Development of New Functional Material for anti-Clone and Authenticity Verification Technique Applicable for Ceramic Products

Masaki Fujikawa, Mariko Hara, Saki Koyama, and Shingo Fuchi

***Abstract*—Multi-modal artifact metrics as an anti-counterfeiting technique is created based on the concept of multi-modal biometrics. Giving more than one characteristic information to the artifact can improve the certainty of authenticity and increase counterfeiting difficulty. To give two-optical feature information (hue and emission intensity) into ceramic products, we developed a new type of glass phosphor. It is a novel approach, because there were few reports on up-conversion phosphors having different color hue and emission intensity at each observation point on the material by infrared light excitation. By welding a small amount of phosphor powder onto the surface of ceramics, the certainty of authenticity and difficulty of counterfeiting could be enhanced than an existing method we proposed. Our study established an appropriate blending ratio of two rare earth oxides for making glass phosphor having the above-mentioned emission characteristics. These characteristics could also be seen in other glass phosphor created by different base material glass with the same blending ratio.**

***Index Terms*—Anti-clone, authenticity, ceramics, glass phosphor, optical excitation.**

I. Introduction

A. Background and Target

Ceramic products made by prestigious as well as well-known potteries or brand holders are highly popular and can be sold at a high price as high-quality accessories. Counterfeiters manufacture imitations of these products and sell them to people with low appraisal skills [1]. The existence of copied ceramic products cannot be overlooked, because the distribution of counterfeit products not only violates the intellectual property rights of potteries and brand holders but cost them a share of income that they could have otherwise obtained. Besides, financial and psychological damages can also be made to consumers who purchase them unknowingly.

We have developed a technique that can verify the product's authenticity mechanically with high accuracy to limit people with low appraisal skills to purchase imitations unknowingly. This technique is defined as the artifact metrics [2] because it makes it difficult for forgers to manufacture the genuine product's clone. In our previous research [3], we focused on a transparent glass phosphor that emits one peak wavelength in response to infrared (IR) light excitement. We also proposed a technique to weld small amount of phosphor powder onto the surface of products. It has three features as shown as follows: (1) The powder has low toxicity and does not affect the product's colors/patterns. (2) The characteristic information (emission intensity) used for verification of authenticity can be extracted from each product in a non-contact manner. (3) It is difficult to manufacture clones using the extracted characteristic information from genuine products.

We also have proposed a concept called the multi-modal artifact metrics hinted by multi-modal biometrics [4] to enhance the accuracy of authenticity and difficulty of counterfeiting by adding over another characteristic information to the artifact. In addition, as a countermeasure of counterfeiting valuable cards (such as credit cards), we proposed a method of adding both sheet resistance (as characteristic electrical information) and phosphor emission (as optical feature information) to synthetic resin cards [5].

To date, we have been trying an approach of applying the multimodal artifact metrics to ceramics and extracting several characteristic optical information from them. In this paper, we describe the development of new glass phosphor for this optical approach. By welding small amount of phosphor on the surface of such ceramic products, the resultant film is expected to give two optical feature information (hue and emission intensity). Therefore, the accuracy of authenticity and difficulty of counterfeiting could be enhanced compared to our previous study findings [3]. Details will be described in Section II.

This paper is organized as follows: In the remaining part of Section I, the artifact metrics and multi-modal artifact metrics are outlined. Section II provides an outline of our idea while the fabrication process of glass phosphor is described in Section III. In Section IV, we show another procedure of welding glass phosphor powder onto the surface of ceramics. Considerations based on the experimental results are then given in Section V, while Section VI finally draws the conclusions.

B. Overview of the Artifact Metrics

Basically, the concept of artifact metrics is similar to biometrics. Each artifact has unique characteristic information. Artifact's authenticity can be verified by extracting characteristic information from target artifact and

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comparing it with the registered feature information. The difficulty of counterfeiting is established based on technological evidence, by which the characteristic information held by the genuine product is difficult to copy. This characteristic information is formed spontaneously and randomly during the manufacturing process, and cannot be formed intentionally even by manufacturers of genuine products. Hence, the difficulty of counterfeiting cannot be decreased if the mechanism of forming characteristic information is accessible to the public.

Microscopically, each artifact has different characteristic information, such as tiny roughness and color shade. However, specifying the area photographed by registration phase and the area shot by verification phase is time consuming, because the area observed using a microscope is quite small [3]. Hence, in artifact metrics, a method is utilized to form unique and easy-to-extract characteristic information in the artifact. Specifically, additives having physical features are added during the manufacturing process. The particles are distributed randomly and fixed in the artifact. The distribution degree reflects the characteristic information. Sensing devices which can extract the physical features of additives are used when extracting characteristic information.

