

Colorimetry and Impression Evaluation of Insert Molded GFRP Plate with Black Silk Fabrics

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Abstract. Black silk fabric, a traditional craft produced using the Kyo-Yuzen dyeing technique, is another luxury product. The intention behind the present report is to mold Urushi-like glass fiber-reinforced plastic, using black silk fabric. We first manufactured a glass fiber-reinforced plastic (GFRP) molded plate consisting of various laminate layers, and compared the surface color with Urushi products. Subsequently, we used an impression evaluation to reveal how the glass fiber-reinforced plastic (GFRP) molded plate using black silk fabric was rated. As the results of this study, it was confirmed that; L* and a* value of FRP sample was similar to the Urushi sample, FRP sample was bluer than the Urushi sample according to b* value, and C* value of FRP sample was higher than the Urushi sample. About half of the subject regarded GFRP using black silk fabric with the lightness similar to the Urushi product as Urushi product in the impression evaluation. The sample regarded as the Urushi product makes subject more feel “Beauty”, “Sense of luxury and high quality”, “Gloss” and “Depth of blackness” than the sample not regarded as the Urushi product. Evaluation point of the subject regarded the FRP sample as the Urushi product showed a strong association between “Beauty” and “Sense of luxury and high quality”, between “Beauty” and “Gloss”, between “Sense of luxury and high quality” and “Gloss”.

Keywords: GFRP · Kyo-Yuzen dyeing · Silk fabric · Urushi · Black · Colorimetry · Impression evaluation

1 Introduction

Plastic products are light, user-friendly, and indispensable to our lives. However, they cannot really be said to give consumers a sense of luxury and high quality. Commodity prices therefore inevitably tend to be kept down, regardless of high functionality. To make plastic products that give consumers a sense of luxury and high quality, we need to know people's sensibilities. A huge range of physical factors affect peoples' sensibilities, including the surface profile, weight and color of a plastic product. Analyzing these factors one by one and recreating the products based on that analysis requires a lot of time.

Japan has products termed traditional crafts which have a long legacy. As traditional crafts are created using traditional processes, carefully selected materials are used and work is often done manually. In line with this, prices are also high. However, traditional crafts give consumers a sense of luxury and high quality that is equal to or higher than the price. Moreover, many traditional crafts provide one with a moment of peace when taking it into one's hand. We think it is therefore a natural development to learn from traditional crafts this sense of luxury and high quality that plastic products are in need of.

The present study focuses on the Japanese traditional craft of Urushi (lacquer) products. Figure 1 shows an example. The black often used in Urushi products has a depth which is regarded as high grade in Japan. In previous study, Urushi product has been evaluated by various analysis methods [1–6]. However there is only a study compared the Urushi product and the plastic injection molding product in the studies compared the Urushi product and the plastic product [7].

Black silk fabric, a traditional craft produced using the Kyo-Yuzen dyeing technique, is another luxury product. The intention behind the present report is to mold



Fig. 1. An example of Urushi product [Incense case with Maki-e decoration “Yukyu no Sasayaki” (made by Yutaro Shimode)]

Urushi-like glass fiber-reinforced plastic, using black silk fabric. We first manufactured a glass fiber-reinforced plastic (GFRP) molded plate consisting of various laminate layers, and compared the surface color with Urushi products. Subsequently, we used an impression evaluation to reveal how the glass fiber-reinforced plastic (GFRP) molded plate using black silk fabric was rated.

2 Method

2.1 Sample

We used glass fiber-reinforced molded plates using black silk fabric and Urushi plates for the samples. For the glass fiber-reinforced molded plate, we used clear resin (2035P, manufactured by U-PICA), glass mats (#230, manufactured by Central Glass), and, as decorative material, blackened silk fabric. Five samples were prepared with the black silk fabric occupying different positions between the layers. Figure 2 illustrates the layered compositions for the glass fiber-reinforced molded plate using black silk fabric. The sample with the black silk fabric in the uppermost layer is labeled FRP1, with the others labeled FRP1-5, depending on the location of the silk fabric. For FRP1, a silk fabric layer was layered on top of a gel coat, with four glass mat layers placed on top of that. The gel coat surface was taken as the sample surface. Curing conditions were 24 h at room temperature. Figure 3 shows the appearance of an FRP sample using black silk fabric.

