High Functional Materials for Global Environmental Protection

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OVERVIEW: Developments such as improvements in the efficiency of thermal power generation to reduce CO_2 emissions and cars or other products that place a lower burden on the environment are supported by new materials with a high tolerance for heat, innovative carbon materials, and many other high functional materials. There is also increasingly strong demand for materials that do not place a heavy burden on the environment, including materials derived from plants and materials that do not contain lead. Hitachi is contributing to the protection of the global environment through technologies such as the high functional materials used in the social infrastructure systems that help achieve a low-carbon society and the creation of new materials that take account of the environment.

INTRODUCTION

WHILE Japan hastens to ensure its ability to provide a reliable power supply to allow recovery and rebuilding following the recent Great East Japan Earthquake, measures for dealing with global warming remain a critical challenge that cannot be ignored. Given this situation, technologies such as environmentally conscious thermal power generation with reduced CO_2 (carbon dioxide) emissions and high functional materials which support the use of renewable energy are growing in importance.

High expectations are also being placed on environmentally conscious materials including the potential for plastics made from plant-derived raw materials and demand for the adoption of lead-free materials in a range of fields over and above what is required by regulation.

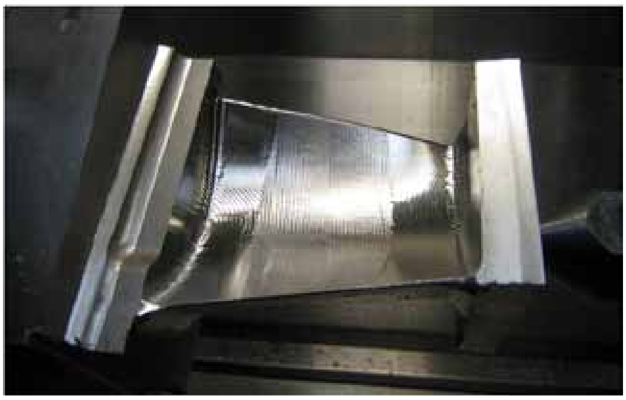

Fig. 1—Rotor Vane Trial-made Using High-strength Ni-base Alloy.
Hitachi developed a high-strength Ni (nickel)-base alloy, for use in 700°C-class A-USC coal-fired power plant turbines.

This article describes Hitachi's high functional materials which support an environmentally conscious society from its foundations.

CONTRIBUTION BY HIGH FUNCTIONAL MATERIALS TO CO_2 EMISSION REDUCTION

Numerous technical developments are in progress aimed at reducing CO_2 emissions. These include improvements in thermal power generation efficiency, use of renewable energy, and the adoption of hybrid power units in vehicles.

Hitachi's high functional materials make a major contribution to implementing a range of systems that reduce CO_2 emissions.

High Functional Materials for Highly Efficient Thermal Power Plants

Progress is being made on operating thermal power plants with higher steam temperatures to improve their efficiency. 600°C-class USC (ultra super critical) plants are already operating and work has started on the development of 700°C-class A-USC (advanced-USC) plants. To meet this demand for high efficiency, Hitachi, Ltd. and Hitachi Metals, Ltd. have been developing new turbine materials with greater high-temperature strength. For example, Hitachi developed a heat-resistant ferritic steel with 12% Cr (chromium) and greater high-temperature strength for use in USC plants. This material has been used to make blades and bolts for 600°C-class USC thermal generation turbines. More recently, Hitachi has developed a high-strength Ni (nickel)-base alloy for A-USC plants (see Fig. 1). This material is currently being considered for use in

Fig. 2—Solder-coated, Soft-annealed Copper Flat Wire for Solar Cell Wiring.
Solder-coated, soft-annealed copper flat wire helps improve quality and reduce production costs by reducing cell bending during the wiring process in solar cell production.

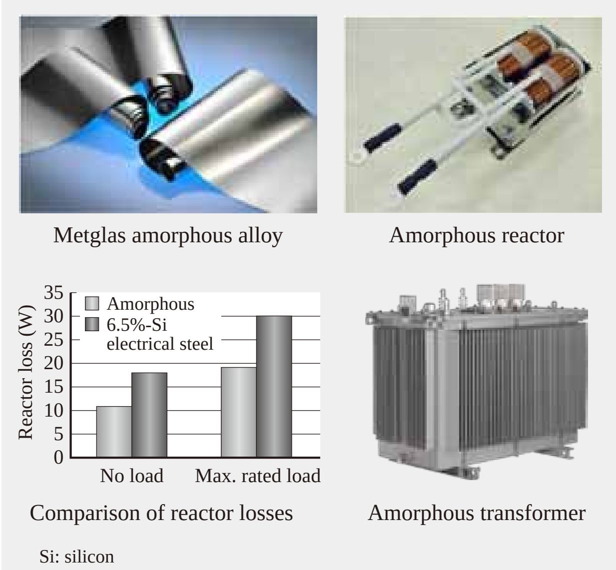

Fig. 3—Metglas Amorphous Alloy and Metglas Reactor and Transformer for Solar Cells.
The Metglas amorphous alloy helps improve photovoltaic generation system efficiency by reducing losses in the power conditioner and distribution transformer.

