

Development of Chlorine-free Waterborne Primer for Bumper

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ABSTRACT

Changes in the production process of the polyolefin substrate used on automotive bumpers have created the need for increased coating adhesion performance. A method of lowering the melting point of polyolefin, the principal component of the primer, in order to fuse the polyolefin resin with the polypropylene (PP) substrate using the heat generated during pre-heating and baking, thus achieving increased adhesion through the interaction force between molecules, was therefore examined. Using a metallocene catalyst, the tacticity of the polyolefin was controlled and its melting point reduced, resulting in the achievement of a higher level of adhesion intensity than the conventional primer. The chlorine that was formerly added to the olefin is no longer used, reducing the burden on the environment.

1. Introduction

Regulations restricting environmentally harmful substances have been put into effect worldwide against a background of increasing concern with reducing the burden on the environment in order to contribute to the safety and well-being of our societies (Fig. 1). In Japan, revision of the domestic Air Pollution Control Act has put into place regulations restricting emissions of volatile organic compounds (“VOCs” below) from April 1, 2006. The reduction of VOC emissions from automotive coating lines has become an important issue, leading to an increased focus on the development of materials

containing reduced amounts of environmentally harmful substances.

Honda has therefore developed waterborne coatings in the bumper coating process in order to reduce emissions of VOCs. Honda has worked to reduce VOCs, introducing a waterborne primer to its North American bumper coating lines in 1983, and introducing a three-coat one-bake coating system using a waterborne primer, a waterborne base, and a super high solid clearcoat to achieve the world’s highest level of environmental performance to its UK lines in 1998. However, recent changes in the production process of bumper materials have led to the need for the achievement of greater adhesion intensity.

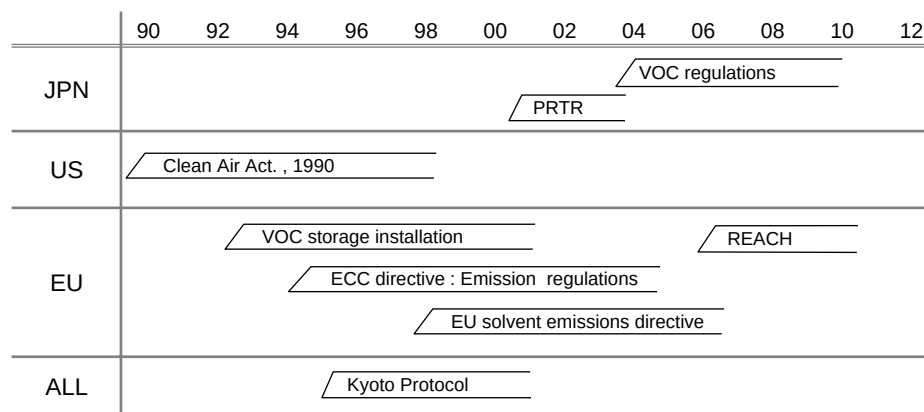


Fig. 1 Global environmental laws and regulations

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This paper will discuss a waterborne primer technology using catalytic control to reduce the melting point of the olefin resin used in the coating, thus increasing adhesion intensity with the substrate.

2. Status and Issues of Bumper Coating

PP is widely used as a material in the manufacture of bumper fascia in order to achieve weight savings, low costs, and other benefits. However, the surface energy of PP is low at less than 100 erg/cm^2 , and it is chemically inert. These properties make PP a substance that displays low adhesion intensity⁽¹⁾. Figure 2 shows the composition of a bumper coating. The most substantial contribution to adhesion between the coating film and the PP substrate is made by the primer, which is applied directly to the substrate. The solvents in the primer infiltrate the rubber component of the substrate, and promote adhesion by means of an anchor effect⁽²⁾. However, the stipulations concerning reduction of VOCs in recent environmental regulations have resulted in the use of reduced amounts of solvents in the coating films, making it a challenge to achieve an anchor effect by expansion and infiltration of the rubber component of the substrate. In addition, recent modification of processes in order to increase production efficiency⁽³⁾ has also resulted in the addition of a reduced amount of rubber to the PP substrate. Figure 3 shows the