The Urushi plates were manufactured by a skilled artisan with 36 years' experience. By adjusting the mix of a glossy and a matt Urushi, he prepared Urushi in ten gradations of luster. For the glossy Urushi “Kourin Nuritate Jyohonkuro” (Kourin finishing black, manufactured by Tsutsumi Asakichi Urushi-ten) was used, and for the matt Urushi, Sugurome (oil-free Urushi, manufactured by Tsujita Urushi-ten). A PMMA (Polymethylmethacrylate) plate measuring 100 mm × 100 mm × 5 mm was used as the base onto which the Urushi was applied. Two layers of Urushi were applied to the top of this PMMA plate, namely a middle layer followed by a top layer. Figure 4 shows the appearance of the Urushi samples. The samples are named Urushi1–10 according to the degree of gloss, with Urushi1 being the sample with the least, and Urushi10 the sample with the most gloss.

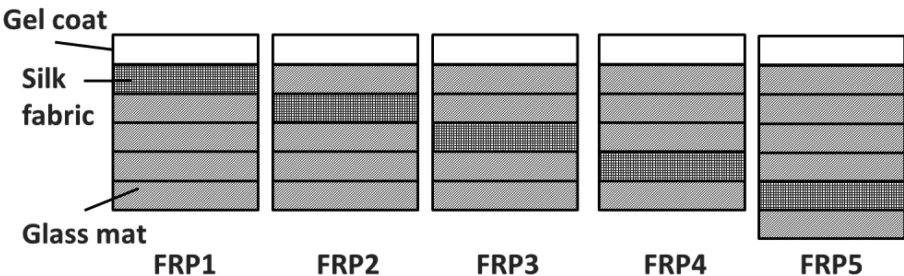


Fig. 2. Layered compositions for the glass fiber-reinforced molded plate using black silk fabric

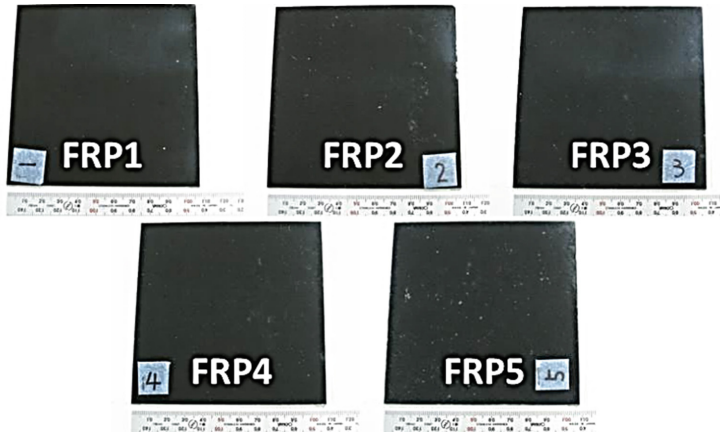


Fig. 3. Appearance of an FRP sample using black silk fabric



Fig. 4. Appearance of the Urushi samples

2.2 Colorimetry

To clarify the difference between the black of the FRP samples and the Urushi samples, color measurements were taken of the sample surfaces using a CM-2600D spectrophotometer (Konica Minolta, Inc.). Figure 5 illustrates the measurement principles of the CM-2600D spectrophotometer. Using a D65 light source, the sample is exposed to light which is diffused through an integrated sphere. The light received at 8° from the sample's perpendicular plane was measured. Regular reflected light was eliminated. The following aspects were measured: L^* (Lightness), a^* (Red/Green Chromaticity), b^* (Yellow/Blue Chromaticity) and C^* (Chroma).

