

Development of New Pearl White Color for Body Coating

Keisuke KOJIMA* Shinichi IKEHARA**

ABSTRACT

Color plays an important role in styling, which is a major element in the appeal of a vehicle. Pearl white is particularly important as a color imparting a “premium” quality to a vehicle. Because of this, the rate of use of the color in the domestic market is high, and it has reached market maturity. In order to increase the commercial appeal of the color, the project discussed here focused on the development of a new high-quality pearl white coating. First, a survey of customer preferences was conducted, enabling quantitative axes for the evaluation of feelings in relation to color to be established. Development targets were set on this basis. The development of a white primer surfacer with high yellowing resistance and color hiding ability enabled the process of application of a white color base coat to be discontinued. As a result, a higher level of atomization could be achieved and the mica base coat could be applied in two stages, producing a higher level of orientation of the mica. This has enabled the realization of a pearl white color with a strong pearl feeling previously unattainable on a conventional mass production line.

1. Introduction

Styling elements represent one aspect of the appeal of a vehicle. In the 2002 APEAL Study conducted by J. D. Power and Associates, styling elements topped the list of aspects of a vehicle that appeal to customers (Table 1). The term “styling” tends to produce an image of the shape of the vehicle body, but the visual quality of the paintwork is also an important element of styling, placing seventh in a list of 116 categories. Color is a major element in the visual quality of the paint. Vehicle colors are influenced by the social trends, the state of the economy, and other aspects of the specific period in question. A survey of color trends today shows silver to be the most popular vehicle color, followed by white. In the Japanese market, super white was the most-used white color in the 1980s. While the popularity of the color showed a decline in the 1990s, white has continued to be extensively used, and remains a staple color. Today, in almost all cases, pearl white is the white color employed in the Japanese market. Used as a color for luxury vehicles, pearl white is also becoming an important color in enhancing the appeal of premium brands in the North American market.

Against this background, value can be seen in moving away from the use of a color that has reached maturity

in the domestic market, and the development of a pearl white giving a stronger image of a “premium vehicle” for the North American market is desirable, but restrictions on the vehicle painting process and on manufacturing costs have made this a challenge.

This paper will discuss the development of a new pearl white paint that can be used on mass production lines and offers a high sense of quality.

2. Criteria for Evaluation of Pearl White Color and Development Targets

It is important to obtain a grasp of customer preferences in order to attempt to increase the appeal of a product in a mature market. A factor analysis was therefore conducted to determine the nature of the sense of quality customers received from pearl white colors. Models of sports cars were coated with 12 pearl white variants. Prior to the factor analysis, 15 descriptive adjectives from the field of color design and their antitheses were selected (Table 2). A survey was conducted in which these adjective pairs and customer preferences were ranked in seven stages. The test subjects were Honda employees (38 men and 23 women) with no special knowledge in the area of color, ranging in age

* Automobile R&D Center

** Honda Motor Co., Ltd.

Table 1 Correlation coefficient of "Fun to Drive" score and score of each question

Ranking	Questionnaire		Correlation coefficient
1	Style	Overall rating	0.931
2	Style	Side profile appearance	0.928
3	Style	Uniqueness of your vehicles overall styling	0.925
4	Style	Front end style	0.923
5	Style	Exterior styling	0.918
6	Style	Appearance of exterior molding and trim	0.911
7	Style	Appearance of exterior paint	0.897
8	Handling	Feel of steering wheel	0.896
9	Style	Ext/int color coordination	0.891
10	Style	Appearance wheels/rims	0.890
11	Style	Rear end style	0.887
12	Handling	Steering effort	0.854
13	Other	Heater keeps interior warm	0.844
14	Interior	Styling of the seats	0.838
15	Handling	Brakes smooth in panic stop	0.835
16	Interior	Overall rating	0.834
17	Interior	Interior styling	0.834
18	Interior	Interior smell	0.834
19	Handling	Brakes slow vehicle quick and safe	0.831
20	Handling	Hold driver when cornering	0.830
21	Other	Rate how quickly the heater gets warm	0.830
22	Style	Open/close side door	0.829
23	Handling	Overall braking	0.825
24	Interior	Interior color coordination	0.821
25	Other	Front defroster performance	0.817
26	Handling	Stability on winding roads	0.815
27	Interior	IP design	0.815
28	Handling	Overall rating	0.813
29	Power plant	Perf in 2-wheel drive	0.811
30	Interior	Understand gauges/instr	0.811
31	Interior	Look/feel of ip materials	0.804
32	Power plant	Smoothness during hard accel	0.801

