Hitachi Chemical
Working On Wonders

Automotive Parts for "Environment, Safety and Comfort Performance"

Tetsuo Ito
Automotive Products Business Headquarters
Marketing Center

A century has elapsed since the first Ford T was produced in 1908. Since then, the strong economic growth of emerging countries, especially the BRICs, has sparked a global explosion in automotive demand. In 2010, motor vehicle production reached 74 million units and is expected to continue growing, with a production total forecast of 140 million vehicles by 2020 and 165 million by 2030.

Conversely, to deal with growing environmental issues such as declining energy resources, global warming and air pollution, automotive makers have recently been focusing on improving existing gasoline engines by enhancing fuel efficiency and reducing emissions-while developing commercially viable next-generation electric and fuel cell vehicles (HEV/EV).

In this report, we will present our latest technological developments to meet the requirements of these next-generation vehicles in sectors of safety, comfort and environmental performance.

1 Introduction

In future, automobiles must meet personal demands from users, including elements of social responsibility such as safety, comfort and support for the trend toward a low environmental-burden hydrocarbon society as well as meeting requirements to improve basic functions to drive automobiles, such as running, turning and stopping. For example, saving weight in engine-driven automobiles, downsizing engines or equipping automobiles with turbochargers may become crucial to meet and improve safety standards while positively supporting the low hydrocarbon society, and meeting the requirements of high power output and fuel efficiency while maintaining traditional drivability.

Conversely, in parallel with the increasing popularization of hybrid vehicles (hereinafter referred to as "HEV") and electric vehicles (hereinafter referred to as "EV"), the escalating performance requirements of motors, inverters and batteries mean the need to develop upgraded parts and materials for the same is intensifying to an ever-greater extent[1].

In this report we introduce the development status of auto parts promoted via fusion of technologies owned by our group.

2 Our Automotive Parts to Achieve Environmental Protection, Safety and Comfort

From an environmental protection perspective, we have achieved an enhanced environmental performance level for our brake pads (hereinafter referred to as "pads"), one of our representative products, thanks to non-asbestos pad, as well as improving safety performance, e.g. with traditional good braking and long service life.

Moreover, in HEV and EV fields, the popularization of which we expect to continue, our IPM (Intelligent Power Module) housing (hereinafter referred to as "housing"), where IPM constitutes the heart of the inverter unit, which is a crucial control system for driving 3-phase motors, and the battery module case are being received favorably in the market.

One of the recommended means of improving environmental performance is weight saving. Accordingly, our group is commercially manufacturing engine peripherals made of resin, including resin gears[2] and resin rear door modules having replaced steel exterior parts. Rear door modules help save weight as well as contributing to safety issues e.g. through high stiffness and strength, vibration durability and collision safety.

Regarding the internal room comfort, our light-control film used for dimming glass can seamlessly control light transmission, since the particles inside the film can align and let light pass through when voltage is applied, meaning our film can effectively save energy. Currently our film is used in the sun roofs of high-grade European automobiles-an example of unique and one-of-a-kind products.

3 Environmentally Responsive Materials

3.1 Abrasion Material

The history of changing regulations governing chemical compounds used in automotive brake pads in North America is shown in **Figure 1**. Due to regulatory limits restricting the use of copper in motor vehicle brake pads[3)-5)] effective post-2012, we

foresee copper-free NAO (Non-Asbestos Organic) materials becoming mainstream from now. Conversely, brake pads capable of suppressing vibration and offering reduced drag resistance to limit brake squeal and boost fuel efficiency are required. We established technology to replace the copper and suppress the vibration, then developed a next-generation pad.

(1) Copper-free NAO material

Copper with high thermal conductivity and superior flattening property is used in the form of a fiber or powder to maintain the wear resistance and friction coefficient. Accordingly, we regularly investigated the improved functional property of friction materials due to the use of copper, and developed copper-free NAO material by compensating the lost function and replacing it with multiple metal- and inorganic-based materials. The friction property of copper-free NAO material is shown in **Figure 2**. The developed material clearly has a service life and friction coefficient equivalent or superior to conventional materials.