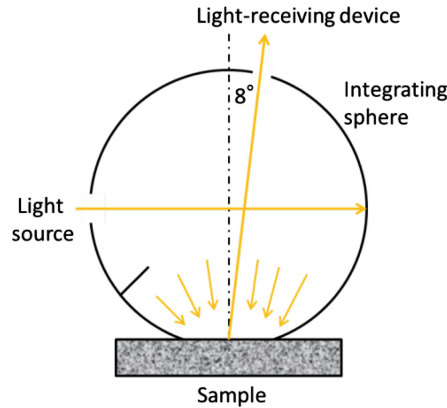


Fig. 5. Measurement principles of the CM-2600D spectrophotometer

2.3 Impression Evaluation

To identify the differences in the way the black is experienced for the FRP and Urushi samples, we performed an impression evaluation using a questionnaire. There were 21 male and female respondents ranging from 21 to 66 years in age (average age 28.5 years, SD = 13.5 years). They were shown the FRP1 and Urushi5 samples in a room lit using fluorescent lighting at a light intensity of 60 lx, and, without having been informed as to what the respective samples were, were asked to respond to the questionnaire. The FRP and Urushi samples most similar to each other in appearance were selected. Respondents were prohibited from touching the samples. The questionnaire first asked to select the sample they thought was an Urushi product, and then asked to grade the respective samples on a 5-point scale for “Beauty”, “Sense of luxury and high quality”, “Gloss” and “Depth of blackness”.

We performed a two-way analysis of variance using the evaluation values obtained from the impression evaluation as dependent variables, and the responses to question 1 and the sample types as independent variables. For the analysis, IBM SPSS Statistics (Var.20) was used. Furthermore, the correlations between the evaluation items were analyzed. In both analyses, the critical p-value was set at 5 %.

3 Results

3.1 Colorimetry

Figure 6 showed the result of L^* in each sample. The lower the position of black silk fabric was in the layer construction of the sample, the higher the L^* value became in the case of FRP1, FRP2 and FRP3. The L^* value of FRP4 and FRP5 was low. The L^* value of Urushi1 was the highest in all Urushi samples. The higher the value of the gloss of Urushi sample became, the lower the L^* value of it became. L^* value of FRP samples were similar to the Urushi samples with the high and middle level of gloss.

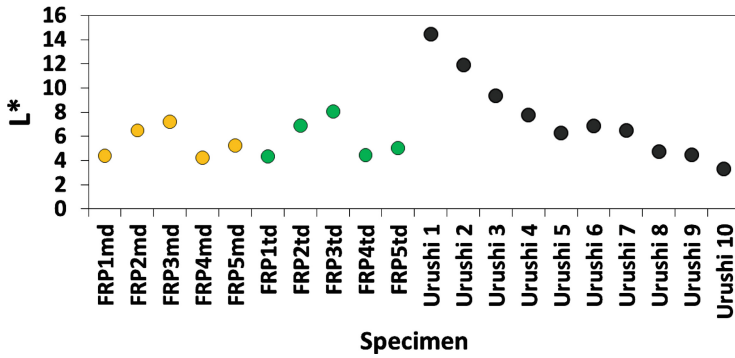


Fig. 6. Results of L*

Figure 7 showed the result of a^* in each sample. The higher the a^* value became, the more the color became red. The lower the a^* value became, the more the color became green. The upper the position of black silk fabric was in the layer construction of the sample, the higher the a^* value became in the case of FRP1, FRP2 and FRP3. The a^* value of FRP4 and FRP5 was high. The a^* value of Urushi1 was the highest in all Urushi samples. The higher the value of the gloss of Urushi sample became, the lower the a^* value of it became. Green was strong in both FRP and Urushi samples because it's a^* value was negative value. The a^* value of FRP sample was similar to the Urushi sample with low level of gloss.