Table 2 Adjective pair and result of factor analysis

Adjective pair				Factor loading			
				1st factor	2nd factor	3rd factor	4th factor
7 ← Score → 1				Pearl feeling	Novel feeling	Male-female feeling	?
Feminine	女性的な	Masculine	男性的な	0.0166	0.1941	0.9071	0.2989
Natural pearl	天然パールのような	Artificial pearl	人工パールのような	0.7373	-0.1129	0.6604	0.0792
Silky	シルキーな	Glare	ギラギラしている	0.8101	-0.2202	0.4122	-0.0201
Delicate	落ち着いた	Glitter	派手な	0.5361	-0.8026	0.1970	-0.1456
Three dimensional	3次元的な	Non three dimensional	3次元的でない	0.7742	0.2242	-0.0330	-0.3200
Bright	明るい	Dark	暗い	-0.2307	0.6338	0.1509	0.5502
Luxury	ラグジュアリー	Sporty	スポーティ	0.3789	-0.1100	0.8620	-0.1712
Color travel	色が変化する	Non-color travel	色が変化しない	0.5971	0.7856	-0.0562	-0.0688
Gentility	上品な	Vulgarity	下品な	0.8179	-0.4007	0.2891	0.0430
Valuable	高価に見える	Cheap	安っぽく見える	0.9187	0.0676	0.2503	-0.0728
Novel	目新しい	Commonplace	ありきたりな	0.0901	0.9349	-0.0739	-0.0009
Fine particles	粒子が詰め込まれた	Rough particles	粒子が詰め込まれていない	0.9002	0.1620	0.2311	-0.0910
Gorgeous	ゴージャスな	Simple	シンプルな	0.1892	0.8785	0.3065	-0.0602
Warm	暖かい感じ	Cool	冷たい感じ	0.3223	-0.0780	0.9099	-0.1068
Contemporary	先進的な	Classic	クラシックな	-0.3141	0.7466	-0.3526	0.4018
Like	好みのカラーだ	Dislike	嫌いなカラーだ	-	-	-	-
Contribution ratio(%)				37.62	25.92	25.48	3.56
Accumulative contribution ratio(%)				37.62	63.54	89.02	92.58

from their 20s to their 50s.

The results of this factor analysis are shown in Table 2. Up to the third factor, the accumulative contribution ratio was 89%, but from the fourth factor, the contribution ratio was less than 3.6%, and this was therefore excluded

from consideration. The first factor was judged as the axis representing the feeling of pearl in the color, as selected from the adjective pairs with the highest factor loading, the second factor as the axis representing the feeling of novelty of the color, and the third factor as the axis

representing the feeling of “masculinity” or “femininity” of the color. Figure 1 shows the correlation between scores for these three factors and the preference scores that were surveyed in parallel with them. The factor score for the feeling of pearl in the color displayed a strong correlation coefficient at 0.8325, but no correlation was observed in the case of the factor scores for novelty and masculinity-femininity, with correlation coefficients of 0.0700 and 0.1442 respectively. Based on these results, despite the fact that customers would perceive the sense of quality in the pearl white color in terms of these three factors, because only the “feeling of pearl” factor would be used in evaluating preference, increasing the feeling of pearl in the color was established as the strategy for increasing the appeal of the color.