TABLE I: PHYSICAL CHARACTERISTICS AND EXTRACTED INFORMATION

Physical characteristics	Extracted feature information
Optical characteristics	Particles' optical characteristics (reflection, transmission, infraction, and fluorescence) and their degree of distribution reflect the characteristic information, which is extracted by sensors that can detect light intensity.
Magnetic characteristics	Particles' magnetic characteristics (attraction and repulsive force) and their degree of distribution reflect the characteristic information, which is extracted by sensors that can detect a change in magnetism.
Electrical characteristics	Particles' electric characteristics (electrical charge) and the degree of distribution reflect the characteristic information, which is extracted by sensors that can detect the quantity of electric charge.
Vibration characteristics	Particles' vibration characteristics (sonic waves) and the degree of distribution reflect the characteristic information, which is extracted by sensors that can detect sonic waves.

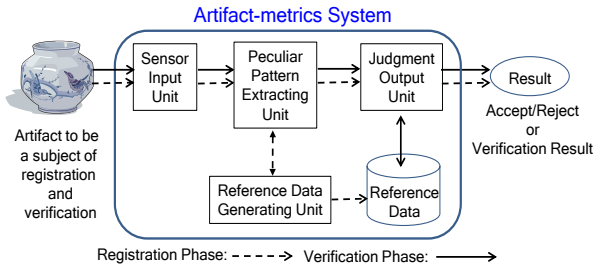

Fig. 1. Overview of the artifact metric system.

Table I shows the physical characteristics of materials added in the manufacturing process and the characteristic information extracted from them. Fig. 1 shows an overview of the system (artifact metric system) that uses artifact metrics. Two phases are almost the same as those of biometrics.

In this system, characteristic information that is extracted from each artifact before it is shipped is stored in a secure database. To verify the authenticity of an artifact, the system extracts the characteristic information from it and compares the information with that of the registered feature in the secure database.

C. Overview of multi-Modal Artifact Metrics

Characteristic information extracted from artifacts can be changed, depending on environmental circumstances during extraction (such as temperature, humidity, and position of artifacts relative to sensing devices). However, even in such situations, the artifact metric system should be able to verify authenticity stably and correctly, using the strong correlation between the characteristic information registered in the database and the information features extracted during verification.

There is an approach to increase the number of characteristic information to find strong correlations between both registered and extracted information [3]. This approach is named "multi-modal artifact metrics [5]" because various characteristic information is used. This approach can be further categorized into two methods. The first one (approach 1) focuses on additives having one physical feature and extracts two or more types of characteristic information from the artifact. For example, in our previous paper [3], especially in the "consideration" section, we focused on the optical feature of glass phosphor and proposed another idea to utilize two distributions (emission spectrum and emission intensity distribution) as the characteristic information. These distributions can reflect the particle size and degree of dispersion of glass phosphor welded on the surface of ceramic products.

The second method (approach 2) adds two or more additives having different physical features to the artifact, from which two or more types of characteristic information can be extracted. For example, in our previous study [5], we proposed an idea of creating thin films inside synthetic resin cards (used for valuable cards) using a conductive polymer paint having electrical features, and infrared up-conversion phosphor powder having optical features. This method utilizes emission intensity and sheet resistance which reflect the size and dispersion of phosphor particles in thin films. This information could be used as the characteristic information.

TABLE II: COMPARISON BETWEEN TWO APPROACHES

	Approach 1	Approach 2
Advantages	Low probability of affecting the artifact's moldability and physical strength.	Increases the number of extractable feature information.
Drawbacks	Limited with regard to the number of extractable feature information.	High probability of affecting the artifact's moldability and physical strength.

The differences of both methods are listed in Table II. Although approach 1 is limited by the amount of characteristic information extracted from the artifact, it could reduce the quantity of materials for the total amount of artifacts. Approach 2 could increase more characteristic information than the former one. However, it could also affect the artifact's moldability and physical strength, because the

material quantity for the total amount of artifacts increases.

II. New Approach

A. Outline of Another Method and Challenges

In this section, we outline another multi-modal artifact metrics method for ceramics as proposed in the "considerations" section in our previous paper [3], and its challenges for practical use. The purpose of this paper is to propose the artifact metrics (single modal) using emission intensity distribution (See Fig. 2) as the characteristic information resulting from glass phosphor particles welded on the surface of products. This study also proposes another method to use both the emission intensity distribution and emission spectrum distribution as feature information to verify the stability of product's authenticity. This method could be identified as the multi-modal artifact metrics because it utilizes multiple characteristic information. It, thus, can enhance the accuracy of authenticity and difficulty of counterfeiting.