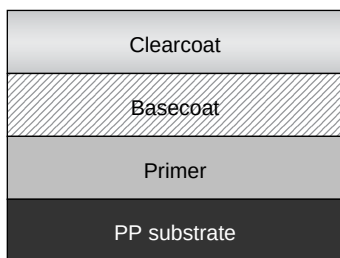


Fig. 2 Bumper coating

change in the structure of a cross-section of the substrate resulting from this reduction in rubber content (the white sections are rubber, and the black are PP). As is immediately clear, there has been a reduction in the amount of rubber close to the surface of the substrate, and this is a factor in the decline in the adhesion of the coating. Given these changes, it has become challenging to balance response to environmental regulations with the maintenance of coating quality.

3. Development of Waterborne Primer

3.1. Concept of Increased Adhesion

The use of an anchor effect or the exploitation of intermolecular interaction are available as means of increasing adhesion with PP substrates. Conventionally, the achievement of an anchor effect by controlling the molecular weight of the olefin, promoting infiltration of solvents, and the like, has been focused on in order to increase adhesion⁽²⁾. Because the mechanical promotion of adhesion using the anchor effect has now become challenging, as discussed above, the project discussed here focused on promoting adhesion via physical adsorption, specifically by means of increasing the intermolecular interaction at the boundary between the coating film and the substrate. Because adhesion is a phenomenon that occurs at the boundaries between materials, the achievement of a sufficient level of intermolecular interaction at the boundary is an important factor in determining whether or not the coating will adhere. Controlling the level of melting during pre-heating, baking, and the like, in order to achieve a sufficient contact area can be considered an important condition for increasing adhesion by exploiting intermolecular interaction. The project therefore focused on the melting point of the polyolefin resin that forms the main component of the primer. The reduction of the melting point of the resin in order to achieve a heat melting effect during pre-heating and baking was considered.

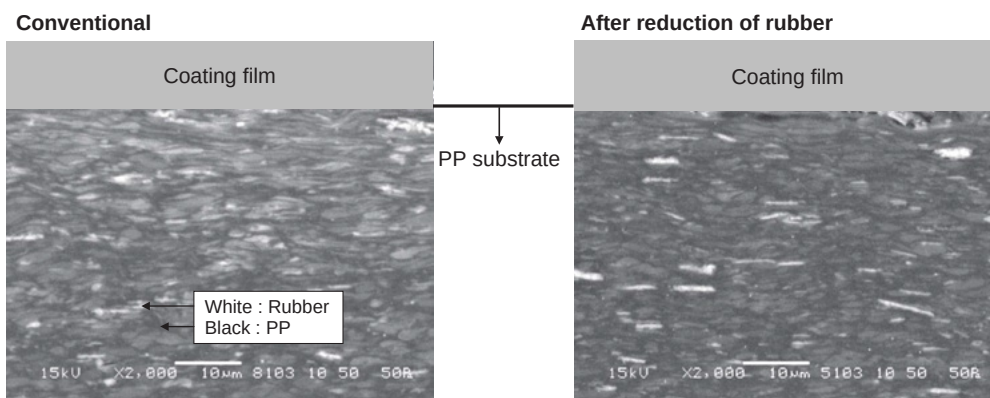


Fig. 3 Cross-section of PP substrate

3.2. Reduction of the Melting Point of Polyolefin

Reducing the crystallinity of polyolefin was considered as a method of reducing its melting point. The addition of chlorine to the olefin resin is a method of achieving this. Chlorine has conventionally been added to reduce the crystallinity of polyolefin in order to help ensure its solubility in the solvents used in the coating and to stabilize the coating. The relationship between the addition of chlorine and the melting point of polyolefin is shown in Fig. 4. As the volume of chlorine added is increased, the melting point becomes lower. Figure 5 shows the relationship between the content of chlorine in the olefin and peeling strength and fuel resistance. Because the peeling strength increases with the addition of higher quantities of chlorine, this relationship shows that a reduction in the melting point contributes to increased peeling strength. However, fuel resistance, which is necessary to the quality of the coating film, tends to decline. The reduction in the melting point and the increase in solubility achieved by the addition of chlorine are in a trade-off relationship, and a lower melting point can be considered to be a factor in reduced fuel resistance. The fact that the addition of chlorine to reduce the melting point results in a decline in fuel resistance as the melting

point is reduced makes it a challenge to achieve a balance between the two characteristics.