Three axes were established for the evaluation of the feeling of pearl in the color. An appearance of three-dimensionality (“three-dimensional feeling” below) and the sense that the mica flakes in the pigment were arranged in a high density (“feeling of fineness and high density” below) were selected as evaluative axes from the adjective pairs with the highest factor loading for the first factor, and the brightness on the face, providing an image of “advancement,” was selected as the third axis based on a unique design taste. The level of “flip-flop” (FF value)

was used as the quantitative target for the three-dimensional feeling, HB value for the feeling of fineness and high density, and IV value for the brightness on the face. FF values are an index that expresses the level of contrast between highlighted sections and shadowed sections. The higher the value, the more three-dimensional the curved sections of the vehicle body will appear. HB values are an index expressing the level of glare of the flakes used to achieve brightness. The denser the flakes are arranged, the silkier the appearance and the lower the HB value. IV values express the level of brightness of the highlighted sections. The higher the value, the brighter they appear.

The development target for the new pearl white color was set as the achievement of higher figures in terms of each of these evaluative axes than those of the current pearl white color (Fig. 2).

3. High-quality Pearl White Paint

3.1. Orientation of Mica and Pearl Feeling

With a few exceptions, the structure shown in Fig. 3 is used in the majority of pearl white automotive body coatings. It was conjectured that the feeling of pearl in the color would change depending on the degree of