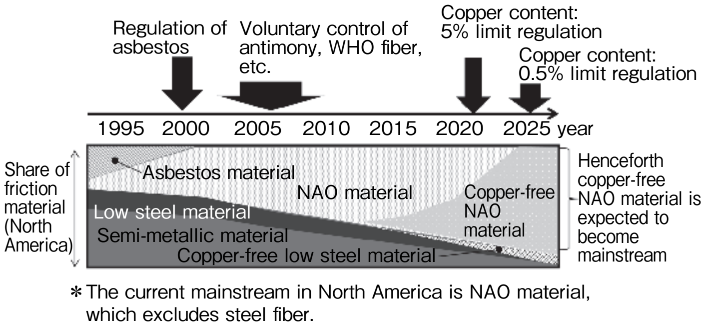

Figure 1 Change in the Regulation of Chemical Substances for Brake Pads

(2) Low-Compression Deformation Change and High Vibration-Suppression Material Using Vibration-Suppression Treatment

We successfully improved the vibration-suppression property and reduced the compression deformation using a high-vibration-suppressive elastomer and incorporating a new manufacturing process. The developed material, as indicated in **Figure 3**, showed a higher friction coefficient (tan δ) from a low to high temperature range and vibration-suppression property outperforming conventional rivals, meaning virtually no brake squeal. Conversely, the lack of compression deformation and drag torque reduction is considered to help improve fuel efficiency and can be applicable electric parking brakes, which generate high hydraulic pressure when the brake pedal is pressed. Henceforth, we will further enhance the stability of the friction coefficient and improve its applicability to controlled brake systems such as brake control/regenerative-friction brake coordination systems.

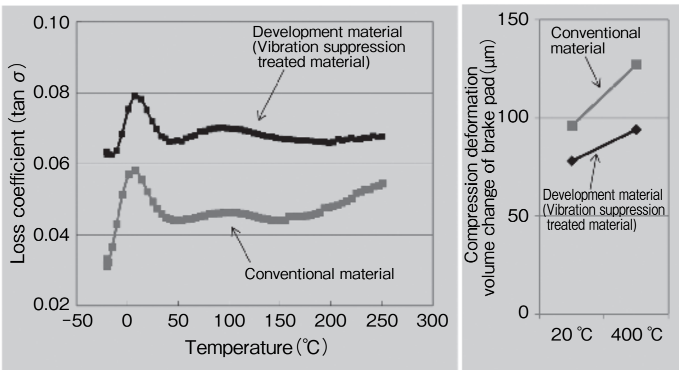

Figure 2 Friction Properties of the New NAO Friction Material without Copper

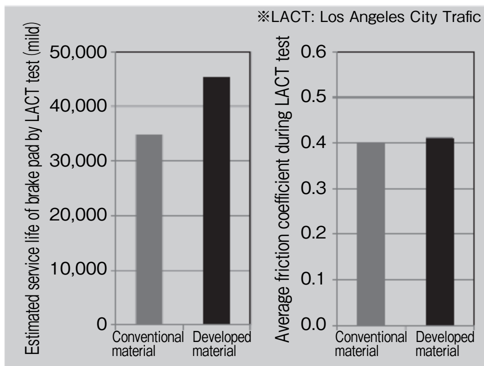

Figure 3 Damping and Compressive Properties of the New Friction Material

3.2 Metal-Insert-Molded Product for HEV and EV

To drive a three-phase AC motor, direct current from a battery is converted to AC via an inverter unit. We have been involved in the production of housing that constitutes the electric power circuit[6] of an inverter unit for one decade (**Figure 4**). The housing is constructed from a bus bar circuit that connects electrical power supplied from an IGBT (Insulated Gate Bipolar Transistor), a key inverter component and from insulation materials. The housing must have sufficient heat resistance and electrical properties to withstand the high temperature and humidity in the engine room. Accordingly, the basic technologies required to build housing cover a broad range from the design/fabrication of bus bar/molds, CAE analysis, insert molding and process control right up to quality assurance technologies. In particular, because housing molding, which involves placement of a metal insert, requires thermoplastic resin to be filled under high temperature and pressure using an injection molding machine, we must prevent flash generation in the clevis clearance between mold and metal inserts such as bus-bars and nuts and also any deformation that occurs during the cooling stage. When joint mating, we thus estimate the dimensional accuracy in advance, the flow path of the thermoplastic resin and the deformation change by CAE analysis, and use those results to optimize mold design and injection molding conditions. Also, as shown in **Figure 5**, we actually performed 3D cross-sectional observations and confirmed that both the resin and bus bar adhered to each other uniformly and a good finish was obtained as designed.

