Analysis of Electronic Photograph by Goniophotometry

Jongpil Kim, Toshiya Nakaguchi, Norimichi Tsumura, and Yoichi Miyake
Graduate School of Science and Technology, Chiba University
Chiba, Japan

Hiroshi Doshoda
Document Products Development Center, SHARP Corporation
Chiba, Japan

Abstract

Many studies have been done on the image quality of the electronic photograph (EP) printed by toner. The image quality of the EP is dependent on many factors, particularly the fixing temperature and the characteristics of printing paper. The appearance of image is influenced by the change of incident angle of light and the observation angle. However, little work has been done on the goniophotometric characteristics of the EP. In this paper, goniophotometric properties of the EP with three different fusing temperature and three kinds of recording paper is analyzed and evaluated by the measurement using gonio-spectrophotometer.

Introduction

An electronic photograph (EP) used toner has been widely used as the copy and the laser beam printer. In the EP, a latent image is formed in a photo conductor surface and after the transferring toner image in the paper, then the image is recorded by fusing process. In general, image quality of the EP is determined by its sharpness, graininess, distortion, banding, tone reproduction and color reproduction characteristics. Various criteria to evaluate these properties have been proposed and used such as MTF, Wiener spectrum, chromaticity and tone reproduction curve. It is necessary to measure spectral density of spectral reflectance of the image to calculate such criteria. However, most of criteria were calculated by the measurement of diffuse and specular reflectance of the image and the goniophotometric properties of image are not considered at all as long as we know.

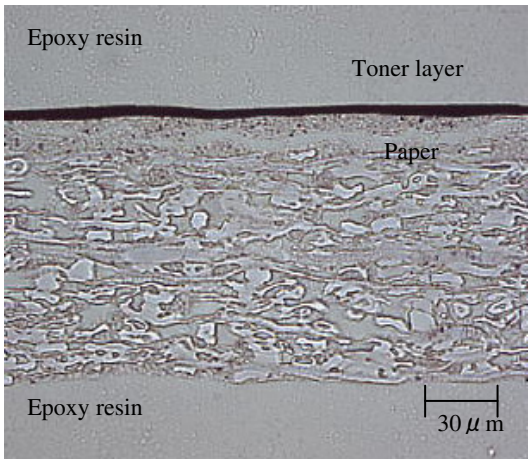
In recent years, it has become increasingly important to evaluate the image appearance such as gross, texture and so on. Therefore, we must consider goniophotometric properties of the printing image. In this paper, gonio-photomertic measurement is introduced to analyze the EP recorded by three different papers and three fusing temperatures.

Cross Section Photograph of Electronic Photograph

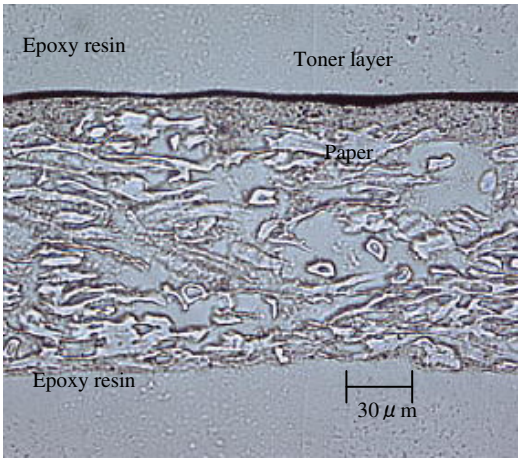
Figure 1 shows the cross-section of the EP which are wrapped in the epoxy resin and cut with an ultra microtome observed by optical microscope. Figures 1(a) and (b) are photographs of toner image on the coated paper at fusing temperature is 170°C and concentration is 100% and 40% each other, and are taken by optical microscope with magnification of 540 times. It is clear that the toner layer on the paper is formed uniformly without the area coverage modulation. On the other hand, Figure 1(c) shows the cross-sectional photograph of toner at concentration 20%. It is found that the distribution of toner is not uniform and we can see the area coverage modulation clearly. From the photograph by the optical microscope, it became clear that the area coverage modulation has occurred when the concentration is less than 30%. It causes artifacts such as banding and boundary line in the EP. In this paper we will discuss the relationship between those artifacts observed by the microscope and gonio-photometric properties of image.