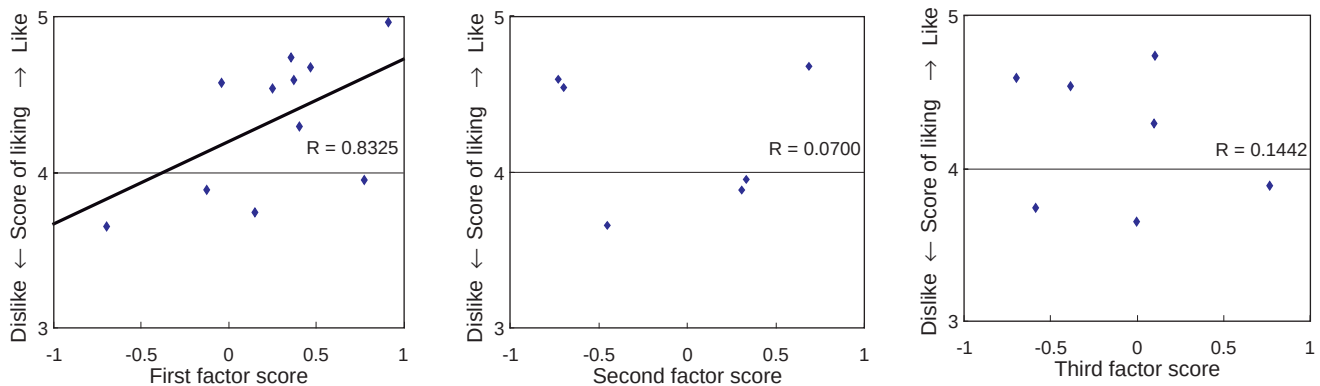


Fig. 1 Correlation between score of liking and each factor score

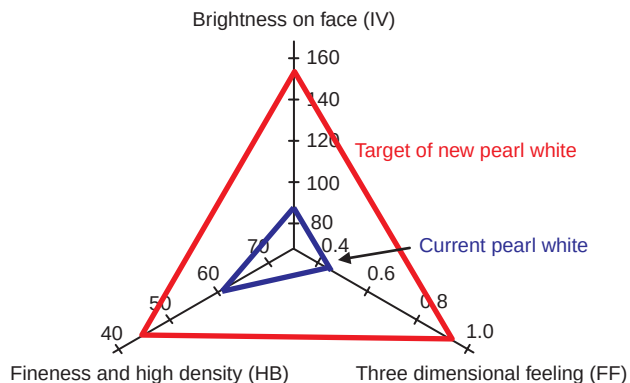


Fig. 2 Target of new pearl white

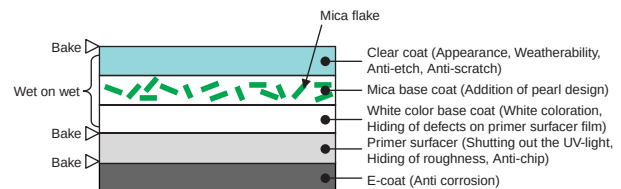


Fig. 3 Current film system of pearl white color for body coating

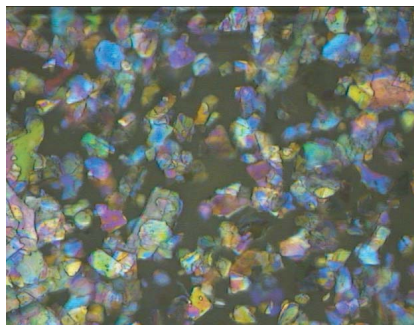
reflection, transmission, and interference of light due to the orientation of the mica in the mica base layer. Paints with two different levels of mica orientation were produced and analyzed in order to determine the relationship between the orientation of the mica and the pearl feeling (Fig. 4). Sections in which the mica is oriented in parallel with the surface of the paint show as white, while sections in which the mica is not oriented in parallel show as grey. Sample B, which displayed a higher whiteness ratio, had a higher level of mica orientation, and recorded good FF, HB, and IV values. This indicated that there was a correlation between an increased level of mica orientation and an increased pearl feeling.

3.2. Status and Issues of Pearl White Color Coating

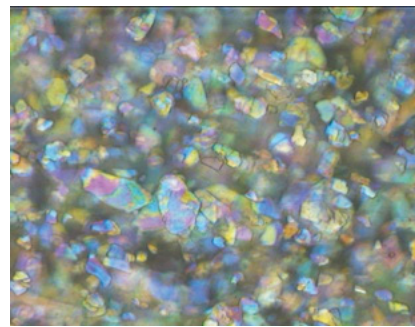
The achievement of the targets discussed above using the current painting process and current paint materials represented a challenge. Broadly speaking, there were two reasons for this. The first of these was the one-stage application of the mica base coat. Following baking of the e-coat and the primer surfacer, the white color base coat

is first applied, after which the mica base coat is applied while the former is still wet (Fig. 3). This wet-on-wet application in the current painting process means that unlike other colors, in which the same coat is applied in two stages, the mica base coat that determines the feeling of pearl in the color is applied in only one stage. Because of this, there is no choice but to achieve a high flow rate for the mica base coat, which reduces the level of fine atomization, in turn limiting the level of orientation of the mica.

The second factor was the wet-on-wet application of the white color base coat and the mica base coat. As shown in Fig. 5, an increased feeling of pearl is achieved when the mica base coat is applied following baking of the white color base coat than when wet-on-wet coating is employed. The mechanism behind this is thought to be the generation of a convection current between the layers ("layer mixing" below) during wet-on-wet application (Fig. 6). In addition to disordering the orientation of the mica, this reduces the usable amount of mica due to its permeation into the white color base layer, thus impeding the increase of the mica orientation.



Sample (A) applied by spray (Low-oriented mica)
IV:90, FF:0.45, HB 65



Sample (B) applied by barcoater (High-oriented mica)
IV:137, FF:0.76, HB 54

Fig. 4 Micrograph of different level of mica orientation

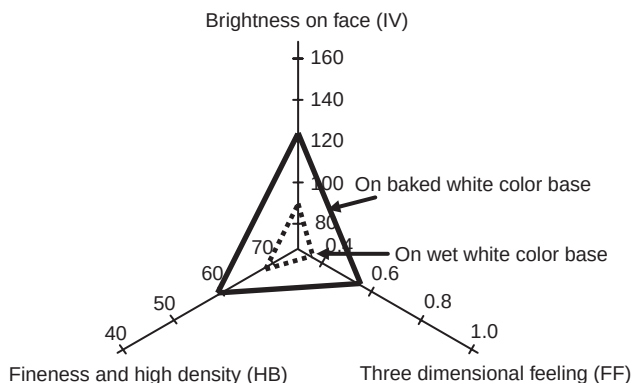


Fig. 5 Pearl feeling difference between on baked white color base and on wet white color base