The battery case for EV, as shown in **Figure 6**, incorporates glass filament-reinforced thermoplastic resin and a metal insert,

because it was suspended under a car body and its impact resistance and joint strength with the car body frame were crucial requirements.

Backed by progressive infrastructure toward a low carbon society and enhanced comfort and convenience, we anticipate further growth in demand for EV and HEV. In response, we promote material performance improvements using new materials, for example, of the high heat dissipation-type as well as developing molded products with electromagnetic interference shielding metal inserted.

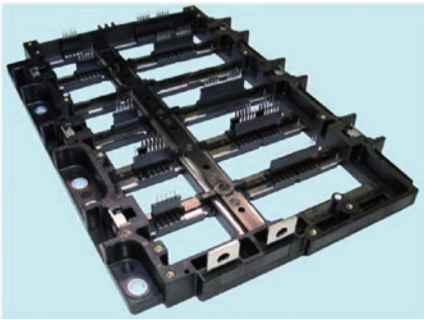

Figure 4 Housing made of a Bus Bar Circuit and Thermoplastic Resin

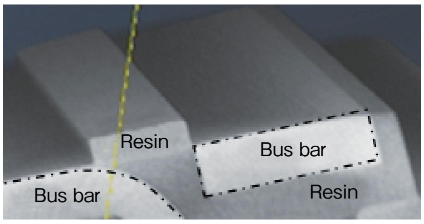

Figure 5 3D Cross Section View of the Bus Bar Area

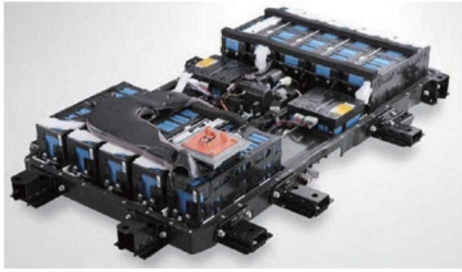

Figure 6 Battery Case for EV

4 Lightweight/Energy-Saving Material

4.1 Interior and Exterior Materials

The component ratio of resin parts in an automobile is 10 to 12 wt%, while interior/exterior and engine-peripheral parts are molded plastic. We commercialized interior parts such as instrument panels, console panels, and exterior parts such as the bumper, front grille, front lid of the truck, spoiler and rear door module. We used a gas-injection-molding method to retain rigidity while preventing shrinkage through the cross-section of a thick part. We also used slash molding and vacuum molding methods to improve the exterior finish and tactile sensation of the console box, and reduced the parts count via a vibration welding method.

Conversely, the rear door module shown in **Figure 7** offers the advantages of low weight, freedom of shape and a reduced parts count, hence we commercialized the rear door modules ahead of rival manufacturers. The structure of this module features inner and outer shells glued together, and meets the required specifications in terms of vibration durability, crash safety and exterior visual quality, thanks to structural optimization through CAE analysis and using high-strength glass fiber-reinforced thermoplastic resin[7].

Henceforth we promote the development of heat-resistant thermoplastic resin used for horizontally placed parts such as trunk lids and sunroofs, as well as developing high-functional parts material to improve the noise barrier property and in-car environment.

Figure 7 Plastic Rear Door Module

4.2 Light-Control Materials

Light-control materials have attracted attention in automobile, aircraft and construction material fields thanks to the privacy protection function by controlling light transmission as well as the energy-saving functions from thermal insulation and light and heat shielding[8)-10)]. We started the commercial production of light-control emulsion and films using our own polymer synthesis and film coating technologies developed based on SPD (Suspended Particle Device) technology licensed by Research Frontier Inc. in the U.S. The drive principle and a case example of the light-control film are shown in **Figure 8**. This is an active-type light-control film, where the deep blue color becomes transparent by applying AC voltage to adjacent transparent electrodes and orienting light-control particles along the directions of an electromagnetic field[11)]. The cross-sectional structure of the light-control glass is shown in **Figure 9**, where light-control film is placed between paired glasses via an adhesive layer. The ability to control visible light transmission by adjusting the AC voltage supplied via terminal electrodes of the light-control film, free control of visible light and heat ray energy and UV light not transmitting via glass, depending on the structure of paired glass[12)], mean applications of light-control glass to roof and rear-side glass are emerging.

