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How Do Craftspeople Distinguish The Appearance of Natural-Lacquerware ? — Approach by Optical Image Analysis —

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Abstract

The light reflective images of natural Japanese lacquer paints applied on a board were analysed in addition to their colour and gloss measurements, in order to clarify the optical characteristics of the paint, which craftspeople can distinguish. The distribution of luminance on sample images was obtained at two angles under visible light irradiation and the envelope intensity curve was taken from the luminance histogram for black natural-lacquer-painted and chemically coated boards. There are no distinguishing differences in the spectrophlectance and gloss characteristics for the three kinds of black sample boards. It was found by the Gaussian curve fitting for the reflected light profile in the vicinity of the edge of reflected light image on the samples that the glossy natural-lacquer-painted sample shows the smallest area and standard deviation value of the reflected light profile. The results show that the glossy natural-lacquer-painted board reflects light most regularly and the diffusion of the light is smallest. Further, the area and standard deviation values for only the glossy natural-lacquer-painted sample decrease with an increase in the angle between the directions of the normal to the plane of the sample and the reflected sample image.

Key-words: Natural Japanese lacquer, Craftspeople, Light reflective image, Optical characterisation, Gaussian curve fitting

1. Introduction

The natural Japanese lacquer (Urushi) paints have been traditionally used for art and craft objects, tablewares, furniture, daily necessities, Buddhist images, interior finishing materials and so on¹⁾. The natural Japanese lacquer solution is taken from the sap of *Toxicodendron vernicifluum* and the principal chemical component in it for forming the resin is urushiol. The solution is purified and mixed with pigments before use. A highly adhesive and moisture/corrosion resistant coating is obtained by applying the mixture to the surface of an object and then drying it in air. The strong and beautiful lacquer coating is produced after a number of thin layers of the mixture are applied, dried and polished repeatedly. The surface of products finished with Japanese lacquer looks generally beautiful and is very popular traditionally. The estimation of the beauty of the lacquer coating and the clarification of the mechanism which produces the beautiful appearance are important and interesting. Especially, craftspeople (natural lacquer <urushi> expert painters) can distinguish the appearance of natural-lacquerwares from other kinds of similar painted wares and identify the natural-lacquer-painted products, which non-

craftspeople cannot easily distinguish. The craftspeople, moreover, evaluate the beauty of natural-lacquer-painted products.

The estimation of their beauty has been attempted from viewpoint of sensory evaluation²⁻⁵⁾. It is not easy to establish the relationship between the beauty estimated by human sense and experimental values obtained by instrumental measurements, because the nature of beauty is associated with human feeling based on such as an individual personality, experiences and skills, and moreover, sensation, perception and cognition. Furthermore, there are no absolute criteria to measure the beauty and the quantification of the beauty is quite difficult.

It can be considered that the appearance feature of the Japanese lacquer paints should be first clarified before discussing the beauty of them. Under such the situation, as the first step to understand the appearance feature of the Japanese lacquer paints, the authors tried to clarify the optical characteristics of them by analysing their images in the study. The goal of the research is finding the way to estimate the optical characteristics of the Japanese lacquer paints. The digital images of natural Japanese lacquer paint applied on a board were obtained as

photographs and their reflective characteristic of light were studied being compared with a board applied with a synthetic paint and a board coated with a film. The painted and coated boards, which have the appearance very similar to the black natural-lacquer-painted board, were adopted as the control samples. The sensory evaluation with the naked eye for the three kinds of painted and coated samples was made by non-craftspeople and craftspeople in order to estimate the optical similarity for the sample and to know whether craftspeople distinguish the samples.

2. Experimental

2.1 Materials

The natural Japanese lacquer paint, Korin Nuritate Uehonguro (glossy, Tsutsumi Asakichi Urusiten), obtained from *Rhus verniciflua* was used without further purification. The other black coated and painted samples employed for comparison were chosen in terms of showing the same appearance. The synthetic paint spray (Asahipen, acrylic paint) and the black coating film material (Nippon Bee Chemical) were kindly supplied by Nippon Paint. The substrate, which was painted or coated by natural and chemical lacquer paints or the black coating material was a 30 × 30 cm clear polymethylmethacrylate (PMMA) board.

