I

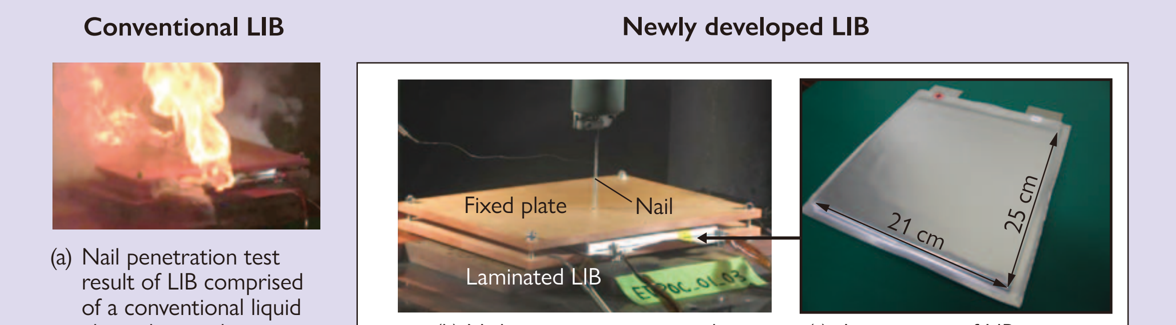
Technology Innovation

High Functional Material

1 Successful Development of a Highly Safe Lithium-ion Battery Prototype Using a New, Hardly Combustible Electrolyte

To improve the safety of battery systems while also making them smaller and less expensive, Hitachi has developed a prototype rechargeable lithium-ion battery (LIB) that uses a new hardly combustible electrolyte. LIBs have a wide range of applications, not only in portable devices but also as power sources for electric vehicles and renewable energy power conditioners. A problem with past LIBs, however, is that their use of liquid electrolytes with a flash point temperature of less than 20°C made them prone to catching fire in case of accidents.

Hitachi has worked with Tohoku University on the development of electrolytes with flash points of more than 100°C greater than the conventional liquid electrolyte currently used in LIBs, using lithium conductivity simulations to successfully develop a new electrolyte possessing high lithium ion conductivity. The new electrolyte was used to assemble a prototype laminated battery with a 100-Wh capacity and a nail penetration test was conducted to verify its safety. The results demonstrated that the battery was less prone to heating and causing thermal runaway in the event of an internal short circuit accompanied by nail penetration. It was concluded from this work that the battery has the potential to make systems smaller and more price-competitive by allowing system designs to reduce and simplify the reinforcing material and cooling systems incorporated into past battery systems to ensure their safety.



(a) Nail penetration test result of LIB comprised of a conventional liquid electrolyte without fire-prevention measures

(b) Nail penetration test result of LIB using new electrolyte

(c) Appearance of LIB using new electrolyte

LIB: lithium-ion battery

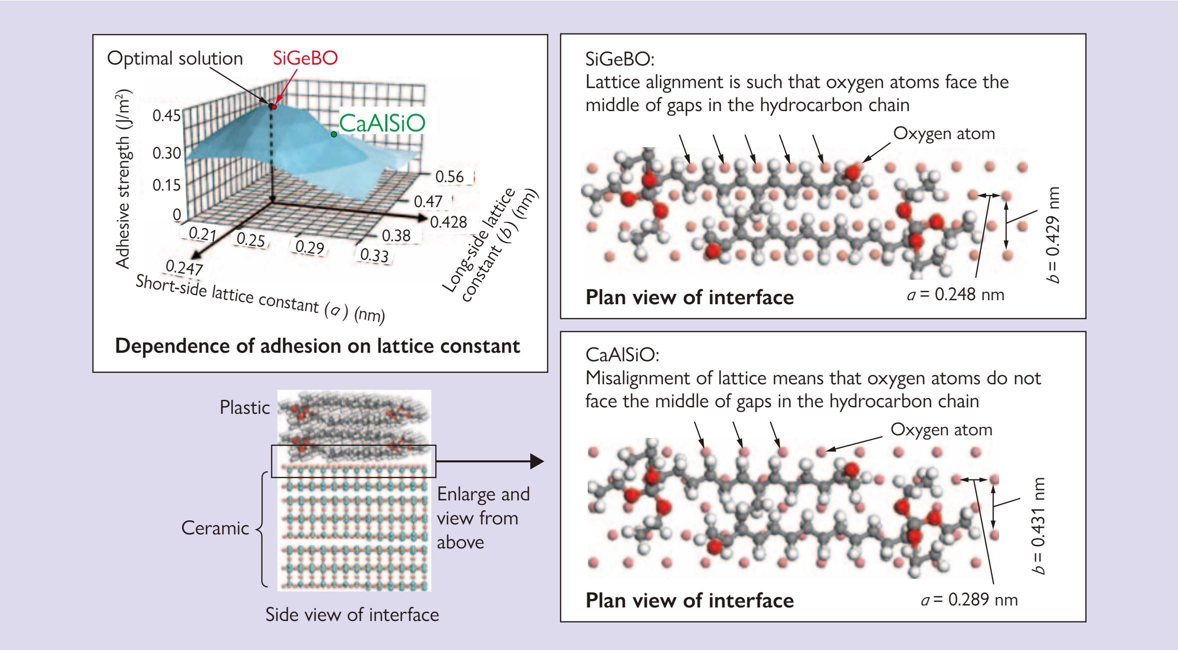
1 Lithium-ion battery that uses new electrolytes and does not cause thermal runaway with nail penetration