The results of a simple simulated sunlight radiation test to measure the thermal management effect of a roof equipped with sunlight-control glass are shown in **Figure 10**. When it is transparent after an electric voltage was applied, the surface temperature on the black paper with an image of head hair was lower by 10 °C compared to that of conventional transparent glass. When the

voltage was turned off, however, the surface temperature decreased further. Accordingly, we believe applying such light-control glass to vehicle roofs should improve comfort and energy saving. The color of the developed light-control material is formulated to deep blue while the voltage is turned off. However, since the need for next-generation light-control film with achromatic black/gray color, which can match the room interior design, has emerged, we are actively promoting its development.

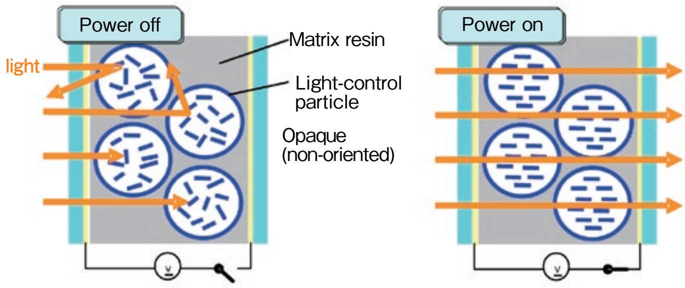

Figure 8 Fundamental Driving Mechanism of Light Control Film

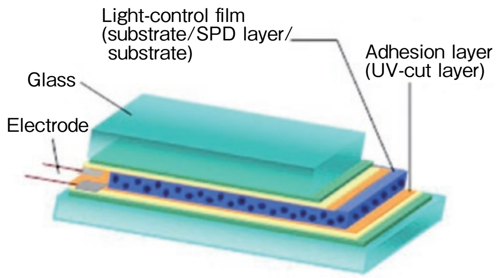

Figure 9 Structure of SPD Glazing

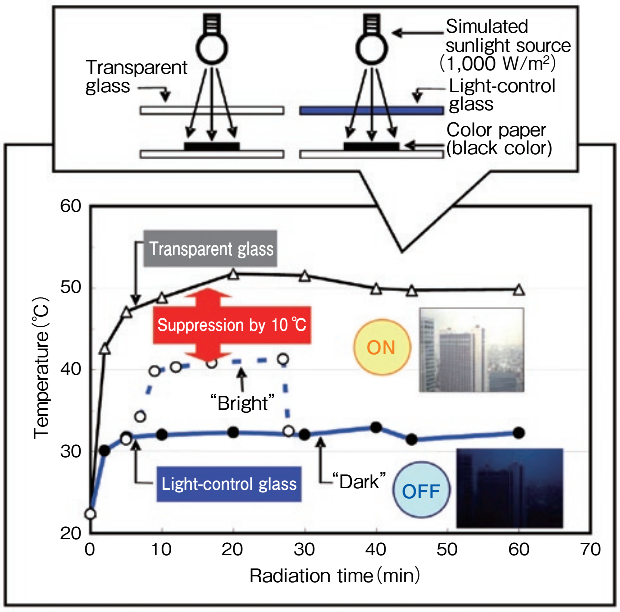

Figure 10 Surface Temperature of Black Paper during the Sunlight Simulator Test

5 Summary

Despite ever-changing social environments around automobiles, promoted by environmental assessments of natural resource-saving on a global level, anti-global warming efforts and new concepts introduced to our social system, such as HEV, EV and the smart grid, we are convinced that automobiles will continue to play mainstream transportation and delivery roles. In this context, new performance requirements for automobile parts are required and their importance has been more keenly recognized.

Our group will continue offering the aforementioned technologies, products and new automotive parts that demonstrate "Environmental Protection, Safety and Comfort Performance" ahead of other manufacturers, thus contributing to our society through the development of the automobile industry.

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