2.2 Painting and coating on PMMA boards

The glossy natural lacquer paint was applied on the PMMA board by hand using a human-hair-brush (3 cm wide) at room temperature. The board was given two coats of the lacquer paint. The painted boards were allowed to stand at room temperature under 60 - 70 % of humidity and the paint was solidified. The synthetic acrylic paint was sprayed upon the PMMA board and was allowed to stand at room temperature until the paint dried. The black coating film material was applied on the PMMA board and fixed at room temperature. The three kinds of painted and coated films on the PMMA board were prepared at thicknesses such that a strong visible light (ca. 1000 lx at the board surface) did not transmit through the samples.

2.3 Sensory evaluation with the naked eye

The sensory evaluation with the naked eye for the three kinds of painted and coated PMMA board samples were made by non-craftspeople and craftspeople. The examinees consisted of 27 non-craftspeople (general people) and 4 craftspeople (natural lacquer <urushi> expert painters). The examinees observed the samples on an ivory table from several angles without handling under ca. 1100 lx of fluorescent lighting. The examinees were not given any information on the samples. The three closed-ended questions were given as follows :

Question 1 : Which sample do you think to be the natural-lacquer-painted one among the three samples?

Choose the sample (multiple answers allowed).

Question 2 : Evaluate the aesthetic score for each of the samples as a : most beautiful, b : beautiful, c : indifferent (medium), d : rather unbeautiful or e : unbeautiful. The score is on the basis of absolute evaluation.

Question 3 : Evaluate the quality for each of the samples as a : top quality, b : high quality, c : average quality, d : rather low quality or e : low quality. The score is on the basis of absolute evaluation.

The results were summarised as the number of examinees for each of the chosen items.

2.4 Measurements

The spectral reflectance and the colour of the painted and coated boards were measured by a colourimeter (Konica Minolta spectrophotometer CM-2600d) under SCE and SCI modes from 360 to 740 nm of wavelength using a D65 light source. The reflected light from the sample excluding the regular reflection is integrated under the SCE mode. All the reflected light including the regular reflection is integrated under the SCI mode. It can be said that the results obtained by the SCE mode show the colour characteristics for extraneous observation of the sample generally with naked eye and those by the SCI mode show the colour characteristics for the sample material itself. The measured colour of the samples was estimated by spectrorreflectance at each wavelength of light (360 - 740 nm).

The gloss of samples was measured by a gloss checker (Horiba IG-331). The gloss was measured at 20 and 60° as the angle between the directions of incidence or reflected light (wavelength = 890 nm) and the normal to the plane of a sample.

The photographs of painted samples were taken by a digital camera (Canon DS126071 with EF-S18-55 mm F3.5-5.6 II USM) in a completely dark room. The light source was a point source light (Schott Nippon K. K. Mega Light 100) equipping a halogen lamp and there were no other light sources. The light was filtered with a cotton textile in order to soften and diffuse evenly the light. The positions of the light source, sample board and camera are illustrated in Fig. 1. The angle of the sample board (θ) is defined as the angle between the board and the horizontal plane as indicated in Fig. 1. The camera picks up the image of the sample board and the light reflected from it. The illuminance of the light at the camera position was 4.5 lx. The shutter speed and exposure were adjusted for obtaining the appropriate image of the light on the sample boards (shutter speed : 1/8 s and exposure : $F = 36$ for corresponding to ISO = 100).

Gamma correction of images obtained by the digital camera is made automatically by the camera system and then the images should be inverse-corrected (inverse gamma correction)

Fig. 1 The illustration of positions of the light source, sample board and camera.

in order to analyse the raw luminance data from the images. The gamma correction curve for images taken by the Canon DS126071 digital camera was acquired by a software (HDR shop, ver.1.0.3 created by USC Institute for Creative Technologies) and the sample images were inverse-corrected by using the inverse gamma correction curve. The obtained colour images were converted into 16-bit gray scale images and the distribution of luminance (histogram) along a vertical meridian of a sample image, which is drawn as a straight white line in Fig. 4, was obtained by Media Cybernetics Image-Pro PLUS (ver.4.5.0.24). The luminance profile was taken from the luminance histogram and curve-fitting for the profile was made by Microcal Software Origin (ver.6.1 J and Origin Pro 8J SR1).