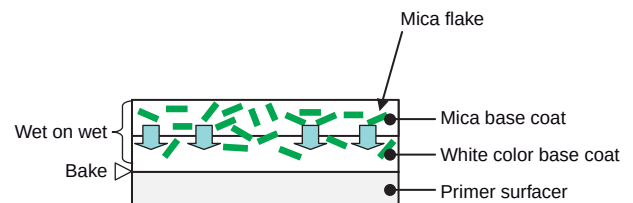


Fig. 6 Mechanism of disorder of mica orientation by convection of white color base coat and mica base coat

3.3. Technology for Achieving Increased Orientation of Mica

Removing the two factors discussed above was the key to increasing the feeling of pearl in the color. The first issue, the one-stage application of the mica base coat, could be addressed by applying the coat in two stages. Doubling the stages of application would halve the requisite flow rate in each stage. This would increase the level of fine atomization, in turn increasing the orientation of the mica via the mechanism shown in Fig. 7.

The method studied to enable this was the replacement of the former first stage, the application of the white color base coat, by the application of a mica base coat, resulting in a two-stage application of the coat.

In the same way, the second issue, the wet-on-wet application of the mica base coat to the white color base coat, could be addressed by incorporating the functions of the white color base coat in the primer surfacer film, thus enabling wet-on-wet coating to be done away with. Because the primer surfacer film was a hard film, there would be no layer mixing with the mica base coat.

The application of the methods discussed above enabled the achievement of the targets for the pearl feeling using existing coating lines, with no increase in space (Fig. 8).

3.4. Technological Issues and Responses

The major technological issues associated with the application of the above methods related to the incorporation of the functions of the white color base coat in the primer surfacer film. Several issues arose in this connection, and these related to imperfections in the primer surfacer film. Because the mica was employed in the form of transparent flakes, the imperfections in the primer surfacer tended to be visible. These visible imperfections would make it challenging to present a quality product to customers.

The first of these imperfections was yellowing of the primer surfacer film. This yellowing occurs because the peroxide chromophores that are a by-product of the oxidation of the plastic during baking are yellow⁽¹⁾⁻⁽³⁾. The degree of yellowness is dependent on the baking temperature and the time spent in baking. On the production line, the baking temperature and time changes

depending on the section of the vehicle body, the length of residence in the baking oven during the rest period, and the application of repairs to the top coat, among other factors. When these factors are in operation during baking at high temperatures and for extended periods, yellowing occurs in the current primer surfacer film, but because of the application of the white color base coat, the imperfection is ultimately hidden. However, this would not be the case when the white color base coat was no longer applied.

The second imperfection was visibility of the color of the e-coat. The e-coat film, which sits beneath the primer surfacer film (Fig. 2), is dark grey in color. Using only the white primer surfacer coat, this color would be easily visible. At present the white primer surfacer and the white color base coat help prevent the color from being visible, but the removal of the white color base coat would enable it to be seen.

To address these technological issues, it was decided to increase the yellowing resistance and enhance the color hiding performance of the white primer surfacer coat. Modification of the primer surfacer was therefore examined.