Figure 8 showed the result of b^* in each sample. The higher the b^* value became, the more the color became yellow. The lower the b^* value became, the more the color became blue. The upper the position of black silk fabric was in the layer construction of the sample, the higher the b^* value became in the case of FRP1, FRP2 and FRP3. The b^* value of FRP4 and FRP5 was high. The b^* value of Urushi1 was the lowest in all Urushi samples. The higher the value of the gloss of Urushi sample became, the higher the b^* value of it became. Blue was strong in all FRP samples because it's b^* value was

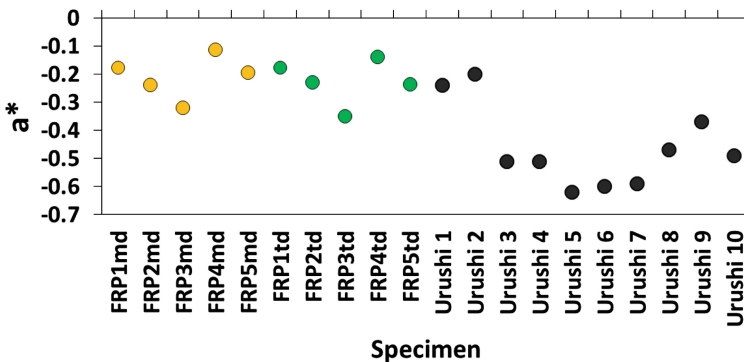


Fig. 7. Results of a^*

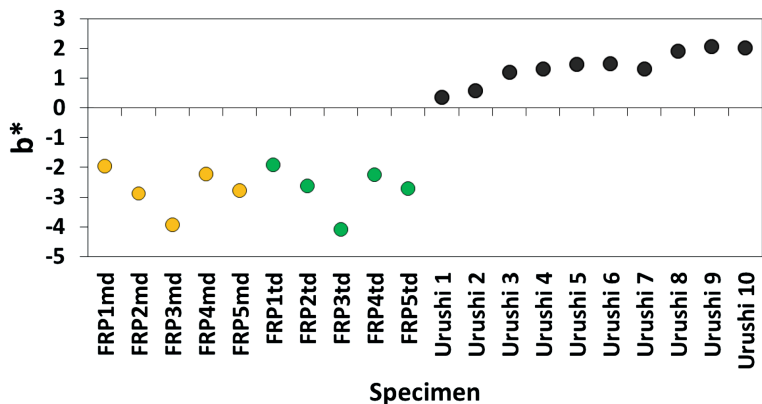


Fig. 8. Results of b^*

negative value. On the other hand, yellow was strong in all Urushi samples because its b^* value was positive value.

Figure 9 showed the result of C^* in each sample. The upper the position of black silk fabric was in the layer construction of the sample, the higher the C^* value became in the case of FRP1, FRP2 and FRP3. The C^* value of FRP4 and FRP5 was low. The C^* value of Urushi1 was the lowest in all Urushi samples. The higher the value of the gloss of Urushi sample became, the higher the C^* value of it became. The C^* value of FRP sample was similar to the Urushi sample with high level of gloss, or it was two times as high as the Urushi sample with high level of gloss.

As these results, it was found that the L^* and a^* value of FRP sample was similar to the Urushi sample, FRP sample was bluer than the Urushi sample according to b^* value, and C^* value of FRP sample was higher than the Urushi sample. Furthermore, it was found that depth of blackness was not sufficient in the FRP products according to the hearing from Urushi craftspeople.

