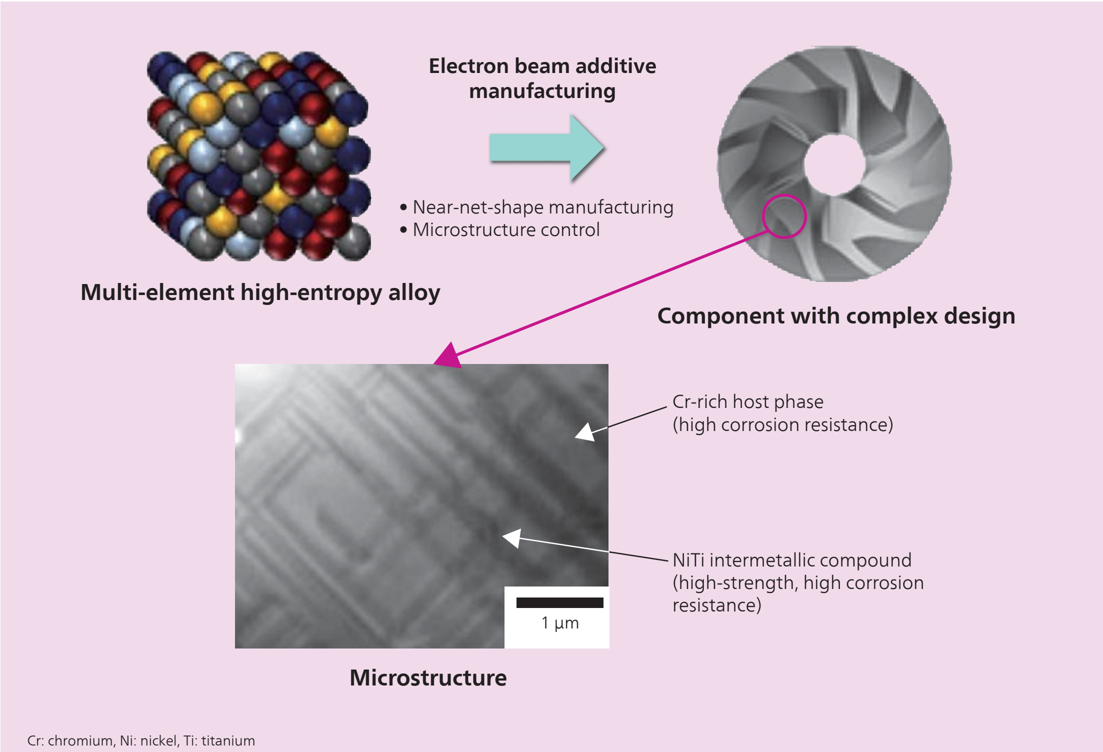
High Functional Materials & Components



1 Use of electron beam additive manufacturing to fabricate components from multi-element high-entropy alloys

1 High-strength, Corrosion-resistant Alloy Components Produced by Electron Beam Additive Manufacturing

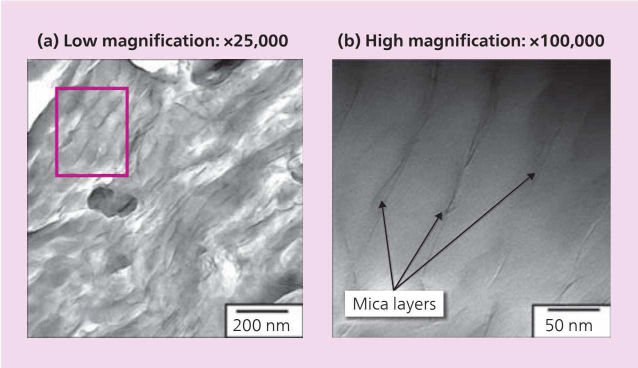
Fields such as resources and energy that require tolerance of harsh environments have a need for alloys with characteristics that surpass the stainless steel widely used in the past. Now, Hitachi is seeking to develop ways of utilizing high-entropy alloys in products. Unlike conventional alloys made by adding alloying elements to a metal, high-entropy alloys ("multi-element high-entropy alloys") are formed from a large number of different elements. While the new alloys feature excellent mechanical properties and corrosion resistance, it is difficult to use them to make large components with uniform properties. Electron beam additive manufacturing has attracted attention for its potential to overcome this problem by manufacturing complex shapes using a repeated process involving selective melting by an electron beam of a uniformly-spread layer of metal powder. Hitachi has developed new alloy components by taking advantage of the local melting and rapid solidification that is characteristic of electron beam additive manufacturing to form a microstructure that is strengthened by precipitated phases. These new alloy components have been demonstrated to provide approximately twice the strength of existing corrosion-resistant dual-phase stainless steel together with equal or better corrosion resistance.