3. Results and Discussion

The black and glossy samples used for comparison were three kinds ; (1) a board painted with glossy natural lacquer paint “glossy lacquer”, (2) a board painted with synthetic acrylic paint spray “acrylic paint” and (3) a board coated with the black thin film “film.” The results of sensory evaluation by the non-craftspeople and craftspeople with the naked eye for glossy lacquer, acrylic paint and film samples were summarised in Table 1. The results of Question 1 show that the number of the non-craftspeople (13) who chose the glossy lacquer as the natural-lacquer-painted sample and that of the non-craftspeople (12) who chose the film as it, are almost equal. Moreover, 5 non-craftspeople chose the acrylic paint as it. In contrast, all craftspeople chose the glossy lacquer as it. The results show that it is not easy for the non-craftspeople to distinguish the glossy lacquer sample from the film with the naked eye, whereas the craftspeople distinguish correctly the glossy lacquer sample as natural-lacquer-painted one. The results of Question 2 (aesthetic evaluation) and Question 3 (quality

Table 1 Results of sensory evaluation with the naked eye for glossy lacquer, acrylic paint and film samples. The numbers are the number of people who chose the corresponding item. See the text for the details on the Questions and evaluation score order (from a to e).

Examinees	Samples	Question 1	Question 2		Question 3	
Non-crafts-people	glossy lacquer	13	a	12	a	6
			b	9	b	10
			c	2	c	5
			d	4	d	4
			e	0	e	2
	acrylic paint	5	a	1	a	2
Non-crafts-people	acrylic paint	5	b	3	b	2
			c	11	c	12
			d	9	d	6
			e	3	e	5
	film	12	a	6	a	4
			b	12	b	11
			c	9	c	8
			d	0	d	3
			e	0	e	1
Craftspeople	glossy lacquer	4	a	2	a	2
			b	1	b	1
			c	1	c	1
			d	0	d	0
			e	0	e	0
	acrylic paint	0	a	0	a	0
			b	0	b	0
			c	1	c	1
			d	0	d	0
			e	3	e	3
	film	0	a	0	a	0
			b	2	b	1
			c	0	c	1
			d	2	d	2
			e	0	e	0

evaluation) show that the non-craftspeople evaluated the beauty and quality for glossy lacquer and film as almost same. In contrast, the craftspeople evaluated the beauty and quality for the glossy lacquer higher than those for the other samples. This shows that glossy lacquer and film appear to non-craftspeople to be very similar from the viewpoint of beauty and quality. The film sample can be said to be a kind of precise imitation of a natural-lacquer-painted one for non-craftspeople. The non-craftspeople, however, were able to distinguish acrylic paint from the other two samples. On the other hand, the craftspeople of lacquer painting can distinguish correctly and evaluate the natural-lacquer-painted sample.

The craftspeople provide comments and opinions on the points, by which they distinguish, identify and evaluate natural-lacquer-painted samples and products. They describe the points as a kind of depth in the painted surface. They represent the impression of the depth of the lacquer-painted samples as the reflected light and images coming from the deeper back of the painted layer. On the other hand, they feel that the reflected light and images come from the very surface of the chemically painted and coated samples. Therefore, the craftspeople may

Fig. 2 Spectra of reflectance measured under SCE mode for the three samples between 360 and 740 nm.

distinguish and evaluate the natural-lacquer-painted sample and products from the viewpoint of the depth of the surface layer. They can check and distinguish the natural-lacquer-painted sample even with the single naked eye. Therefore, their impression of the depth is not caused by binocular parallax processing. In addition, they do not employ factors such as colour, gloss, smoothness and the surface structure for identifying the natural-lacquer-painted ones. They say that because these factors vary with the technique and depend upon the category of products, these factors are not the evaluation criteria.

Consequently, it is interesting to clarify the optical characteristics of glossy lacquer, which craftspeople use to distinguish natural-lacquer-painted wares. **Fig. 2** shows the spectra of reflectance for the three samples between 360 and 740 nm, which were measured under SCE mode. The spectra for all the samples are almost flat throughout the wavelength measured and they are nearly the same in values and shape. The results show that the three samples are the same in colour (black).