In the above study, a glass phosphor emits a peak wavelength at 1000 nm by optical excitation (808 nm of IR light). This is called a down-conversion phosphor, because the emission wavelength shifts to the opposite direction (or long wavelength side) of the optical excitation wavelength.

The challenge of this method is the requirement of complex optical system having high price, such as near-infrared hyper spectrum cameras [6]. Although this system can extract two distributions in the infrared wavelength band, it provides huge implications on the device configuration of the artifact metric system and manufacturing cost. It would be a barrier for practical use.

B. Solutions

To eliminate the barrier for practical use and realize the method (the multi-modal artifact metrics) for ceramic products, we propose an approach of putting the light emission of phosphor in the visible light band instead of the IR band. In concrete, a phosphor with visible light emission by optical excitation was developed and a light emission was observed using visible camera.

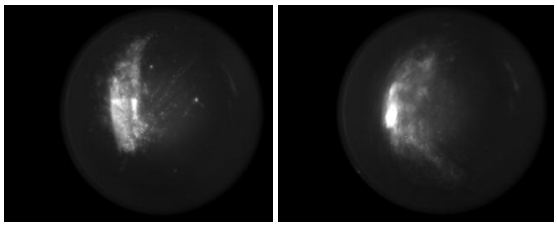

Fig. 2. Emission intensity distribution images.

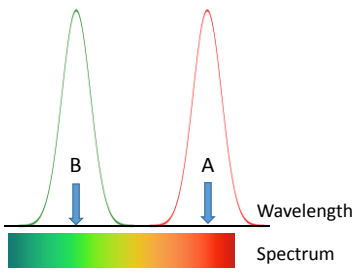

Fig. 3. Two emission peaks of wavelength (image).

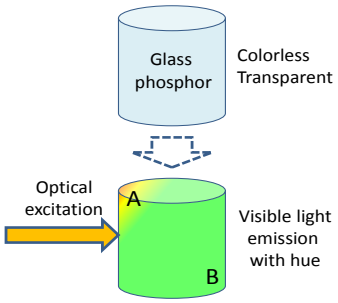

Fig. 4. Visible light emission with optical excitation (image).

As shown in Fig. 3, the former idea could be realized by developing transparent glass phosphor that provides two peak wavelengths in visible light band. The difference of emission colors could be observed by mixing light colors (See Fig. 4) if the heights of peak wavelengths are different at each observation point. According to our previous study [3], glass phosphor as an additive derives without toxicity and has a high affinity for glaze as well as paint due to the same glassy component. The ceramic's patterns/colors could not be affected if the amount of phosphor is small.

Visible cameras have simple system composition and are cheaper than infrared hyper spectrum cameras; therefore, cost would not be a barrier for practical use. The emission spectrum distribution (the wavelength and corresponding color) and emission intensity distribution (the light's strength) could also be captured in visible light band.

C. Features of the Novel Glass Phosphor

Unlike the phosphor described in our previous study [3], the novel glass phosphor shows different light emissions and intensity based on the locations where the excitation light is irradiated (see Fig. 3 and 4). Red color could be observed at observation point A, while green color could be observed at observation point B. The yellow color means that red and green light are emitted at that point. The emission difference based on the observation point occurs because of the distance between ions and the ratio difference of the number of ions from multiple rare earth oxides contained in glass phosphor.

Similar to our previous study [3], we chose to weld the glass phosphor powder onto the surface of ceramic products. Two types of feature information, namely, emission spectrum distributions (hue) and emission intensity distributions, could be extracted by photograph, when the unevenness of distance between ions and the number of ions were retained in the powder.

Generally, the up-conversion phosphor (emission wavelength shifts to the short wavelength side rather than the optical excitation wavelength) was developed with the aim of having one sharp peak wavelength (or single color), which exhibits one-peak wavelength in the visible light band and requires infrared light as the light source. Because so far, developing an up-conversion phosphor with a two-peak wavelength by changing the ratio of rare earth oxides has been rarely reported, our approach seems to be novel. An approach exists for developing the down-conversion glass phosphor having the same features, which use an ultraviolet (UV) light source. However, UV light could affect the colors/pattern of the ceramic during the irradiation on the surface of ceramic products. Hence, in this study, we developed an

up-conversion phosphor which utilizes an infrared light source.