2 Use of Materials Informatics to Design Highly Adhesive Surface

The weight reduction benefits of plastics have led to their use in a wide range of products, from electronic components to electrical machinery. A common problem, however, is delamination due to their poor adhesion to inorganic materials. In response, Hitachi has developed a materials informatics technique involving the analysis of molecular simulation data to enable the efficient design of ceramics that demonstrate excellent adhesion to plastic.

When the technique was used to analyze the most important factors for increasing the strength of adhesion to aliphatic plastics, the determining factor was found to be the lattice constant of the ceramic, with peak adhesion occurring for a short-side lattice constant (a) of 0.247 nm and a long-side lattice constant (b) of 0.428 nm. Utilizing this knowledge, a number of ceramics chosen for having values of a and b close to the above optimal numbers were combined to fine-tune the lattice constants. The result was a mix of silicon oxide, germanium oxide, and boron oxide that achieved a short-side lattice constant (a) of 0.248 nm and a long-side lattice constant (b) of 0.429 nm, and that had an adhesive strength 45% higher than the mixture of calcium oxide, aluminum oxide, and silicon oxide used previously. The mechanism behind this strength of adhesion in the case of SiGeBO was also determined to be a strengthening of the inter-molecular bonds due to the lattice alignment, which was such that the oxygen atoms in the ceramic are positioned so as to face the middle of gaps in the hydrocarbon chain.

Plans for the future include utilizing the technique in the design of other materials such as high-strength alloys or fiber-reinforced composites.



2 Use of materials informatics to design plastic-ceramic interface

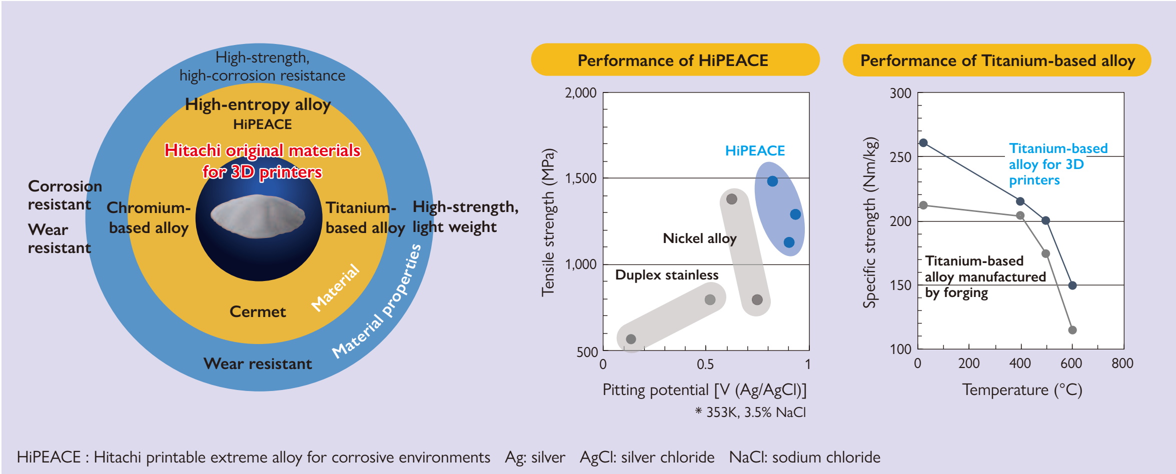
3 Materials Technology for Metal 3D Printer

In recent years, additive manufacturing (3D printing technology) has been used in a wide range of applications, including the aerospace, automotive, and medical industries. Hitachi has been developing metals utilizing the advantages of additive manufacturing processes.