The target for yellowing resistance was set as a yellow value (color notation: Δb^* value) of 0.5 or less, such that a difference between a film that had received the maximum thermal history projected for the production line and a film that had received the standard thermal history could not be perceived in a visual comparison. Based on

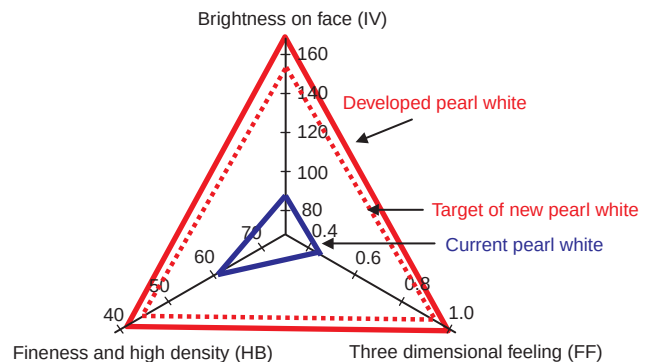


Fig. 8 Pearl feeling potential of new pearl white technology

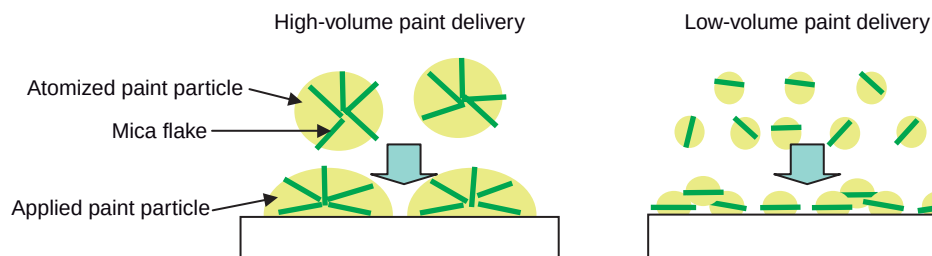


Fig. 7 Mechanism of enhancing mica orientation by low size atomization

the mechanism of yellowing, in order to enhance resistance to yellowing, studies were conducted to determine the type and amount of an anti-oxidant agent to be added to help prevent oxidation, and of a peroxide decomposing agent to break down the peroxides that had formed in the oxidized plastic.

On the basis of the yellowing resistance target value and the degree of hardening of the material, the design values for the coating were set at 1.0 parts per hundred resin of a special anti-oxidant agent and a peroxide decomposing agent (“parts per hundred resin” is abbreviated as PHR below) (Fig. 9).

The target for color hiding performance was selected as lack of visibility of the base color through a film of 27 μm in thickness, based on the assumption of 3 μm being abraded from the surface of a film of the lowest thickness of 30 μm . (3 μm is the normal amount abraded from the surface in repairing an imperfection). The definition of lack of visibility was a color difference (color notation: ΔE^* value) of 0.3 or less in a comparison of an area of film of a thickness able to hide white and black and a 27 μm thick area of film, such that no difference could be determined visually.

Color hiding performance was enhanced by adding aluminum flakes^{(4),(5)} and increasing the amount of the white pigment titanium oxide that was employed. Depending on the amount added, the addition of