In addition to making further improvements in the properties of these alloys, Hitachi intends to develop applications for them in components that are used in harsh environments.

2 Epoxy Composite with High Insulation Voltage Produced with High Dispersion of Mica

As part of the trend toward smaller size and higher output, automotive, industrial, and other electrical and electronic equipment are increasingly expected to deal with higher voltages. However, as higher voltages are accompanied by thicker insulation, combining this with smaller size is difficult. Accordingly, there is a need for insulators that are able to withstand higher voltages.

Epoxy composites are made from epoxy resin and inorganic powder. They are widely used as insulators in electrical and electronic equipment because they offer an excellent balance between insulation, heat-resistance, adhesion, and mechanical properties performance. While it has been known for some time that dispersing insulator nanoparticles through the epoxy resin increases the insulation voltage, and because of the large surface area of the nanoparticles, simply adding such material is very detrimental to productivity due to problems such as higher viscosity and thixotropy (tendency to become less viscous when shaken or otherwise stressed). In response, Hitachi and Kansai



2 Transmission electron microscope (TEM) image of cured epoxy resin composite containing highly dispersed mica

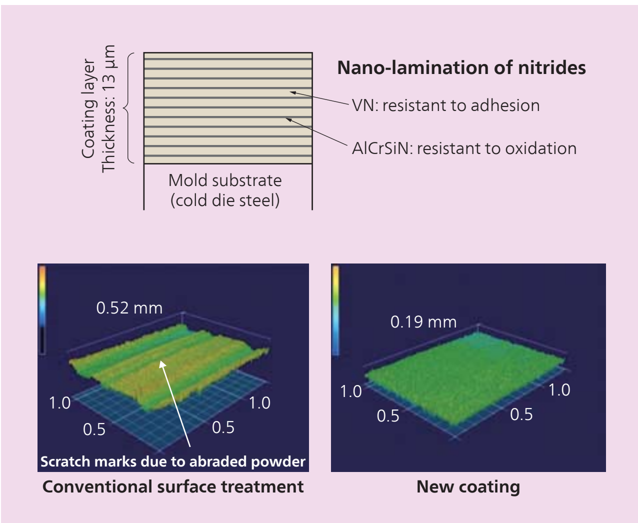
University have jointly developed a technique that uses micrometer-size mica particles with a small surface area that cause less of an increase in viscosity, and achieves a high degree of dispersal through the epoxy resin by separating the mica layers from each other during the curing process to form nanometer-thick flakes. This produces an excellent epoxy resin composite with three or more times the insulation life of previous materials, without compromising productivity.

3 PVD Coating for High-tensile Steel Sheet Press Molds

The use of higher tensile steel sheet in components such as vehicle frames is resulting in increasingly harsh operating conditions for the molds used in press-forming. The very high surface pressures to which molds are subjected in the forming of high-tensile steel sheet result in heating of the forming surfaces and localized wear.

Based on the concept of improving wear performance under high-surface-pressure conditions, Hitachi has developed a physical vapor deposition (PVD) multi-layer coating "vanadium nitride (VN)/aluminum-chromium-silicon nitride (AlCrSiN) coating" for high-tensile steel sheet press molds formed from the nano-level lamination of oxidation-resistant AlCrSiN and VN which has excellent resistance to adhesion (metal sticking). In addition to inhibiting excessive wear of the coating due to oxidation at high temperature, the vanadium in the coating prevents adhesion with the steel being pressed by forming vanadium-based oxide on the coating surface. Furthermore, by reacting with the iron (Fe) oxide that forms as the surface of the steel slides during pressing, the vanadium oxide acts to lower the eutectic point of the vanadium-iron oxides. This suppresses the formation of abraded particles that cause abrasive wear. Hitachi has demonstrated that the new coating can significantly extend mold life relative to conventional surface treatments.