Next, the use of a catalyst technology as a method of controlling crystallinity was studied. The project considered using a metallocene catalyst⁽⁴⁾ enabling free and highly accurate control of the tacticity of PP (Fig. 6) to polymerize the low-melting point polyolefin, while

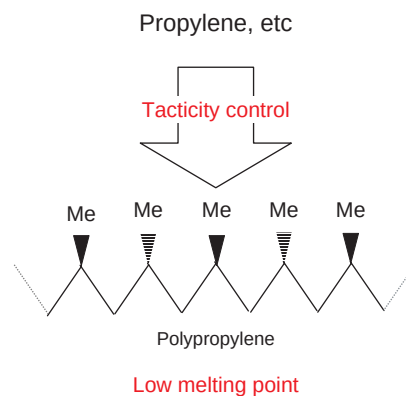


Fig. 6 Tacticity control of polyolefin by developed catalyst

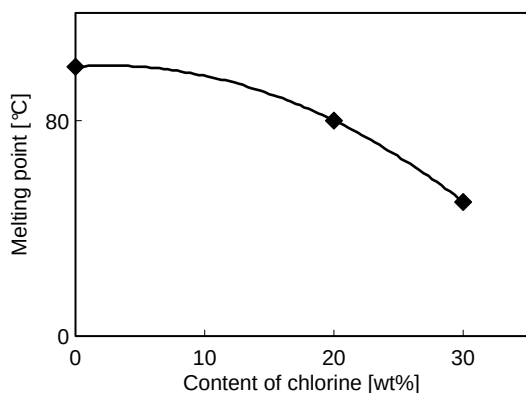


Fig. 4 Influence of chlorine weight % on melting point

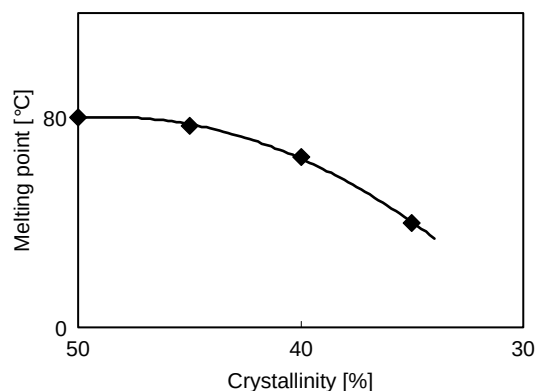


Fig. 7 Influence of crystallinity on melting point

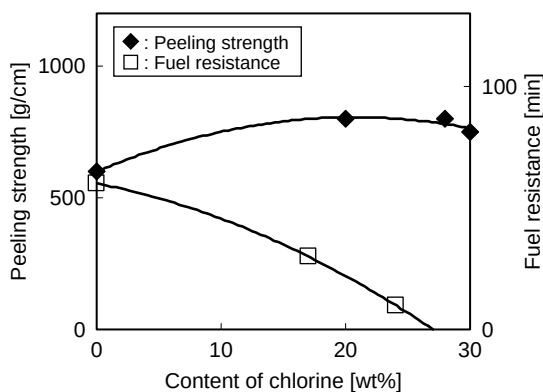


Fig. 5 Influence of chlorine weight % on peeling strength and fuel resistance

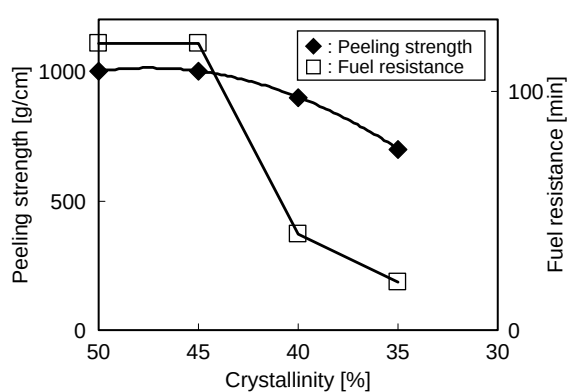


Fig. 8 Influence of crystallinity on peeling strength and fuel resistance

maintaining the poor-solubility characteristic of the olefin. Tacticity is an important primary structural factor which determines the higher-order structures of crystals, such as crystal morphology and crystallinity, that govern the properties of high molecular substances. The mesopentad fraction (mmmm) necessary for the formation of crystals was measured using the ^{13}C -NMR method, and defined as crystallinity. The results shown in Fig. 7 indicate that the reduction of crystallinity using the metallocene catalyst reduces the melting point. As Fig. 8 shows, peeling strength could be increased while maintaining fuel resistance. Because the polyolefin does not contain chlorine, solubility in solvents is low, and the substance displays superior fuel resistance. The low melting point of the olefin fuses the polyolefin resin with the substrate using