Experimental

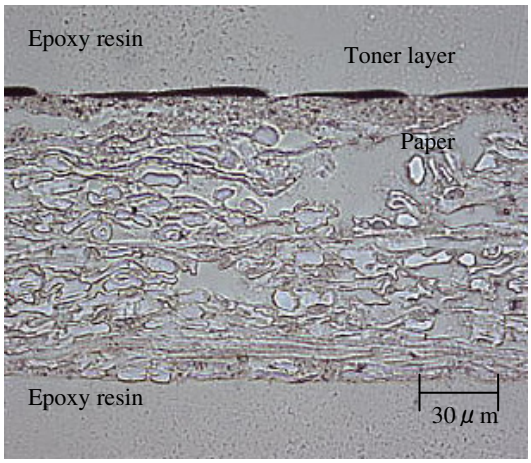
The solid toner images of black with six different concentrations (100%, 50%, 40%, 30%, 20% and 15%) are printed on to three different papers (coated paper , wood free paper (67gsm) and wood free paper (128gsm) with 7cm × 14cm size by three fusing temperature; 140°C, 170°C and 190°C within ±3°C error.



(a) Concentration 100%



(b) Concentration 40%



(c) Concentration 20%

Figure 1. Cross-section of the EP cutting by an ultra microtome

The spectral reflectance from 390nm to 730nm of samples is measured by gonio-spectrophotometer, (GSP-2S, Murakami Color Research Laboratory). The geometry for the measurement deals with only zenithal angle of a light source and observation direction, as shown in Figure 2 and azimuthal angle is fixed at 180 degree. Every 10 degree of the incidence angle θ_i and the observation angle θ_r was measured. Measurement area of the goniospectro-photometer can be changed according to the geometry. For example, the area is 8mm × 16mm at $\theta_i = 0$ degree, it becomes 8 × 106mm when θ_i equals to 81 degrees. The values of CIE 1976 L*a*b* color space were calculated from those measured reflectance spectra.

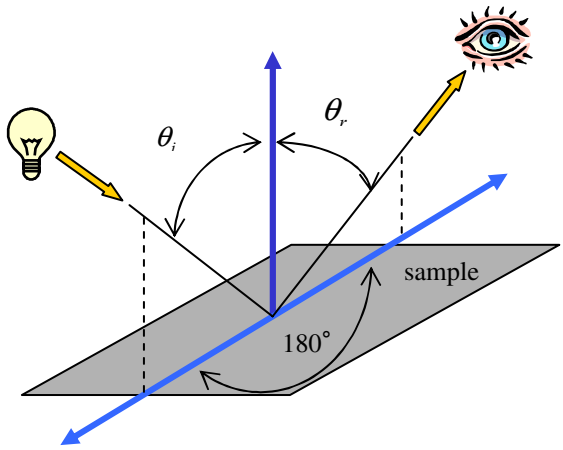


Figure 2. Illumination and observation angles

Results and Discussion

Behavior of Reflected Luminance by the Change of incident Angle of a Light Source

Figures 3 and 4 are shown the examples of goniophotometric characteristics of the EP. Figure 3 shows the L* with different incidence angle and observation angle (the concentration is 100%, a coated paper, fusing temperature is 170°C). In all degrees of incidence angle, peaks of L* is appeared and L* becomes higher gradually according to the incidence angle. The peak of L* is over the marginal value 100 in CIE L*a*b* by the influence of a specular reflectance component.