III. Experiments

The glass phosphor was made from the rare earth oxide and base material glass. In this section, a method is described to search the ratio of the rare earth oxide required to make the above-mentioned phosphor. We also show another phosphor having the same features, which could be prepared using this ratio even the base material glass was changed.

A. Searching Method for Finding Ratio of Rare Earth Oxide

In this section, we explain a searching method for finding an appropriate ratio of rare earth oxides. To have two emission peak wavelengths (red and green light emission) as shown in Fig. 3, we used Er_2O_3 for red and green light emissions as well as Yb_2O_3 for absorbing IR light and transmitting the light energy to Er ions as excitation energy. The glass phosphor can be made by putting regents into a crucible, melting them in a furnace (about 1,230 degrees Celsius for several tens of minutes) and cooling it rapidly after extracting from the furnace.

These compositions could generate points in the glass phosphor, where the numbers of Yb and Er ions and the distance between them would be spontaneously uneven during the synthesis process. This phenomenon could provide different emission spectra (hue) and emission intensity at varied observation points. The emission spectra (hue) can be changed by the distance between ions and the ratio of the numbers of Yb and Er ions, while emission intensity was controlled by the number of Er ions.

In our experiment, we made candidates of glass phosphor by changing the weight of each Er_2O_3 and Yb_2O_3, while the mass of the glass phosphor was fixed as 10 grams. If the difference of the hue and emission intensity could be observed on the surface of the product by naked eyes, the ratio was gradually changed to be close to the appropriate value, based on the weight of the rare earth oxide contained in the candidate. A concrete process is shown below. In this process, $10ZnO\text{-}45Sb_2O_3\text{-}45GeO_2$ was used as the base material glass.

(1) Define the value of mol % of each Yb oxide and Er oxide as X and Y, respectively, and calculate the corresponding weight. X and Y correspond to the red colored letter indicated in Fig. 5.
(2) Put the weighed reagents into the crucible and melt it in the furnace. Take the melted reagents from the furnace and cool it rapidly.
(3) Regarding a candidate A, if the difference of the hue and emission intensity could be seen at any observation point while irradiating by IR light, adjust X and Y to find the existence of a candidate B which provide more intense light emission than A.
(4) Return to step (1).

$$\underline{X Yb_2O_3} - \underline{Y Er_2O_3} - \underline{(10ZnO - 45Sb_2O_3 - 45GeO_2)}$$

Fig. 5. Chemical formula of targeted glass phosphor.

In our experiment, candidates were set in a system (See Fig. 6) to photograph visible light emission. We used a commercially available single-lens reflex camera (SONY alpha 7s) with an IR cut filter. The emission spectrum and emission intensity were observed using a system as shown in Fig. 7.

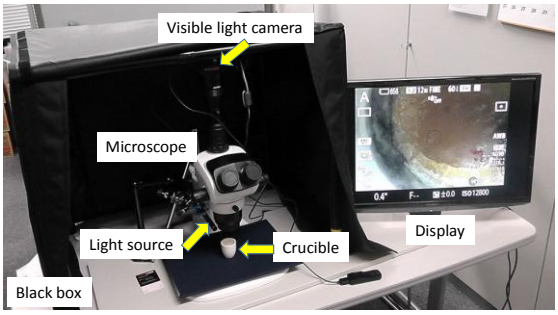

Fig. 6. Visible light emission observation system.

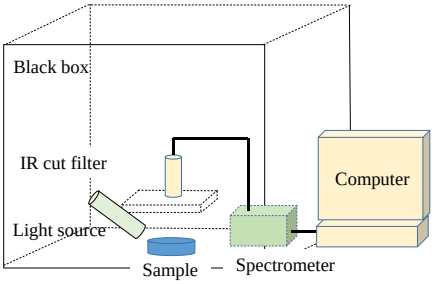

Fig. 7. Light emission spectrum observation system.

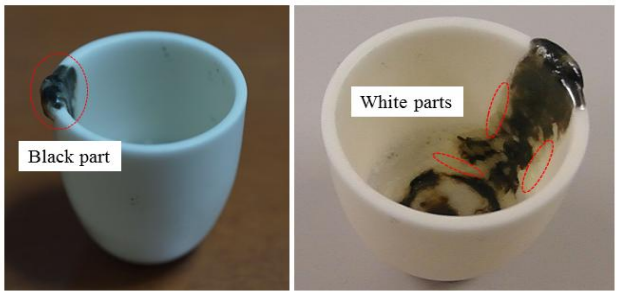

Fig. 8. A glass phosphor made in the experiment 1.