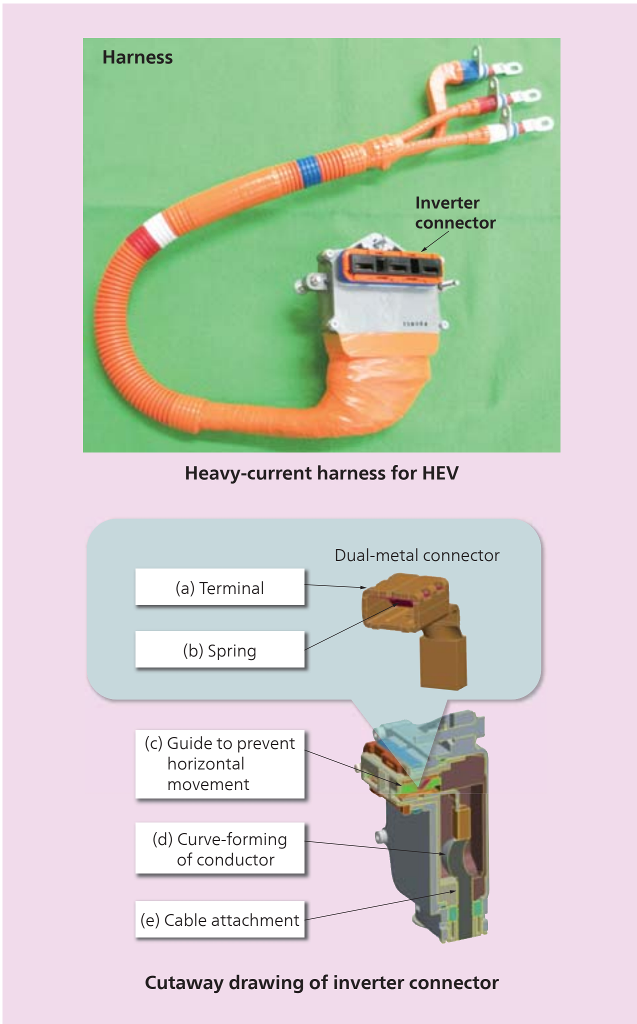
(Hitachi Metals, Ltd.)



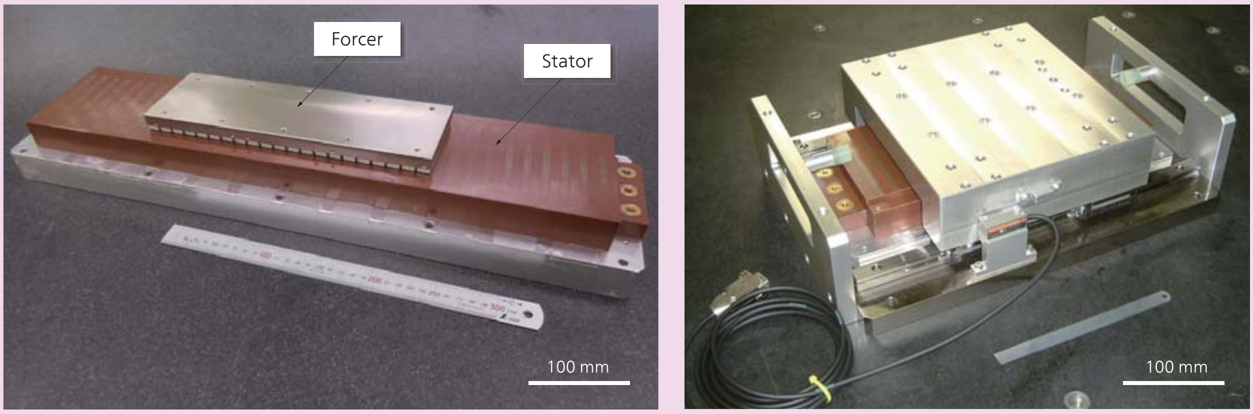
3 Coating structure and condition of mold surface after press-forming

