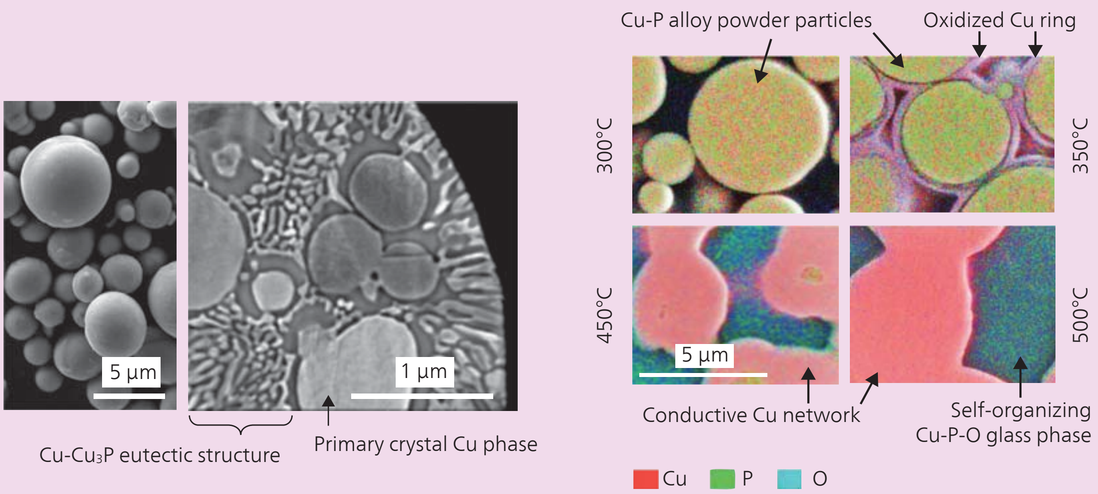
High Functional Materials & Components



Note: The illustration of the atmospheric sintering process was created by compositing a chemical composition map obtained from energy dispersive X-ray analysis on an SEM photograph of an application film cross-section.

1 SEM overview photograph of developed Cu-P alloy powder particles (Cu-7 mass%P), and SEM photograph of cross-sectional structure (left) and atmospheric sintering process (right)

1 Copper Electrode Application Film for Silicon Solar Cells Formed by High-temperature Atmospheric Sintering

To create sustainable society, there is a demand for greater use of renewable energy from non-depletable resources such as sunlight. Hitachi has developed a copper (Cu) -based paste for cell electrode formation. It is a high-function paste material that can help lower the cost of silicon solar cells.

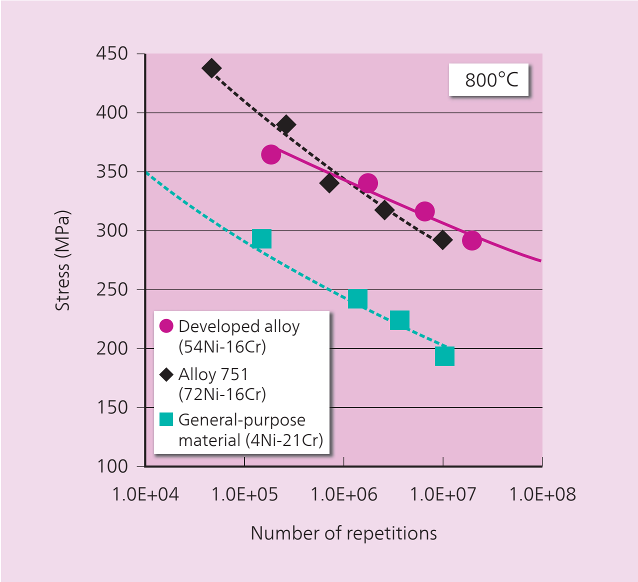
To lower cell cost, researchers throughout the world have been working on developing electrode materials made of copper, which is significantly cheaper than the silver (Ag) paste normally used in silicon solar cells. But so far no low-cost material has been discovered that can function as an electrode and can be manufactured using the same high-temperature atmospheric sintering process (at 200 to 900°C) as Ag. Hitachi has responded to this need by developing a material technology that enables electrodes to be manufactured from a low-cost copper-based material with high-temperature atmospheric sintering at a temperature above 200°C. The material is a copper-phosphorus (Cu-P) alloy designed mainly for use in back electrodes of silicon solar cells. It is applied in paste form as an application film.