700°C-class A-USC coal-fired power plant turbines and other components.

High Functional Materials for Photovoltaic Generation Systems

(1) Photovoltaic wire for solar cells

A drop in the price of solar cell modules is desirable to reduce generation costs and one way in which progress is being made toward this goal is to make the cells thinner. However, because these thinner cells are more likely to bend or crack when the wiring between them is connected, a type of photovoltaic wire that reduces the load on the cells is needed.

Because it combines both high conductivity and flexibility, Hitachi Cable, Ltd.'s solder-coated, soft-annealed copper flat wire makes a significant contribution to improving quality and reducing the cost of solar cell production by reducing cell bending during the wiring process. The soft-annealed copper flat wire is also able to be used with environmentally conscious lead-free solder (see Fig. 2).

(2) Amorphous alloys for photovoltaic generation systems

One issue faced by photovoltaic generation systems is how to improve the efficiency of the power conditioner (inverter) that converts the direct current produced by the photovoltaic cells to alternating current. This requires a reduction in the losses of the reactors used in the power conditioner. If reactors that use amorphous alloy are adopted, it is possible to reduce these losses compared to reactors made using 6.5%-Si (silicon) electrical steel (see Fig. 3).

Similarly, losses in the distribution transformer that connects the photovoltaic generation system to the grid can also be reduced by using a highly efficient amorphous transformer(1) in place of one made using electrical steel. Although there used to be a problem with amorphous transformers being larger than an equivalent electrical steel transformer, this has been addressed by the commercialization of the Metglas 2605HB1M high-flux-density amorphous alloy(2).

High Functional Materials for Eco-cars

(1) Anode material for high-performance lithium-ion battery

Lithium-ion batteries able to provide superior environmental performance have been used in applications such as hybrid vehicles and electric vehicles in recent years. The carbon anodes used in lithium-ion batteries play an important role in determining battery performance. The anode material in a hybrid vehicle, for example, requires characteristics that allow fast but steady discharging (during acceleration) and charging (during regenerative deceleration). Hitachi Chemical Co., Ltd.'s amorphous carbon anode material (see Fig. 4) is controlled in a way that ensures its structure allows lithium ions to be easily absorbed into and released from the carbon, and it is able to achieve high battery performance by reducing changes in the carbon structure during charging or discharging.

Fig. 4—Carbon Anode for High-performance Lithium-ion Battery.
The unique carbon structure of Hitachi Chemical Co., Ltd.'s amorphous carbon anode material makes possible lithium-ion batteries with high capacity and excellent discharge load characteristics.

Vehicles such as electric vehicles and plug-in hybrid vehicles require batteries with high energy density to provide a long driving range. To achieve this, the anode material incorporates graphite particles that have been controlled to have a special particle shape. Also, by giving a functionally gradient characteristic on the structure of the carbon on the anode material surface, the electrode material structure can be stabilized with respect to factors such as the electrolyte and temperature to extend the battery's operational life and improve safety.

(2) Ceramic filters for scrubbing diesel exhaust gas

With regulations governing exhaust gases growing stricter around the world, there is a need to reduce significantly the amount of PM (particulate matter) contained in diesel engine exhaust gas. This requires filters that can trap these particles. Hitachi Metals' Diesel Particulate Filter (see Fig. 5) is a ceramic filter with high porosity in a large integrated housing (standard size: 266.7-mm diameter × 304.8-mm length). By optimizing the macrostructure (cell structure) and microstructure (pore structure) of the filter whose main component is cordierite ($5SiO_2 \cdot 2Al_2O_3 \cdot 2MgO$), it not only achieves a high level of performance at trapping PM but also contributes to improving fuel economy by reducing pressure losses. It is currently used on large diesel engines in commercial and other vehicles.

Fig. 5—Diesel Particulate Filter for Large Diesel Engines.
Through optimization of the macrostructure and microstructure, Diesel Particulate Filter not only achieves a high level of performance at trapping PM (particulate matter) but also contributes to improving fuel economy by reducing pressure losses.

ACTION ON ECOSYSTEM PROTECTION

Our current way of life is supported by products and services that use a diverse range of chemical substances such as plastics. Many of these substances depend on non-renewable resources such as oil. There are some chemical substances with harmful effects including to people's health and the ecosystem. Biomass is a renewable resource and as awareness of ecosystem protection grows, there is strong demand for its use along with other materials that take account of the environment.

Hitachi is working on developments including new high functional materials that can substitute for lead-containing materials used in the past and material technologies that use biomass as a raw material.

Promotion of Elimination of Lead

(1) Environmentally conscious vanadium-based low-melting-point glass

Low-melting point glass sealants that contain significant quantities of lead are used to provide an air-tight seal in a variety of applications including IC (integrated circuit) ceramic packages, crystal oscillators, MEMSs (micro-electromechanical systems), and semiconductor sensors. For reasons that include reliability and the environment, however, there is a need for new sealants.