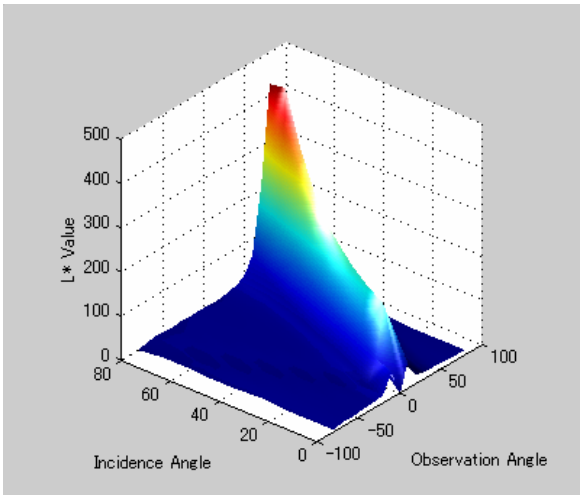


Figure 3. Reflected luminance by the change of incident angle of a light source

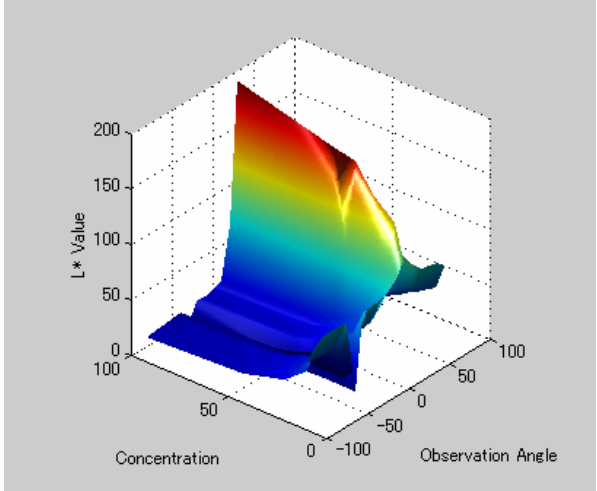


Figure 4. Reflected luminance by the change of concentration of toners

Behavior of Reflected Luminance by the Change of Concentration of Toners

Figure 4 shows distribution of L* by the change of concentration of toner, which is measured with several observation angles at fixed incidence angle 30 degree. The sample is printed on coated paper, at fusing temperature: 170°C. Regardless of generating existence of area coverage modulation, the diffuse reflectance component is not only decreasing, but also the specular reflectance component is increasing according to the concentration of the sample becoming high. We consider that the surface roughness of the toner layer becomes smooth, when the sample concentration becomes high. The result is considered that the quantity of the light which transmits the toner layer and illuminates paper layer increase and diffuse reflectance becomes high, when the concentration becomes low. At the same time, the quantity of light reflected in the toner layer decreases and specular reflectance becomes low. We also confirmed that the other samples have the similar results.

The representative example (coated paper, the concentration is 100%, incident angle is 30 degree) of the behavior for reflected luminance value (L*) by the change of fusing temperature of samples is shown in Figure 5. We found that the specular reflectance peak is high as fusing temperature becomes high. On the other hand, the result of the surface roughness measured by VK-9500 (Keyence Co.) shows so small when fusing temperature is high. We found that the toner surface becomes smooth and the peak of a specular reflectance component is high as fusing temperature became high. We also confirmed that the other samples have the similar results.