In the observation and estimation of the lacquer-painted products by a lacquer craftsman with the naked eye, the observer watches their shiny part or the vicinity of a bright spot for the light image. Therefore, it may be significant to measure the spectroreflectance of the samples including the regular reflection. **Fig. 3** shows the spectra of reflectance measured under SCI mode for the three samples between 360 and 740 nm. The spectra for all the samples are almost the same in shape nevertheless the reflectance values for film are somewhat lower. As shown in the results, it can be said that the spectroreflectance characteristics for the natural lacquer paint and the other black samples are similar.

Accordingly, the gloss of samples was measured and the resulting values are shown in **Table 2**. The gloss value of glossy lacquer at 60° is 98 and is highest. Those of acrylic paint and film are 96 and 83, respectively. On the other hand, in the results of sensory evaluation with the naked eye made by non-craftspeople, 67 % of the people answered that the

Fig. 3 Spectra of reflectance measured under SCI mode for the three samples between 360 and 740 nm.

Table 2 Gloss of samples measured at 20 and 60°.

Samples	20°	60°
(1) glossy lacquer	94	98
(2) acrylic paint	92	96
(3) film	73	83

glossy order is glossy lacquer > film > acrylic paint and 33 % of the people answered that the glossy order is film > glossy lacquer > acrylic paint. The difference in the measured gloss value between the glossy lacquer and the other samples is not large enough to be discriminated for non-crafts-observers with the naked eye. In addition, all craftspeople answered that the glossy order is glossy lacquer > film > acrylic paint.

The results show that no notable characteristics for the glossy lacquer among the three kinds of samples were obtained in the colour and gloss measurements. It is also difficult for the nonexpert observers to distinguish the natural-lacquer-painted sample from the chemically painted and coated samples with the naked eye. On the other hand, expert lacquer painters (craftspeople) are able to discriminate the lacquer-painted sample and observe the lacquer-painted sample by changing its angle. The craftspeople are able to grasp and perceive some optical characteristics of the glossy lacquer. If a novel technique estimating the optical feature or quality of a sample through instrumental measurements could be invented, it should be very useful.

In order to find the optical characteristics of the natural-lacquer-painted sample in the light refraction, the images of samples taken by a camera from two angles were analysed. Only the angle of sample boards was changed and the position of the light source and the camera was fixed in the experiments. An obtained and processed digital photo image in 16-bit gray scale for glossy lacquer and the vertical meridian indicated as a straight white line, along which the distribution of luminance was determined, are shown in **Fig. 4** as an example. The direction of the straight line is parallel to direction of the longitudinal section linking the light source, sample and camera.

The images were taken at 15 and 20° of the angle θ of the sample board and were used for analyses. The distributions of luminance (L_v) along the vertical meridian expressed as a histogram of the samples for $\theta = 15^\circ$ are shown in Fig. 5 (1) - (3). The L_v is dimensionless number running from 0 to 65535. The centre of the histogram is the centre of the reflected light, where the light shows maximum values and they are out of the range. The envelope curves for the glossy samples decrease steeply and their line wings (skirts) of the histogram are narrow. The width of the profile at $L_v = 32768$ is 121 pixel for glossy lacquer, 196 pixel for acrylic paint and 140 pixel for film and the width for glossy lacquer is narrowest. Spike-like noises are found in the histogram of acrylic paint (Fig. 5 (2)). This shows that there are asperities on the surface of the acrylic-painted sample.

Fig. 4 Digital photo image for glossy lacquer sample reflecting incident light and white straight line, on which the distribution of luminance was determined. θ of the sample is 15° .