The developed alloy powder appears as spherical particles when viewed under a scanning electron microscope (SEM). The cross-sectional structure of the powder comprises a Cu phase (primary crystals) that starts crystallizing in the cooling process during manufacture, and a Cu phase and copper phosphide (Cu_3P) compound phase that exhibit final crystallization between the primary crystals. This layered structure is a special structure known as a eutectic structure. Atmospheric sintering causes the Cu phase to oxidize and disappear at temperatures up to 400°C. At temperatures over 450°C, the Cu_3P compound is oxidized and disappears, while the previously oxidized Cu phase [copper oxide (Cu_2O) phase] is deoxidized. As a result, a completely new conductive Cu phase is networked in the sintered application film, creating a material that can satisfy the electrical resistance specification that back electrodes require. Hitachi has also concurrently developed basic technologies supporting a paste able to guarantee barrier performance between the developed Cu-based application film and silicon substrate, and connectivity with tab lines.

2 Nickel-saving High-strength Heat-resistant Alloy for Engine Exhaust Valves

A key component of vehicle engines, exhaust valves reach temperatures of over 800°C due to exposure to the high-temperature combustion-gas exhaust from the combustion chambers. Exhaust valve materials therefore need to be strong at high temperatures, wear-resistant and oxidation-resistant. Wanting to increase the fuel efficiency and power of vehicle engines to help protect the environment and save resources, manufacturers are moving toward smaller engines and direct-fuel-injection turbo types. As a result, exhaust temperatures are increasing, and there is increasing demand for engine exhaust valves with high strength at high temperatures.

The developed alloy is a low-cost, nickel-saving heat-resistant



2 Rotary bending fatigue characteristic of engine valve material at 800°C

alloy composed of 54% nickel (Ni) and 16% chromium (Cr). It has the high strength and long-term structural stability demanded for use in exhaust valves in high-performance vehicle engines. It was developed using an alloy design method, with a strengthening mechanism devised from precipitation strengthening enabled by increasing the amount of gamma-prime-phase precipitates, and solute strengthening enabled by adding molybdenum (Mo). It contains more than 15% less Ni than alloy 751 (a conventional heat-resistant alloy composed of 72% Ni and 16% Cr), while exhibiting high strength at high temperatures and maintaining outstanding characteristics after extended high-temperature heating.

Exhaust valves made of this alloy have already been used in mass-produced vehicles.

(Hitachi Metals, Ltd.)

3 Development and Mass-production of Low Dy NEOMAX Magnets

The NEOMAX* neodymium (Nd), iron (Fe) and boron (B) rare earth sintered magnet shows better coercive force by replacing the main component (Nd) with dysprosium (Dy) since Dy has a higher anisotropic field than Nd. Increased coercive force improves demagnetization durability, and created huge demand of these magnets in applications requiring heat resistance such as factory automation, electric power steering (EPS), and hybrid electric vehicles (HEVs). But since the scale of the commercial production of Dy is very limited, there was supply and price risk. Actually, in 2011, the price of Dy jumped up to about 20 times of its 2008 price, and the reduction of Dy consumption became the top priority issue.

This technology is focusing on magnetic interaction to improve coercive force for Dy reduction. Coercive force can be obtained by separating the main phase (ferromagnetic phase) with a non-magnetic grain boundary phase. Hitachi succeeded in reducing the weight of Dy used in magnets by at least 2%, utilizing the new knowledge on the effect of the additive element to the phases other than the main phase, and the improvement of the magnetification process.

Hitachi will start mass-production of low Dy series magnets in April 2014, and is planning to add a higher-performance series in October.