B. Experiment 1 (Usage of $10ZnO\text{-}45Sb_2O_3\text{-}45GeO_2$)

We used $10ZnO\text{-}45Sb_2O_3\text{-}45GeO_2$ as the base material glass and conducted an experiment by following the above-mentioned process to determine the appropriate ratio of the two types of rare earth oxides. This material glass could enhance the emission intensity of glass phosphor based on our past experiments.

Fig. 8 shows the glass phosphor which showed the most noticeable difference of the hue and emission intensity. This phosphor contains 5.0 mol % of Yb oxide and 0.08 mol % of Er oxide. Because the viscosity was higher than other melted materials, it could not be taken from the crucible. The black-colored phosphor was welded on the side, while the white-colored phosphor was adhered on the bottom, respectively.

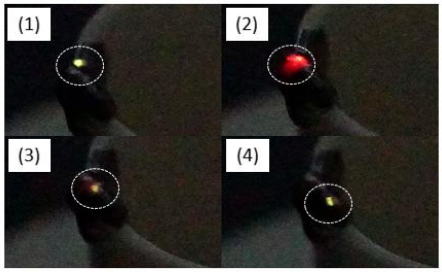

Fig. 9. Visible light emission (Black part).

The visible light emission in the black and white parts are shown in Fig. 9 and 10. The difference of the emission spectrum (hue) and emission intensity could be seen at each observation point.

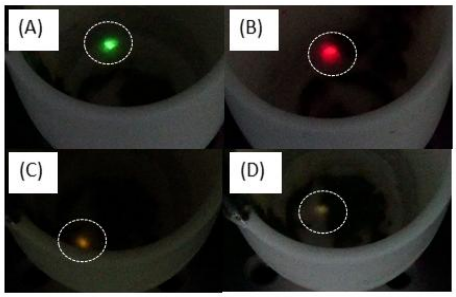

Fig. 10. Visible light emission (White part).

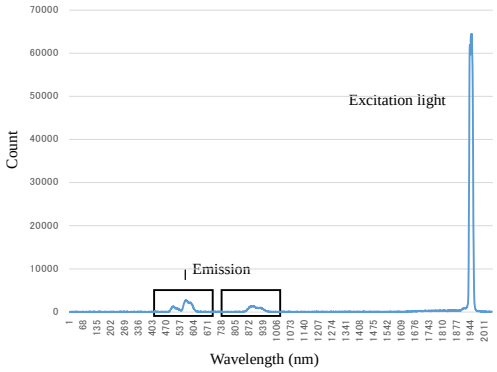

Fig. 11. Light emission spectrum at point (1).

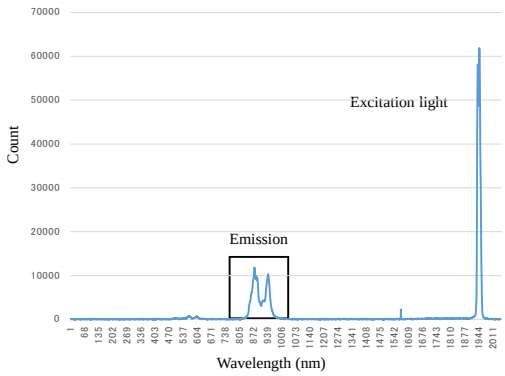

Fig. 12. Light emission spectrum at point (2).

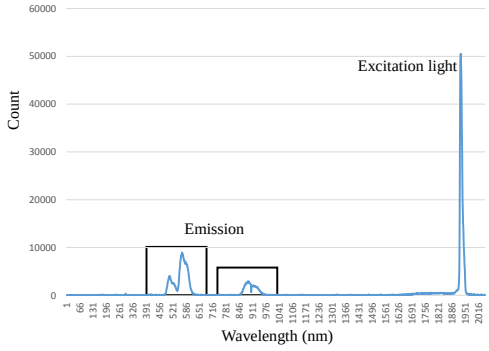

Fig. 13. Light emission spectrum at point (A).

The emission spectra of observation points (1) and (2) in Fig. 9 are shown in Fig. 11 and 12, respectively. The vertical axis shows the emission intensity while the horizontal axis shows the wavelength. Fig. 12 indicates that the emission intensity was stronger than that of Fig. 11 and corresponds to Fig. 9.

The emission spectra of observation points (A) and (B) in Fig. 10 are shown in Fig. 13 and 14, respectively. Fig. 14 indicates that the emission intensity was stronger than that of Fig. 13 and corresponds to Fig. 10. Hence, a glass phosphor having different hue and emission intensity at any observation point was successfully created.