Next, the envelope curves of the profiles were taken out and curve fitting were made by using Gaussian, Boltzmann and Lorentzian functions in order to know whether there are differences in fitting. As a result, the Gaussian function was found to fit best not only to the envelope curve of glossy lacquer but also to the other curves. Therefore, a result that the sort of the fitting function depends on the sort of the sample is not obtained. The information on the optical characteristics of the glossy lacquer paint is not taken out by the kind of fitting function. The reflected light profiles for evaluating the roughness of solid surfaces have Gaussian distribution⁶⁾ and it was found that the scattering of the light from metal aventurine surface are statistically modelled by using Gaussian function⁷⁾. The results that the Gaussian function fits the envelope curves of the luminance profiles show the luminance of reflection on the samples decays following a normal distribution curve at the edge. This indicates that the reflected light image is formed by a number of factors specific to the paint and coating.

The Gaussian function employed here is

$$y = y_0 + \left\{ A / (2\pi)^{1/2} \sigma \right\} \cdot \exp \left\{ -(x - x_0)^2 / 2\sigma^2 \right\} \quad (1)$$

where A is the area between the curve and base line, σ the standard deviation. The y corresponds to L_v , x corresponds to the position, y_0 is the base line offset and x_0 the centre position of the signal. The A and σ were determined to know if those of the glossy lacquer show specific values. The calculation results are shown in Fig. 6 and determined parameters are listed in Table 3. The resulting data show that the area and standard deviation for glossy lacquer are smallest and those for

Fig. 5 Distribution of luminance (L_v) along a vertical meridian expressed as the histogram for each sample. θ of the sample is 15° .

Fig. 6 Observed envelope curves (solid line) for the histograms and fitted curves (broken line) by the Gaussian function for each sample. θ of the sample is 15° .

Table 3 Determined area (A) and standard deviation (σ) by the Gaussian curve fitting for envelope curves of histogram for the painted and coated samples at each angle of the sample (θ).

Samples	$\theta = 15^\circ$		$\theta = 20^\circ$	
	A	σ	A	σ
(1) glossy lacquer	2.57×10^6	15.5	2.14×10^6	12.9
(2) acrylic paint	2.59×10^6	16.6	3.21×10^6	20.5
(3) film	2.67×10^6	16.5	4.22×10^6	20.6

acrylic paint and film are same and larger. The area and standard deviation values might be able to quantitate the characteristics relating the gloss and quality of painted samples. The smallest values show that the curve for glossy lacquer is steep and the sharper image of light is observed on it. The values for glossy lacquer at $\theta = 20^\circ$ are smaller than those at $\theta = 15^\circ$, while those for acrylic paint and film at $\theta = 20^\circ$ are larger than those at $\theta = 15^\circ$. The light reflective characteristics at the different angles for glossy lacquer are different from those for acrylic paint and film. The area and standard deviation values for only the glossy natural-lacquer-painted sample decrease with an increase in the angle between the directions of the normal to the plane of the sample and the reflected sample image. Such angle dependency of the light reflective characteristics might be associated with the specific appearance of the glossy lacquer products.

4. Conclusion

In the study, the information on characteristics of the intensity

distribution over the position for the reflected light from the painted and coated samples was found out. The glossy lacquer paint shows the smallest area and standard deviation value in the normal distribution histogram of light intensity profile for the edge of reflected light. The authors are trying to further study the angle dependency of the reflected image characteristics for the natural-lacquer-painted sample.

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漆職人はどのように天然漆器の外観の特徴を識別しているのか —光学画像解析による研究の試み—

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要 旨

漆塗りの熟練職人が見分けている髹漆物の光学特性を明らかにするため、測色と光沢測定に加えて、天然漆塗平面板が反射した画像の解析を行なった。天然漆塗り試料・合成ペイント塗り試料・フィルムコーティング試料の2つの角度から撮影した光学画像における輝度の分布を取得し、そのヒストグラムの包絡線から輝度変化曲線を抽出した。髹漆の専門家のみが違いを見分けるような3種の黒色平板試料の分光反射特性や光沢度に明瞭な違いは観測されない。しかし、試料の光反射画像の輝度変化曲線はガウス関数によってフィッティングされ、正規分布を示す光画像の周縁の輝度変化において、天然漆塗り試料は輝度分布曲線の面積が最も狭く、その標準偏差が最も小さい。さらに、試料法線と反射画像取得角間の角度が大きくなると、天然漆塗り試料のみ、その輝度分布曲線の面積と標準偏差が減少する。