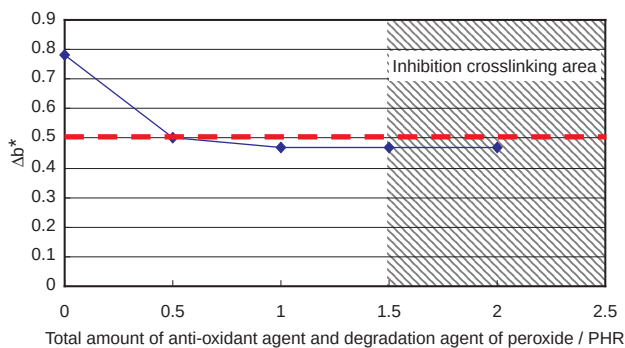


Fig. 9 Effect of addition of additive for anti-yellowing

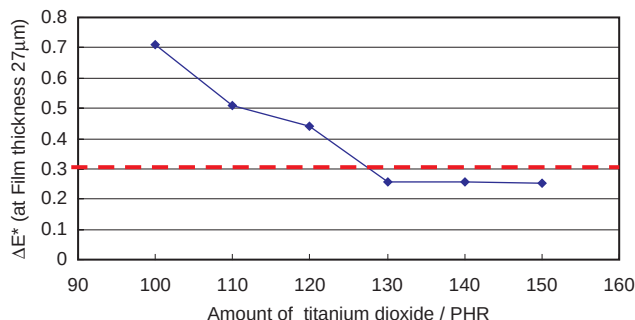


Fig. 10 Effect of addition of titanium dioxide for color hiding

aluminum flakes is an effective method of enhancing color hiding ability, but because the substance is grey in color, there is a limit to the amount that can be added while maintaining the target whiteness value (color notation: L^* value) of 92. The limit was set at 3 mass% of the mass of titanium oxide added. The amount of titanium oxide to be added was set at 130 PHR, a figure at which color hiding ability becomes saturated (Fig. 10). The application of these methods enabled the achievement of target performance, with color hiding at a film thickness of 26 μm .

4. Conclusion

The use of the technologies discussed above has enabled the realization of a pearl white color with a pearl feeling previously unattainable on current mass production lines. The development can be summarized as follows:

- (1) The feelings of customers towards white pearl colors (pearl feeling, feeling of novelty, feeling of “masculinity” or “femininity”) were isolated. Development targets were set using the pearl feeling axis, the only axis that demonstrated a strong correlation with customer preference.
- (2) It was determined that it would be necessary to increase the level of orientation of the mica flakes in the paint in order to increase the pearl feeling of the color. In order to increase the fineness of the atomization of the paint and increase the level of orientation of the mica, the functions of the white color base were incorporated in the primer surfacer film, enabling the white color base application process to be abandoned and the mica base coat to be applied in two stages.
- (3) The new issues raised by imperfections in the primer surfacer film were addressed by increasing the resistance to yellowing and the color hiding ability of the primer surfacer.

5. Afterword

In the 1980s, pearl white was a color reserved for luxury vehicles in the Japanese market. It was able to be applied only to luxury vehicles because of its high production cost. At the time, the primer surfacer was applied in two coats, and no enhancement in terms of yellowing performance or visibility, of the type discussed above, were made. Increasing the amount of coating procedures on a normal coating line would generate issues of productivity and cause efficiency to decline, and a specialized coating line was therefore established. In the 1990s, the strong commercial appeal of the color led to increased demand for its employment on regular vehicles. To enable this, the coating method currently in use, in which the primer surfacer is applied in one coat, was developed. This resulted in rapid diffusion of the color, and it has now reached a stage of market maturity. This

made it challenging to develop a pearl white with a stronger pearl feeling, to distinguish it from the pearl white colors used by competitors. For this reason, techniques involving the use of mica and other brightening agents in special coatings in order to produce a sense of individuality have been employed. The technology discussed in this paper represents a base technology that enables the realization of a stronger pearl feeling while maintaining the current level of productivity, and can be expected to contribute to further evolution of the pearl white color. Use of the new pearl white coating will commence with the 2008 year model ACURA RL, and it will begin to be employed in a wider range of models following this.

References

- (1) Okatsu, Y.: Dai 18 kai Kobunshi no Rekka to Anteika Kiso to Ouyou Kouza, Kobunshigakkai Kouen Yoshisyu, Tokyo, 1998-7-2/3, The Society of Polymer Science of Japan, p. 1-5 (1998) (in Japanese)
- (2) Tsunooka, M.: Dai 18 kai Kobunshi no Rekka to Anteika Kiso to Ouyou Kouza, Kobunshigakkai Kouen Yoshisyu, Tokyo, 1998-7-2/3, The Society of Polymer Science of Japan, p. 6-13 (1998) (in Japanese)
- (3) Sasaki, M.: Dai 18 kai Kobunshi no Rekka to Anteika Kiso to Ouyou Kouza, Kobunshigakkai Kouen Yoshisyu, Tokyo, 1998-7-2/3, The Society of Polymer Science of Japan, p. 55-58 (1998) (in Japanese)
- (4) JP, 2609513, B (1997)
- (5) JP, 3755844, B (2006)

■ Author ■



Keisuke KOJIMA



Shinichi IKEHARA