Behavior of Reflected Luminance by the Change of Fusing Temperature of Samples

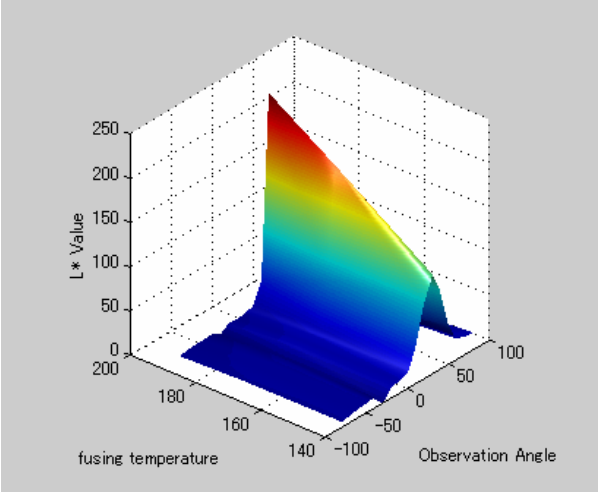


Figure 5. Reflected luminance by the change of fusing temperature of samples

Behavior of Reflected Luminance by the Difference of Paper Types

Figure 6 show the L* for three different papers at the condition (the concentration is 100%, fusing temperature is 170°C and incident angle is 30 degree). Although both wood free paper (67gsm) and wood free paper (128gsm) have the same luminance value, but the specular reflectance is lower than the coated paper. Since the surface of the coated paper is smooth, the toner is spread uniformly and smoothly.

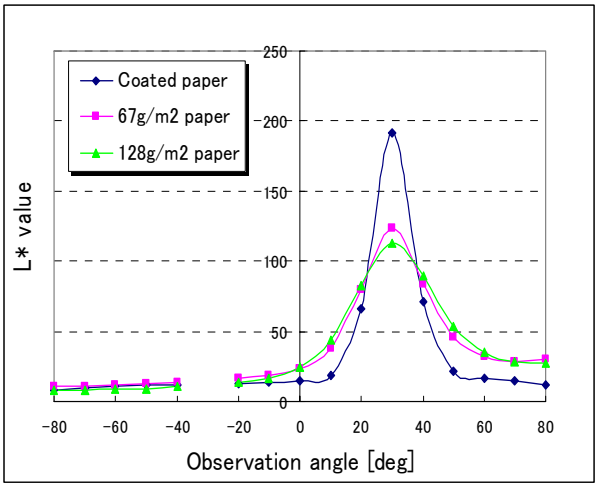


Figure 6. Reflected luminance by the difference in the kind of paper of samples

Conclusions and Future Work

We evaluated and analyzed the goniophotometric characteristics with the change of the incidence angle of light, the observation angle, and the manufacture conditions (fusing temperature, the paper types, stage of concentration). By using the gonio-spectrophotometer, we could obtain the goniometric characteristics of the luminance value (L*). We found that the characteristics of the obtained gonio-photometric characteristics are caused by the penetration concentration and the surface roughness of samples. In our future work, we will develop the physical model of these phenomena for image quality prediction of the electronic photograph. The further research is continued about the appearance of image and artifacts（banding etc.）of the EP.

References

1. C. S. McCamy, Observation and Measurement of the Appearance of Metallic Materials: Part I, Macro Appearance, Color Res. Appl, 21(4), 292-304, 1996
2. C. S. McCamy, Observation and Measurement of the Appearance of Metallic Materials: Part II. Micro Appearance. Color Res. Appl, 23(6), 362-373, 1998.
3. J. M. Medina Ruiz, Proposed metameric indices for goniochromatic objects, Color Research and Application, 7(6), Dec, 2002.
4. R. Guillén, M. François, B. Bourniquel, and E. Girard, Texture and residual-stress analysis using a kappa goniometer, J. of Applied Crystallography, 32, 393-396, 1999.
5. B. Allan and J. Rodrigues. Color and appearance measurement of metallic and pearlescent finishes. ASTM Standardization News, 23(10), 68–72, 1995.

Biography

Jongpil Kim was born in 1972, received B.E. degrees in Department of Graphic Arts Engineering, from Pusan National University of Technology, Pusan, Korea in 1996 and M.E. degrees in Department of Graphic Arts Engineering, from Pukyong National University, Pusan, Korea in 1999. He becomes Ph.D course student from April, 1, 2000. His research interests are in electronic photograph, Ink-jet printing and color science. E-mail:gold@graduate.chiba-u.jp