In an additive manufacturing process, metal powders are rapidly melted and solidified, thereby realizing metal structures and material properties that are not achievable using conventional practices such as casting.

Moreover, it can manufacture products with “near net shape” and also allow the use of materials that have traditionally been difficult to use because of workability issues. Materials have been developed for 3D printers include a new high-entropy alloy called the Hitachi printable extreme alloy for corrosive environments (HiPEACE) that realizes high strength with corrosion resistance, which has been difficult to achieve in the past with nickel alloys. Use of this alloy in industrial machinery helps improve productivity by allowing less-frequent maintenance.

Hitachi also has developed chromium-based alloys with high corrosion and wear resistance that perform better than the conventional cobalt-based alloys. And, highly



3 Hitachi materials for 3D printers

wear-resistant materials composed of cermet and lightweight, high-strength materials made of a titanium-based alloy, which have superior properties to conventional materials also have been developed.

Hitachi intends to evaluate these materials in practical trials, and to further improve these materials' performance.

(Hitachi, Ltd., Hitachi Metals, Ltd.)

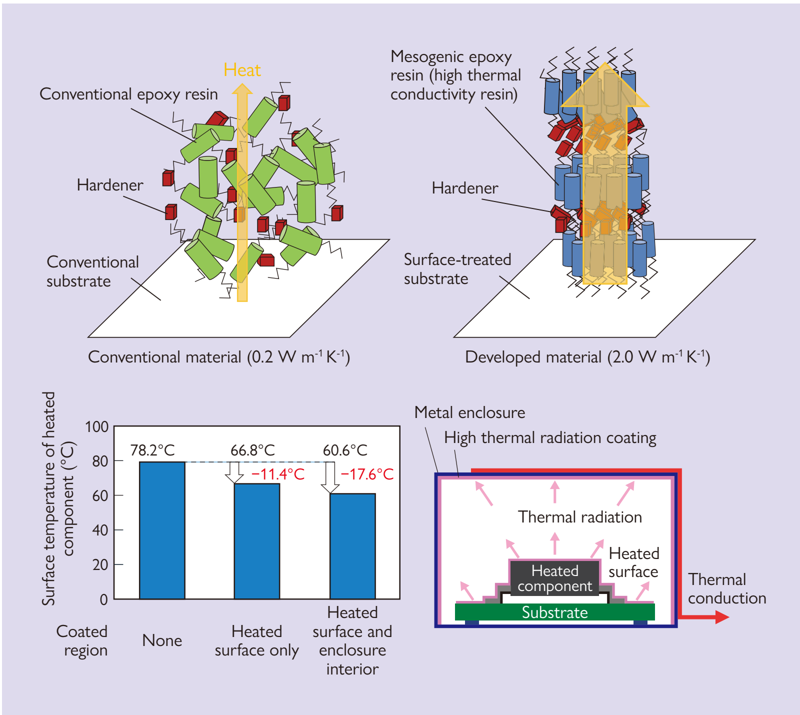
4 High Thermal Conductivity Material and High Thermal Radiation Coating for Increasing Efficiency of Heat Dissipation from Electronic Devices

Since electronic devices are rapidly being downsized and their output density is being enhanced, the heat generated in such devices is continuously increasing. Hitachi has developed a high thermal conductivity material and high thermal radiation coating for effective heat dissipation in such devices.

A mesogenic epoxy resin (high thermal conductivity resin) that can be self-organizing at nanoscale was aligned in the vertical direction to a substrate treated by UV light. This aligned mesogenic epoxy resin had a thermal conductivity in the film thickness direction of 2.0 W m^{-1} K^{-1}. That value is ten times higher than that of a conventional epoxy resin.

Hitachi has also improved the filler dispersion performance to develop a high thermal radiation coating with excellent manufacturing process stability. The heat dissipation efficiency of heat-generating components can be improved by applying this coating to the surface of electronic devices and the interior of metal enclosures.

These heat dissipation materials are expected to be applied to the next generation of electronic devices.



4 Models of the molecular arrangements of a conventional epoxy resin and a high thermal conductivity resin on substrate surfaces (top), the efficiency of the high thermal radiation coating depending on coated region (bottom left), and a model of a cross-section of an electronic device in which the high thermal radiation coating was applied to the heated surface and the enclosure interior (bottom right).