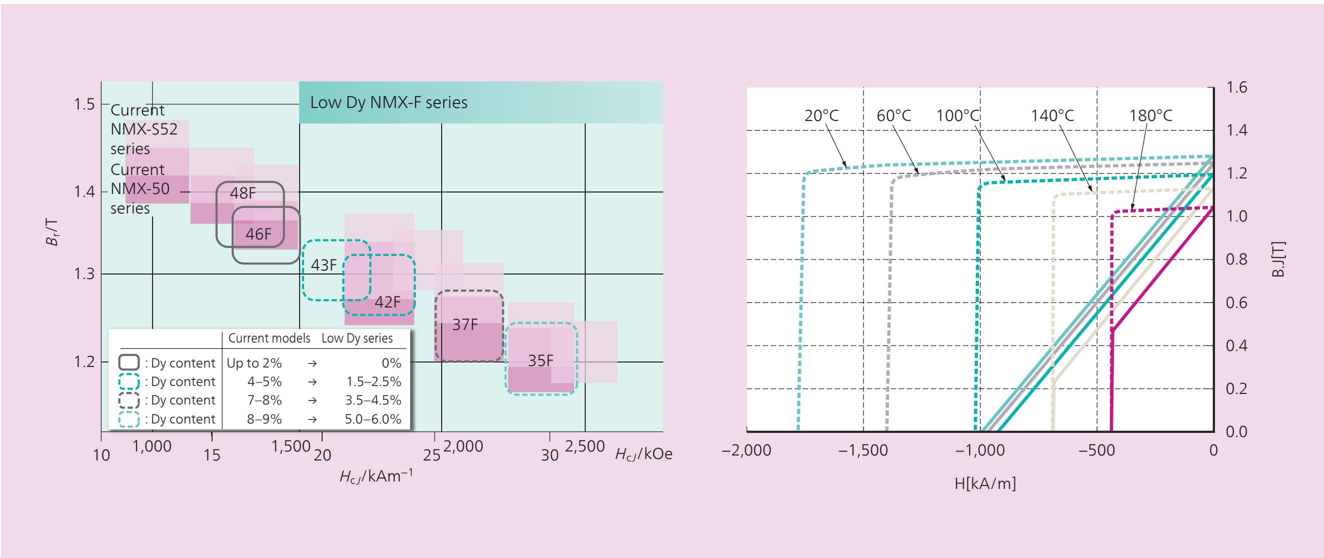
(Hitachi Metals, Ltd.)

* NEOMAX is a trademark of Hitachi Metals, Ltd.

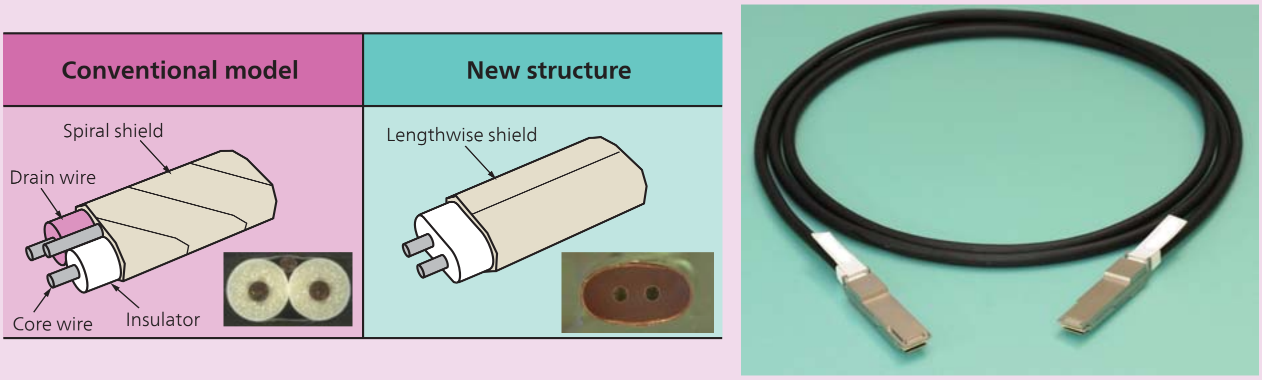
4 New Structure Metal Cable for High-speed (25 Gbit/s) Transmission

Servers, switches, storage devices, and other information network devices are increasing in speed and capacity. New structure cable is a metal cable for device interconnection, enabling high-speed transmission of up to 25 Gbit/s to meet near future network device needs.

Due to cost and performance considerations, the cables generally used for interconnection are two-core differential coaxial metal cables. But the faster the signal transmission speed becomes, the greater the effect of signal waveform deterioration caused by the propagation time lag (intra-pair skew) of the signal generated between the two conductors comprising the transmis-