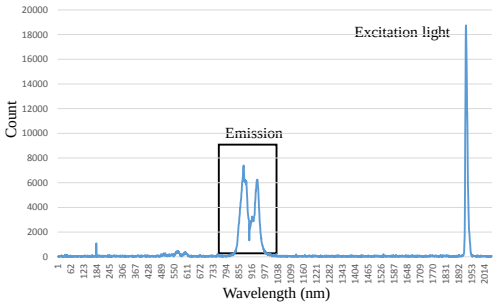

Fig. 14. Light emission spectrum at point (B).

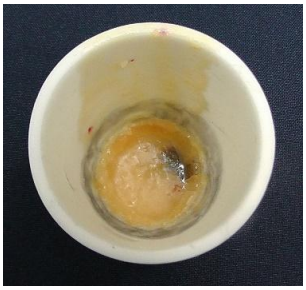

Fig. 15. A glass phosphor made in the experiment 2.

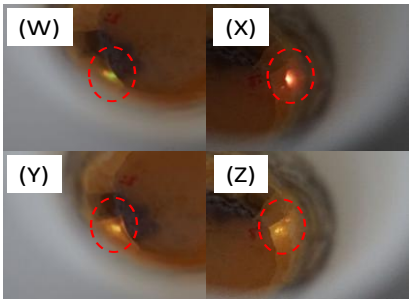

Fig. 16. Difference of the light emission.

C. *Experiment 2(Usage of $10Bi_2O_3$-$45Sb_2O_3$-$45GeO_2$)*

The aim of this experiment was to establish whether another glass phosphor having different hue and emission intensity at any observation point could be created utilizing the ratio of rare earth oxide determined in the previous section, even when the base material glass was replaced with another one. We had two intentions: One was to confirm the invariance of the ratio of rare earth oxides. The other one was whether the glass phosphor's color could be changed. The color and transparency of glass phosphor were determined by the composition of the base material glass. Therefore, the transparency could be increased if the color is changed.

In the experiment, we changed the composition of the base material glass from $10ZnO$-$45Sb_2O_3$-$45GeO_2$ used in experiment 1 to $10Bi_2O_3$-$45Sb_2O_3$-$45GeO_2$. Because the color of the phosphor having Bi_2O_3 is likely yellow, the phosphor created in this experiment had a yellow color.

The created glass phosphor is shown in Fig. 15. Although it contained the same ratio of rare earth oxides as in experiment 1, it showed the yellow color as we predicted. The light emission at each observation point is shown in Fig. 16. The

emission spectrum (hue) and emission intensity were different. The emission spectra of observation points (W) and (X) in Fig. 16 are shown in Fig. 17 and 18, respectively. Fig. 18 indicates that the emission intensity was stronger than that of Fig. 17 and corresponds to Fig. 16. Hence, the ratio of rare earth oxide could be applicable to another base material glass. There is a possibility of increasing the transparency of the glass phosphor.

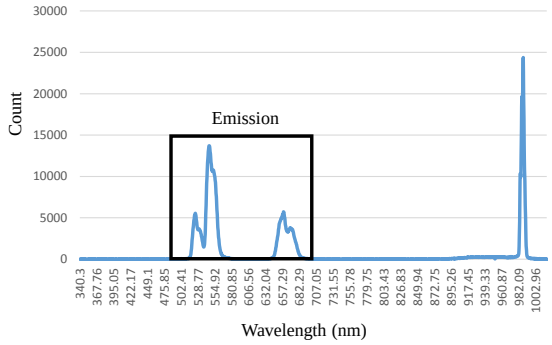

Fig. 17. Light emission spectrum at point (W).

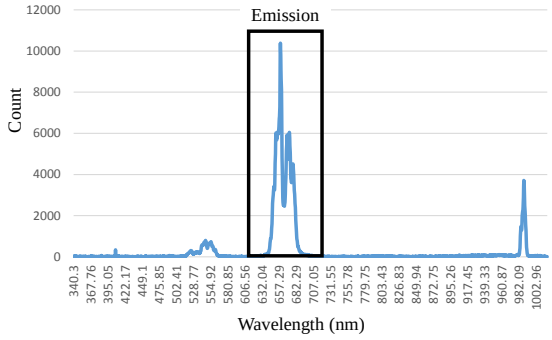

Fig. 18. Light emission spectrum at point (X).

IV. Applicability Assessment

In this section, we conducted two experiments to assess the applicability of the glass phosphor. One was to weld the glass phosphor powder onto the surface of a pottery plate. The other one was to observe the difference of the emission spectrum (hue) and emission intensity on the surface of the baked plate.