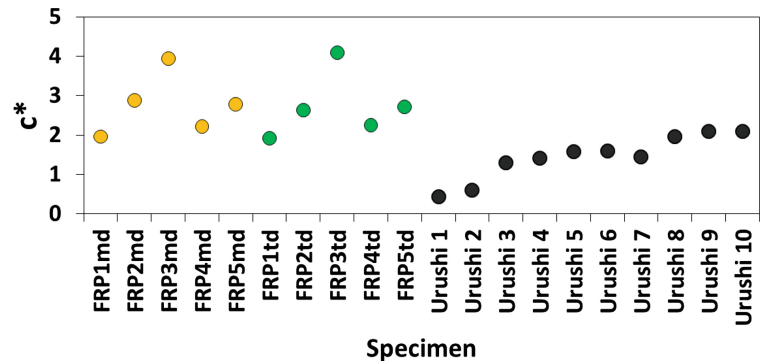


Fig. 9. Results of C^*

3.2 Impression Evaluation

Question 1 was “Which sample is Urushi?” 10 subjects selected the FRP sample, and 11 subjects selected the Urushi sample. Figure 10 showed the result of the impression evaluation about “Beauty” of FRP and Urushi sample. Gray bar showed the subject selected the Urushi, and black bar was showed the subject selected the FRP sample in the question 1. All subjects felt the sample regarded as the Urushi product in question 1 more beautiful than the other sample. As a result of an analysis of variance, a main effect was not shown, but a significant interaction was shown ($F(1.42) = 10.3, p < .01$). Figure 11 showed the result of the impression evaluation about “Sense of luxury and high quality” of FRP and Urushi sample. Figure 12 showed the result of the impression evaluation about “Gloss” of FRP and Urushi sample. Figure 13 showed the result of the impression evaluation about “Depth of blackness” of FRP and Urushi sample. All subjects felt the sample regarded as the Urushi product in question 1 more “Sense of

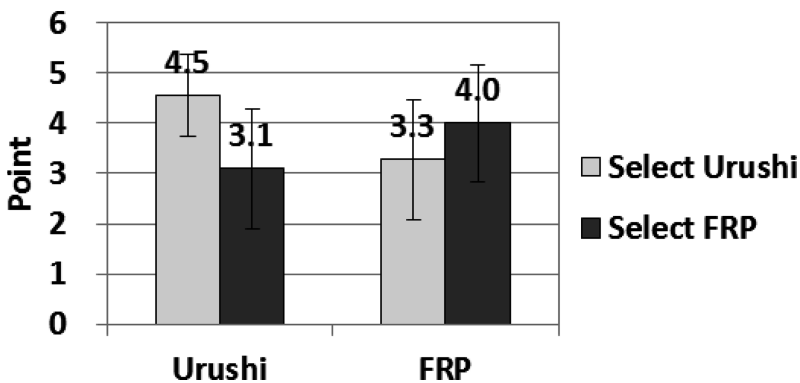


Fig. 10. Result of the impression evaluation about “Beauty” of FRP and Urushi sample

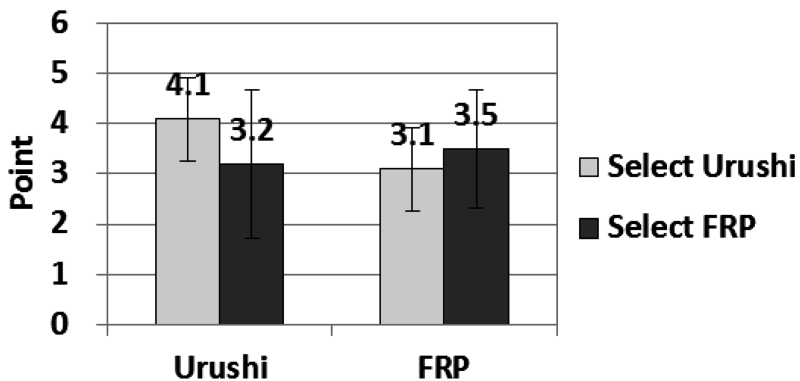


Fig. 11. Result of the impression evaluation about “Sense of luxury and high quality” of FRP and Urushi sample.