3 Low Dy magnet lineup (left) and temperature characteristic curve of NMX-42F (right)



4 New structure for high-speed (25 Gbit/s) metal transmission cable (left) and harness using new structure cable (right)

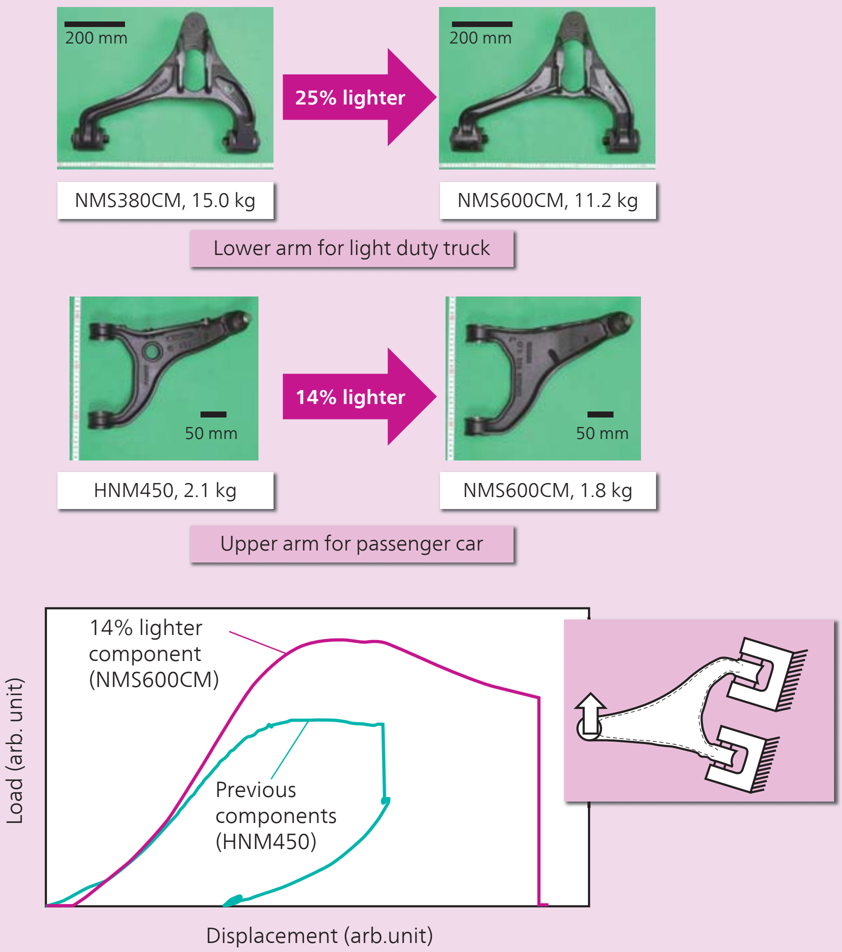
sion path. Hitachi has solved this problem by optimizing the interval between the two conductors and strengthening the electrical bond between them by bundling them with an insulator, making the dielectric constant around the two conductors equal. These changes reduce intra-pair skew by over 50% (compared to previous Hitachi Metals models), enabling a cable with no signal waveform distortion even during 25 Gbit/s signal transmission.

Hitachi is planning to focus on developing faster and slimmer cables, and to augment the lineup of new structure models and harness products using them.

(Hitachi Metals, Ltd.)

5 High-strength, High-toughness Ductile Cast-iron Lightweight Suspension Components

Automotive suspension components should combine enough strength to support the vehicle body with enough toughness to withstand the shock of a collision, while being lightweight. In 2005, Hitachi Metals, Ltd. released NMS380CM, a material with greater toughness than the general cast-iron material FCD370 [stipulated in a superseded Japanese Industrial Standards (JIS) standard]. To meet increased demand for more lightweight suspension parts, Hitachi Metals developed NMS600CM in 2008,



5 Example applications for NMS600CM in lightweight suspension arms (top) and the load-displacement graph obtained by bench testing an upper arm for passenger cars (comparison of previous Hitachi model and lightweight NMS600CM) (bottom)

which offers improved material strength. Starting with NMS380CM as a base material, NMS600CM is created by heat treatment and control of components such as silicon, manganese, and copper. It is a material with improved strength, good bending deformation performance and good shock resistance.

NMS600CM has been trialed for the front suspension lower arm of a light duty truck since 2009, and mass production of the arm was commenced in 2010 aiming to reduce weight by 25% relative to the NMS380CM version. In 2011, use was expanded into passenger car rear suspension upper arms. Lightweight components made with NMS600CM have been made 14% lighter than previous components made of Hitachi Metals's HNM450 material (equivalent to JIS FCD450), and have improved the maximum load and deformability of the finished products they are used in. The suspension arms are thin-walled cast components with a minimum wall thickness of 4 mm. Hitachi Metals is working on further development of high-strength, high-toughness materials, helping reduce the weight of suspension components.

(Hitachi Metals, Ltd.)