A. Welding Powder onto the Pottery Plate

In general, the biscuit of ceramic products is coated by liquid glaze. After the glaze dried, each product was baked in the furnace. The surface of the product became smooth because it was covered by the glaze with glassy substance. As the method of welding glass phosphor powder onto ceramic products, coating biscuit products by liquid glaze with phosphor powder seemed to be better. However, in this assessment, we welded the powder using the following method as a matter of convenience, because the amount of phosphor powder was not enough to do so.

(1) Make the dried glaze powder. This glaze turns into transparent glassy material after firing.
(2) Coat the biscuit plate by liquid glaze. After the glaze has dried, adhere the glass phosphor powder (0.05 grams) onto the surface of the plate by tip of a finger.
(3) Sprinkle the small amount of glaze powder over the area with phosphor powder and smooth the surface by tip of a finger.

We baked two plates with and without phosphor powder, respectively, in the furnace. The temperature in the furnace was increased up to 1,230 degrees Celsius in 8 hours. After keeping this degree for 10 minutes, the temperature was decreased to the room temperature in 24 hours. The plates with and without glass phosphor powder are shown in Fig. 19. They had indistinguishable differences in appearance.

Fig. 19. A plate without powder (left) and with it (right).

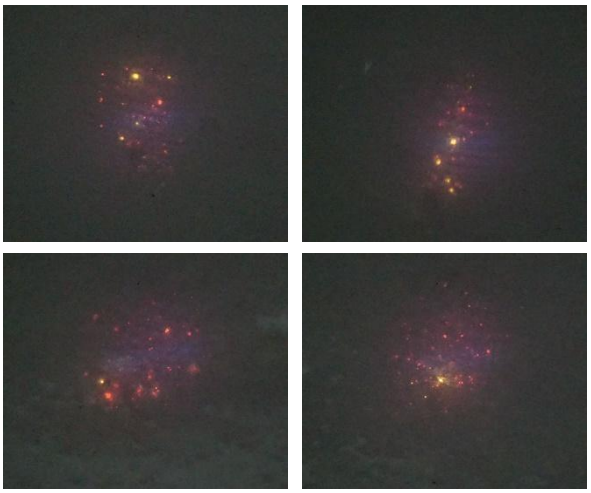

Fig. 20. Difference of the light emission at each observation point (2.5 magnification, ISO 40000).

B. Emission Observation

Regarding the baked plate with glass phosphor powder as shown in Fig. 19, we photographed the light emission at four observation points (See Fig. 20) using the system as shown in Fig. 6. The emission spectrum (hue) and emission intensity were different at each point. The glass phosphor can withstand the high temperature while keeping its optical feature.

V. Considerations

A. Safety of the Phosphor

While small amounts of rare earth elements are used to produce the glass phosphor, no apparent toxicity can be observed from the rare earth elements [7]. Materials of the supporting glass (oxide glasses of boron oxide system, phosphoric acid system, and boron anhydrate system) are stable oxides that are incombustible and insoluble. Their toxicities are very low. For example, lead oxide is contained in high quality transparent glass called crystal glass. Such glass is used as tableware and brings a serious safety concern.

Furthermore, glass phosphor that is the compound between rare earth elements and the supporting glass is an incombustible and insoluble oxide glass. As mentioned above, glass phosphor added to the artifact is less risky in affecting human health and environment. However, care should be taken to prevent inhalation and adhesion of the particles to naked eyes in handling the powders.

B. Advantages of the Glass Phosphor

As shown in Fig. 15, the current glass phosphor was pale yellow. The colors/patterns of the ceramic products could be affected if the amount of phosphor powder welded on the surface of the product was increased. However, the amount of the powder was low. It seems to be difficult to distinguish the existence of the glass phosphor by naked eyes.

Although some transparent materials exist, each candidate has application problems to for the porcelain products (See Table. III). This shows the advantage of glass phosphor for practical use.

C. Detecting Dishonest Action

People can easily distinguish the imitation with a pasted photo (see Fig. 21), where the light emission observed on the surface of the genuine product is located. However, the artifact metric system could make a wrong decision if it only used a simple image processing mechanism for extracting optical feature information from ceramic products. In this section, we proposed a measure to counter the above-mentioned dishonest action.

The system could receive optical information as characteristic information from the pasted photo, although the system did not irradiate the excitation light onto the surface of the target product. Hence, we propose a method to identify whether the received optical information derived from the excitation light. To realize it, we adopted the optical modulation/demodulation method with random number.