the heat generated during pre-heating and baking, resulting in efficient adhesion. In addition, the removal of the formerly added chlorine from the olefin settles concerns over the burden on the environment represented by the emission of gases when the coating film is burned at disposal⁽⁵⁾.

3.3. Effect of Developed Primer

Figure 9 shows the melting points of the former and

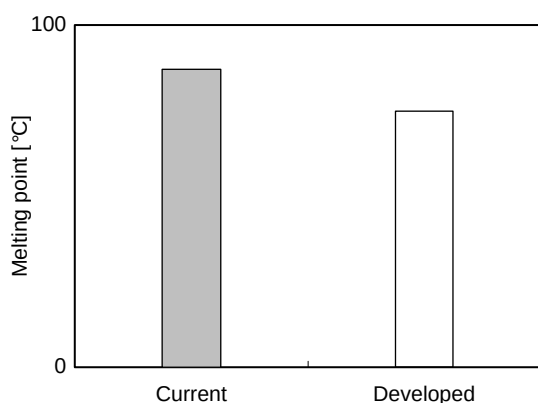


Fig. 9 Melting point of polyolefin

newly developed polyolefins. The results of measurements of the peeling strength of the primer in which the polyolefin is employed are shown in Fig. 10. The newly developed primer has enabled the achievement of a 28% increase in peeling strength against the former product.

4. Conclusion

A metallocene catalyst has been employed to control the tacticity of polyolefin in order to reduce its melting point, enabling the development of a waterborne primer displaying enhanced adhesion.

- (1) The developed primer displays a 28% increase in peeling strength against the former product, in addition to enhanced adhesion.
- (2) The use of a metallocene catalyst has enabled the development of a chlorine-free primer.

In addition to reducing the use of environmentally harmful substances, the outcome of the research discussed in this paper offers outstanding automotive coating performance. The developed product was introduced to Honda's UK coating lines in January 2008, and has been employed in the manufacture of the CIVIC and the CR-V (Fig. 11).

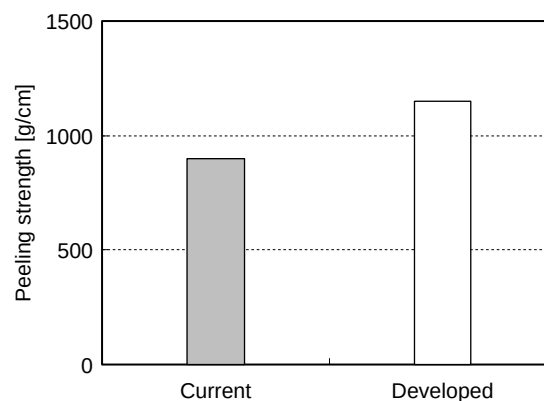


Fig. 10 Peeling strength of primer



Fig. 11 Honda CIVIC and Honda CR-V

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