Hitachi, Ltd. and Hitachi Chemical Co., Ltd. have developed their own highly reliable and environmentally conscious vanadium-based low-melting-point glass (see Fig. 6) that contains neither lead and other restricted substances nor halogens. It changes the glass structure from laminar to a three-dimensional lattice by controlling the valence of the vanadium. By introducing elements with a large ion radius and elements with a low melting point into

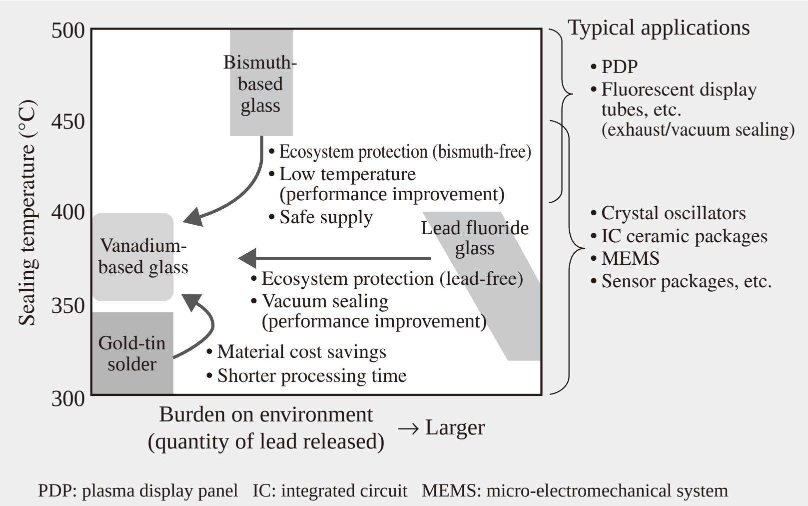

Fig. 6—Vanadium-based Low-melting-point Glass which Contributes to Reducing Burden on Environment.
Vanadium-based low-melting-point glass provides a lead-free and halogen-free sealant.

the lattice, vanadium-based low-melting-point glass provides an air-tight seal at low temperature (350 to 400°C) together with moisture resistance that is superior to previous lead-based glasses. Also, because the thermal expansion coefficient of the material can be adjusted over a wide range, it is able to be bonded to glass, ceramics, metals, and semiconductors.

(2) Development of lead-free piezoelectric thin-film material

The development in recent years of piezoelectric materials in the form of thin films has seen them widely adopted in applications such as heads for high-precision inkjet printers and angular velocity sensors. However, because piezoelectric thin-film materials have a high concentration of lead, environmental concerns mean there is a strong demand for finding replacements.

Hitachi Cable turned its attention to KNN [(K, Na) NbO_3], a lead-free ceramic with excellent piezoelectric properties, and succeeded in producing KNN films with high c-axis orientation and low residual stress on 100-mm wafers by using spattering, a mass production technique already in wide use. The resulting piezoelectric thin film achieved a piezoelectric coefficient of more than 100 pm/V which is similar to existing lead-based piezoelectric thin films and it is anticipated that this material will provide a practical lead-free alternative (see Fig. 7).

Fig. 7—(K, Na) NbO_3 Piezoelectric Thin Film Formed on 4-inch Silicon Wafer.
Hitachi Cable successfully developed the world's first practical lead-free piezoelectric film, using spattering to achieve a high c-axis orientation and low residual stress.

Use of Biomass-derived Plastics

Unused woody biomass from trees has attracted attention as a material for a society based on resource recycling that can be used as a substitute for plastics made from oil. Plastics such as polylactate that make use of biomass are already being used in applications such as the cases for electronic devices or car interiors. They have not yet, however, been adopted for uses that require a high level of heat resistance and insulation performance such as circuit boards, generators, and electricity distribution equipment.

Epoxy resin hardeners exhibit high level of heat resistance and insulation performance. However, in the past, epoxy resins delivered from biomass had difficulties to form into various shapes, because they were insoluble in organic solvents. Working with The University of Tokushima and Yokohama National University, Hitachi, Ltd. has succeeded in developing an epoxy resin that is soluble in organic solvents despite using the lignin contained in woody biomass as its main raw material. Further, by using lignin as a hardening agent, Hitachi has successfully produced a highly heat-resistant epoxy resin hardener with a glass transition temperature of more than 200°C.

Fig. 8—Prototype Printed Circuit Board Made from Epoxy Resin with Lignin as its Main Raw Material.
The newly developed epoxy resin which has lignin as its main raw material provides characteristics such as heat resistance and insulation performance that are similar to those achieved when epoxy resin made from oil is used.

Printed circuit boards made using the new epoxy resin (see Fig. 8) have demonstrated characteristics such as heat resistance and insulation performance that are similar to those of epoxy resin made from oil. Research and development continues with the objective of commercializing the product in fields such as industrial equipment.

CONCLUSIONS

This article has described Hitachi's high functional materials which provide benefits that include reducing use of harmful substances and helping create a low-carbon society.

To achieve a low-carbon society, Hitachi intends to help protect the global environment in ways that include creating new materials that take account of the environment and high functional materials that support social infrastructure systems.

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