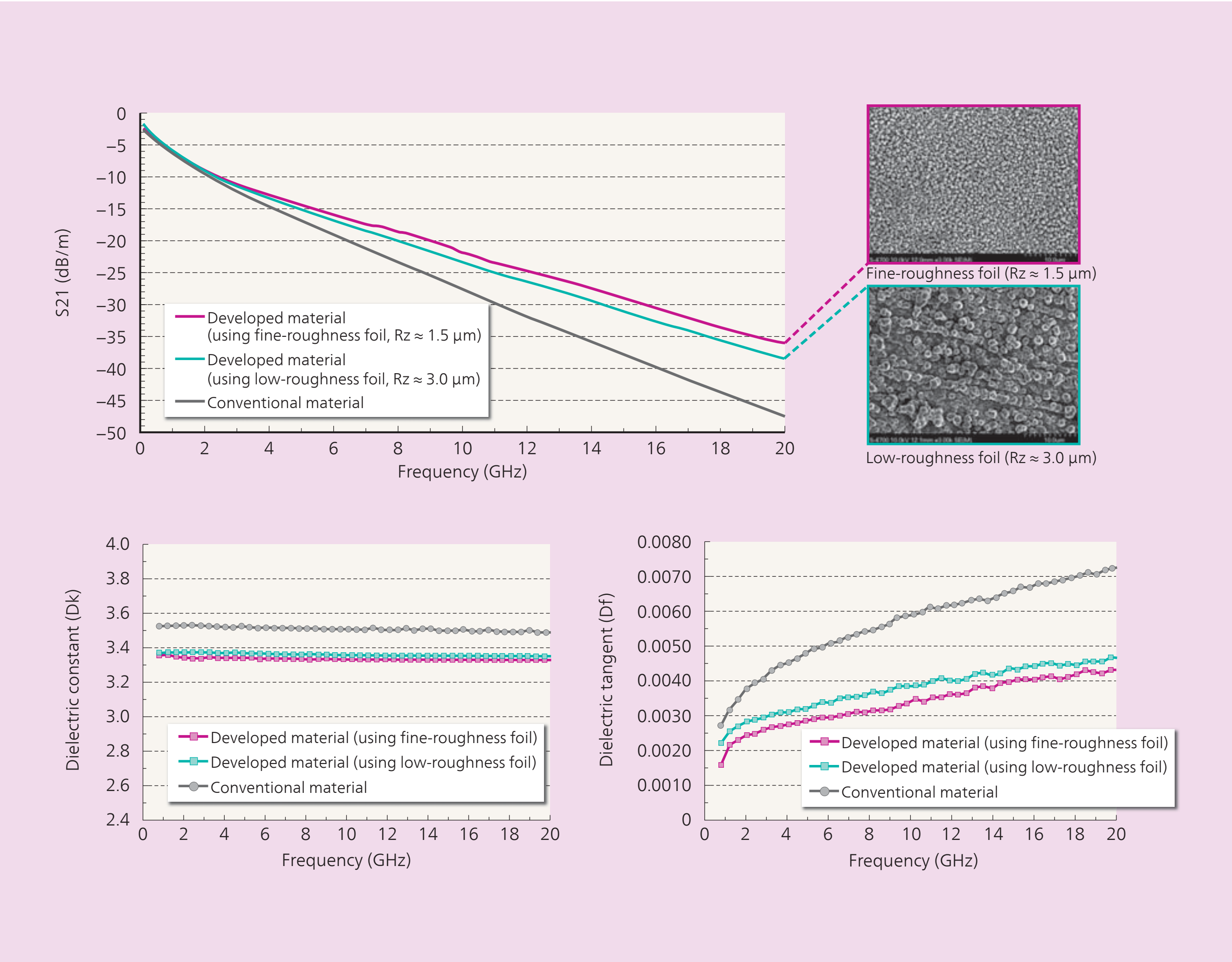
6 Low-transmission-loss Multilayer Material for High-speed/high-frequency Signals

In recent years, the ability to handle high speeds and high frequencies has become indispensable for the printed circuit boards (PCBs) used in the high-speed digital devices (such as servers and routers) and wireless devices (such as mobile devices) that require high-speed/large-capacity transmission. For high-speed digital devices, efforts to release a technology for electrical transmission at a next-generation transmission speed (25 Gbit/s per link) are gaining momentum, and there is increasing demand for PCB materials with better high-frequency characteristics than current low-loss materials.

Hitachi has developed a low-transmission-loss multilayer material that supports these types of next-generation high-speed/high-frequency applications. This material has a better high-frequency characteristic than conventional materials, and when combined with a fine-roughness copper foil, enables signal transmission supporting next-generation transmission speed. In addition to its outstanding high-frequency characteristic, it has high heat resistance, high insulation reliability and good workability, while its halogen-free composition for reducing environmental load makes it highly flame retardant. Its use can therefore be extended to high-frequency semiconductor packages for which non-halogen materials are becoming a requirement.

Hitachi is planning widespread release of the material.

(Hitachi Chemical Co., Ltd.)



6 Transmission loss measurement result for developed material (top) and electrical characteristics (frequency dependence of dielectric constant/dielectric tangent) measurement result (bottom)