TABLE III: COMPARISON BETWEEN GLASS PHOSPHOR AND OTHER MATERIALS

Material	Consideration
Transparent magnetic substance	The magnetizing process is required after firing because the magnetic force wanes at high heat during firing.
Transparent conductive material	It loses transparency above 600 degrees C during firing.
Quartz with rare earth oxide	It cannot melt 1200 to 1300 degrees C during firing. It melts above 1550 degrees C.
Glass phosphor	It melts 1200 to 1300 degrees C and doesn't lose its function (transparency and IR emission) after firing.

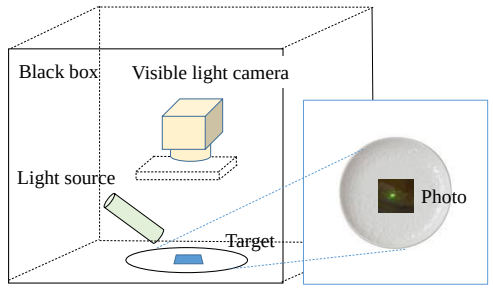

Fig. 21. Pasting a light emission image onto fake product.

Currently, three optical modulation/demodulation methods have been proposed (i.e., TDMA (Time Division Multiple Access), FDMA (Frequency Division Multiple Access), and CDMA (Code Division Multiple Access)).

The TDMA method controls whether each light source is on or off using extremely short time intervals. The time interval synchronizes with the light-receiving unit so that this unit can determine the light source unit. The size of the modulation and demodulation circuits is small because this method is simple; however, it is easily affected by disturbance light.

The FDMA method controls whether each light source is on or off using different frequencies for each light source. The light-receiving unit can determine the source of the received light because it knows each light source's modulation frequency, even when several light sources are simultaneously active. This modulation method is complex, and the size of the modulation and demodulation circuits tends to be large; however, it is not easily affected by disturbance light.

The CDMA method controls whether each light source is on or off using different random numbers allocated to each light source. The light-receiving unit can determine the source of the received light because it knows each light source's random number, even when several light sources are simultaneously active. This modulation method is simple, and the size of the modulation and demodulation circuits tends to be small. In addition, it is not easily affected by disturbance light.

TABLE IV: COMPARISON OF THE TDMA/FDMA/CDMA SYSTEM

	TDMA	FDMA	CDMA
Modulation and demodulation method	Simple	Complex	Simple
Size of modulation and demodulation circuits	Small	Large	Small
Influence degree of disturbance light	Large	Small	Extremely small

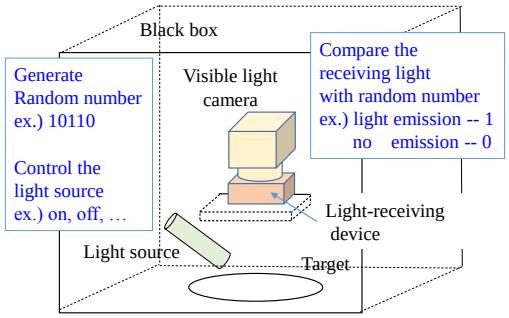

Fig. 22. Detecting fake product by using light modulation.

The characteristics of each method are listed in Table IV. Because the CDMA method is superior than other methods, we will adopt it to develop our prototype system (See Fig. 22). In this system, different random number is generated in every verification phase and the excitation light is irradiated based on the number's bit string data. For example, if the random number "10110" is generated, the system controls the light source, such as "On, Off, On, On, Off." Because the light-receiving unit knows the random number, the system could determine the fake product (the imitation with a photo

pasted onto the product) when it receives the optical information with wrong timing.

VI. Conclusion

We developed the glass phosphor which shows two peak wavelengths in visible light band by optical excitation to apply the multi modal artifact metrics for ceramic products. Two optical feature information (hue and emission intensity) could be extracted from any observation point by welding glass phosphor powder onto the ceramic product during manufacturing process. The authenticity could be verified using registered images stored in the artifact metric system because two characteristic information was recorded as images in verification phase.

In the experiment of creating glass phosphor, we made two types of glass phosphor by changing blending ratio of Yb and Er oxides to estimate the appropriate component of phosphor. Therefore, we successfully made the glass phosphor having different hue and emission intensity at any observation point. This result could support the fact that the glass phosphor having the same optical feature could be made, even if the base glass material changed.

Two types of pottery plates were made (with and without glass phosphor) in our experiment. No big difference in appearance can be seen between them. However, the difference of the hue and emission intensity at each observation point can be shown by irradiating the IR light onto the plate with welded phosphor powder. The patterns/colors of the product were not affected by the small amount of phosphor powder. The phosphor's function can withstand high temperature and the component of glaze.

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