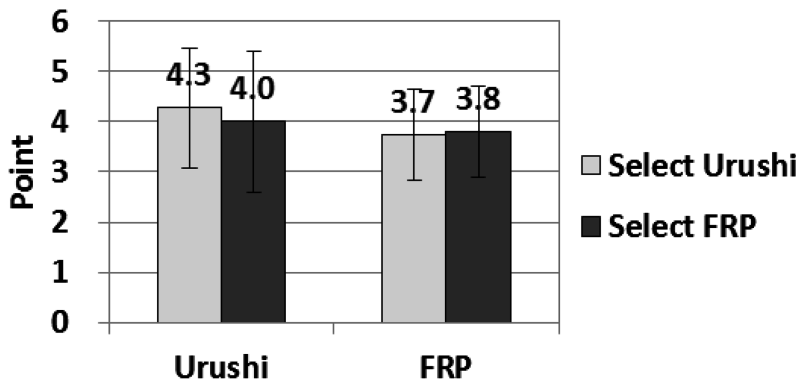


Fig. 12. Result of the impression evaluation about “Gloss” of FRP and Urushi sample

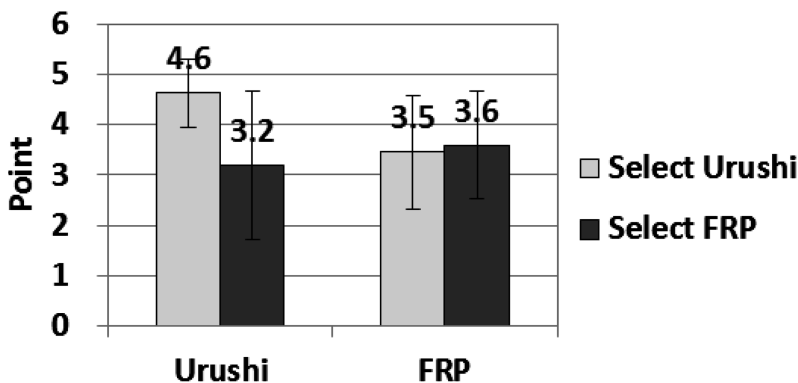


Fig. 13. Result of the impression evaluation about “Depth of blackness” of FRP and Urushi sample.

luxury and high quality”, “Gloss” and “Depth of blackness” than the other sample. A significant difference according to the analysis of variance was not shown.

Table 1 showed the correlation coefficient (r) of “Beauty”, “Sense of luxury and high quality”, “Gloss” and “Depth of blackness” about the sample judged the Urushi in question 1 in each subject selected the FRP and Urushi sample. Evaluation point of the subject selected the FRP sample in question 1 showed a strong association between “Beauty” and “Sense of luxury and high quality”, between “Beauty” and “Gloss”, between “Sense of luxury and high quality” and “Gloss”. Evaluation point of the subject selected the Urushi sample in question 1 showed a middle association between “Beauty” and “Gloss”, between “Sense of luxury and high quality” and “Depth of blackness”.

Table 1. Correlation coefficient of “Beauty”, “Sense of luxury and high quality”, “Gloss” and “Depth of blackness”.

Selected product	Beauty-Sense of luxury and high quality	Beauty-Gloss	Beauty-Depth of blackness	Sense of luxury and high quality-Gloss	Sense of luxury and high quality-Depth of blackness	Gloss-Depth of blackness
FRP	0.816	0.733	0.0895	0.821	0.0877	-0.315
Urushi	0.360	0.549	0.214	0.377	0.422	-0.113

4 Discussions

It is found that b^* and C^* value of GFRP using black silk fabric was different from the Urushi product as a result of the colorimetry. However, about half of the subject regarded GFRP using black silk fabric as Urushi product in the impression evaluation. Although Urushi crafts is a traditional crafts in Japan, Urushi product is a high quality product now, the use of Urushi product is reduced in public life, and it is little seen by many people. Therefore, it seems that it is difficult to recognize the Urushi product. Interaction of question about “Beauty” in the impression evaluation was significant. It seems that this means the Japanese stereotype which Urushi product is more beautiful than the other material products. Furthermore, it suggests that black board with a lightness equivalent to the Urushi product makes people feel beauty and high quality equivalent to the Urushi product because evaluation point of the subject selected the FRP sample in question 1 showed a strong association between “Beauty” and “Sense of luxury and high quality”, between “Beauty” and “Gloss”, between “Sense of luxury and high quality” and “Gloss”. Therefore, there is a possibility that the GFRP inserted the black silk fabric immediately beneath the gel coat is used as the Urushi-like FRP.