4 Heavy-current Harnesses for HEVs

Heavy-current harnesses for hybrid electric vehicles (HEVs) are used to connect power electronics units such as those for the drive motor, inverter, and batteries. In the case of the inverter connection, harness contact terminals are used for easy assembly via connectors. Harness contact terminals are dual-metal, meaning they are made of two different metals. The terminals themselves are made of a copper alloy with conductivity of 90% or better in terms of the International Annealed Copper Standard (IACS) to minimize conductor heating when carrying a heavy current, while the harness uses a stainless steel with good stress relaxation characteristics to stabilize the contact pressure even at an ambient



4 Harness (top) and cutaway drawing of inverter connector (bottom)



5 Moving magnet linear motor capable of high acceleration (left) and single-axis linear motor stage (right)

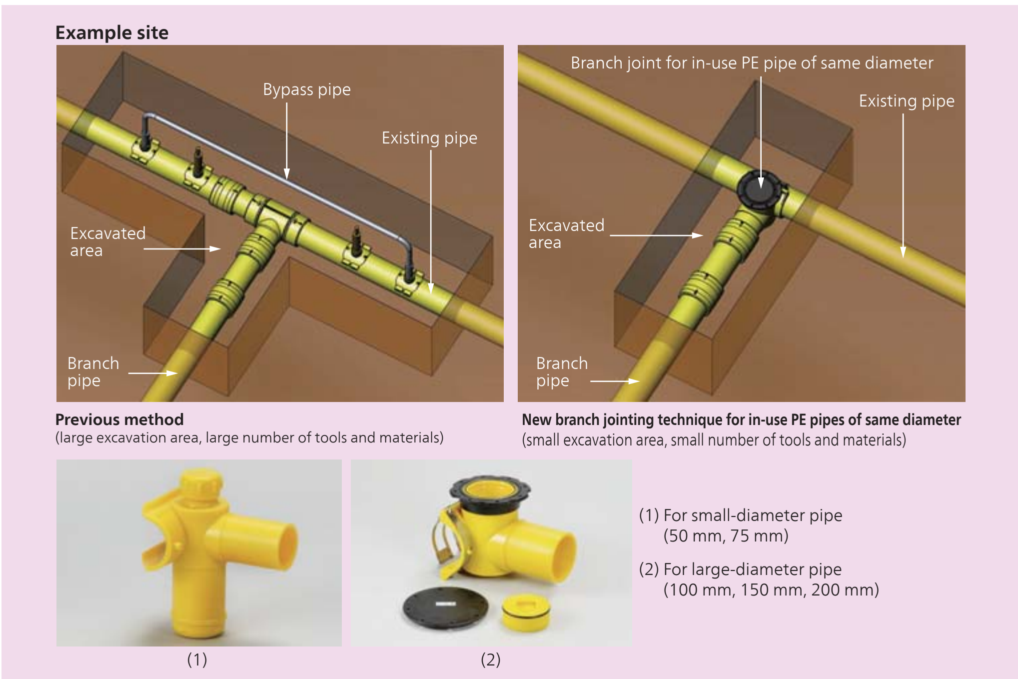
temperature of 85°C. Other features include the provision of guides to prevent horizontal movement of the terminals, forming of curved conductors, and structures for holding cables in place to maintain a reliable connection even when subjected to vibration. (Hitachi Metals, Ltd.)

5 Moving Magnet Linear Motor Capable of High Acceleration

While the key objectives for past linear motors have been limited to propulsive force and maximum speed, the emphasis in applications such as component mounting machines where the work head requires a fast response is on how to deal with high acceleration by seeking to reduce the weight of the forcer (moving part) of the linear motor.

Linear motors can be broadly categorized according to whether or not they incorporate a core, with core-less configurations being adopted in high-acceleration applications in order to satisfy the requirements by reducing the weight of the forcer. Unfortunately, maximum propulsive force places a limit on the extent to which this approach can be used. Conventional linear motors with a core, on the other hand, are not suited to achieving high acceleration because of their heavier forcer. In response to this problem, NEOMAX ENGINEERING Co., Ltd. has developed a moving magnet linear motor, which is capable of a mean acceleration of 98 m/s^2 (10 G).