5 Conclusions

This study aimed to mold the glass fiber-reinforced plastics (GFRP) using black silk fabric with the color equivalent to the Urushi product. Colorimetry and impression evaluation about the GFRP using black silk fabric and Urushi board was conducted. As the results of this study, it was confirmed that;

1. L^* and a^* value of FRP sample was similar to the Urushi sample, FRP sample was bluer than the Urushi sample according to b^* value, and C^* value of FRP sample was higher than the Urushi sample.
2. About half of the subject regarded GFRP using black silk fabric with the lightness similar to the Urushi product as Urushi product in the impression evaluation.
3. The sample regarded as the Urushi product makes subject more feel “Beauty”, “Sense of luxury and high quality”, “Gloss” and “Depth of blackness” than the sample not regarded as the Urushi product.

4. Evaluation point of the subject regarded the FRP sample as the Urushi product showed a strong association between “Beauty” and “Sense of luxury and high quality”, between “Beauty” and “Gloss”, between “Sense of luxury and high quality” and “Gloss”.

For the above results, there is a possibility that the GFRP using black silk fabric immediately beneath the gel coat is used as the Urushi-like FRP.

References

1. Shimode, Y., Takahashi, Y., Nakai, A., Kotaki, M., Hamada, H.: Surface characteristics of Urushi products. In: Proceedings of 11th Japan International Sampe Symposium and Exhibition (JISSE-11), TC-6-1 (2009)
2. Shimode, Y., Takahashi, Y., Endo, A., Narita, C., Takai, Y., Nishimoto, H., Yamada, K., Goto, A., Yasunaga, H., Hamada, H.: Surface shape characteristics of shellfish pieces used for Urushi products. In: Proceedings of 12th Japan International Sampe Symposium and Exhibition (JISSE-12), TRA-1 (2011)
3. Shimode, Y., Takahashi, Y., Endo, A., Narita, C., Takai, Y., Nishimoto, H., Yamada, K., Goto, A., Yasunaga, H., Hamada, H.: Optical characteristics of shellfish pieces used for Urushi products. In: Proceedings of 12th Japan International Sampe Symposium and Exhibition (JISSE-12), TRA-3 (2011)
4. Shimode, Y., Takahashi, Y., Endo, A., Narita, C., Takai, Y., Yamada, K., Goto, A., Yasunaga, H., Hamada, H.: Optical characteristic of gold powder processed by traditional *Maki-e* technique. In: Proceedings of 12th Japan International Sampe Symposium and Exhibition (JISSE-12), TRA-4 (2011)
5. Shimode, Y., Ohtani, Y., Yasunaga, H.: How do craftspeople distinguish the appearance of natural-lacquerware? Approach by optical image analysis. *J. Jpn. Soc. Colour Mater.* **84**(3), 81–86 (2011)
6. Narita, C., Endo, A., Shimode, Y., Yamada, K.: Study on the appearance and peel strength of Byakudan-Nuri works. *Mater. Sci. Appl.* **5**, 81–85 (2014)
7. Shimode, Y., Takahashi, Y., Endo, A., Narita, C., Murakami, M., Takai, Y., Yamada, K., Goto, A., Yasunaga, H., Hamada, H.: Wide angle reflection properties of Urushi (Japanese lacquer) products and black injection molded article. In: Proceedings of 12th Japan International Sampe Symposium and Exhibition (JISSE-12), TRA-2 (2011)