By adopting a forcer made up of only a magnet and ferromagnetic material (low-carbon steel), the weight of the forcer on the new linear motor has been reduced to 40% or less of that on previous moving-coil linear motors that incorporate a core. By adopting a low-impedance design for the stator, this combines propulsive force step response performance equivalent to a core-less design with a maximum propulsive force that benefits from the presence of a core.
(NEOMAX ENGINEERING Co., Ltd.)
(Scheduled commencement of production: March 2016)



6 Comparison of new branch jointing technique for in-use PE pipes of the same diameter with the previous method (top) and special-purpose joint used by the new method (bottom)

6 Branch Jointing Technique for In-use PE Pipes of the Same Diameter

With the rapidly growing use of polyethylene (PE) pipes in the underground gas pipe market, there is rising demand for a way of installing branch joints in existing PE pipes that have the same diameter without interrupting the flow of gas. Past practice for branching off a new pipe of the same diameter from an existing PE pipe required considerable work and the excavation of a large area to allow the fitting of bypass piping to avoid the need to turn off the flow of gas, with localized blocking of gas and cutting of PE pipe.

A new technique developed by Hitachi uses a special-purpose saddle-shaped branch joint and a dedicated tool. It eliminates the need for a bypass pipe and significantly reduces both the area to be excavated and the time required for the job. The technique has been adopted by a large number of gas operators as a means of cutting costs and Hitachi believes it will continue to make a major contribution to the gas business in the future.

(Hitachi Metals, Ltd.)

7 Semiconductor Packaging Film

The spread of smartphones and other mobile devices has created a need for semiconductor packages that are smaller and slimmer, and that can be manufactured at low cost. To ensure that sealant coverage is not too thin and to improve ease of production, small quantities need to be supplied uniformly to a large surface area of unsealed package.

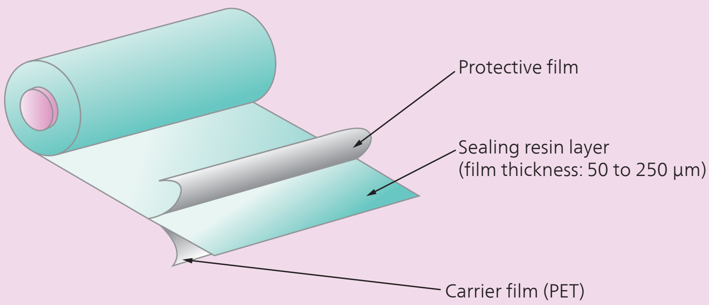
To produce packages that are both slim and low-cost, Hitachi has developed a semiconductor packaging film that has low thermal expansion and excellent fluidity during thermoforming.

Features of the new film include its fluidity, its flexibility (essential for maintaining ease of handling), and its reduced thermal expansion (achieved by incorporating a high level of inorganic filler). These were achieved by using a resin with high fluidity and a technique for improving the filler surface quality.

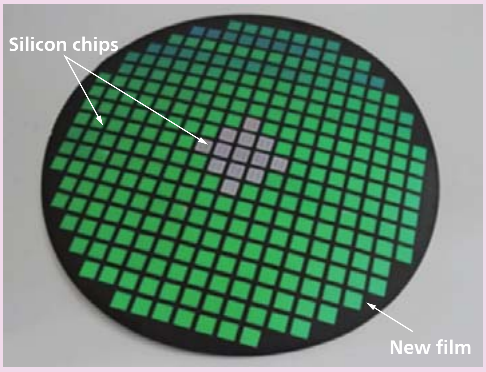
Being a film, the new product can be used not only in conventional molding, but also in thermal laminators that make it easy to seal large surface areas. While ultra-thin packages are difficult to seal using existing sealants, selecting the correct film for the desired thickness of seal makes it possible to seal a large surface area in a single operation. The new film also helps reduce the load on the environment by producing much less dust than powdered sealants.

In the future, Hitachi intends to expand its range of products that take advantage of film forming to suit different types of packages, and to market them both in Japan and elsewhere.

(Hitachi Chemical Co., Ltd.)



Structure of new film



Sealed package produced using new film (size: 200 mm)

PET: polyethylene terephthalate

7 Structure of new film and example sealing