Experimental Study on the Optical Phenomena on the Surface of Inkjet Photo Papers

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Abstract

Inkjet printing is digital technology that has achieved an acceptable level of color quality with a reasonable price for commercial large format and desktop small format print for home or office users. As a result, there is a demand for inkjet media with high gloss finishes in order to obtain vivid images for inkjet printing. Although color reproduction is one of the most important qualities for inkjet printing and inkjet media, metallic shiny appearance, 'Bronzing', that brings poor image qualities, is occurred occasionally but unexpectedly. In this study, phenomena of the bronzing with dye based ink were investigated to reveal its mechanism in terms of using various approaches.

Introduction

Inkjet printing has been considered to be the first digital technology that has achieved an acceptable level of color quality with a reasonable price for commercial large format and desktop small format printing for home or office end users [1]. As a result, there is a demand for inkjet media with high gloss finishes, so that the inkjet printing images may resemble a photographic image [2]. It is predicted that inkjet printing will continue to expand into additional printing markets and begin to challenge electro photography in many high-end applications.

The basic imaging technique in inkjet printing involves the use of one or more inkjet assemblies connected to a source of ink. The droplets are directed onto the surface of a moving web and controlled to form printed characters and graphics. The quality of the record obtained in an inkjet recording process highly depends on the jetting operations of the inkjet head, the properties of the ink, and the recorded substrates, as well as by the physical-chemical properties of printing ink and substrates.

One of the most important roles of inkjet media is to reproduce images and colors just the same as them on the display. Although the reproduction of colors should be strictly controlled especially for the photo finishing usage, the 'Cyan bronzing', that is a phenomenon the blue image looks like the red, sometime makes some troubles among customers like a photographer.

The main purpose of this study is to investigate the phenomena of 'Cyan Bronzing' by using various approaches in order to reveal its mechanism for giving some hints to avoid the phenomenon during media development.

Experimental

Paper Samples Preparation

Several gloss coated paper samples for ink jet printing shown in Table 1 were used in this study. The coated paper samples were prepared by using a pilot cast coater to investigate how the coating structures effect on 'Cyan bronzing' phenomena. These samples had basically two layers, such as an 'under layer' and a 'top layer', illustrated in Figure 1. Although both layers consisted of silica, polyvinyl alcohol, and cation polymer, a large size fumed silica was mainly used in the under layer to enhance an ability of the ink absorption. The top layer, on the other hand, included small size colloidal silica to get a higher gloss applicable to photo finishing usage. The amount of the coating was 12g/m^2 with the under layer and 3 g/m^2 with the top layer for each paper sample.

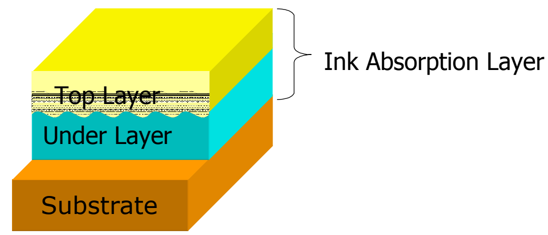


Figure 1 Coating Structure of Substrates

Ink and Printer for Evaluation

The dye water based cyan ink, EPSON ICC50, was mainly employed in this study. The solid cyan patterns were printed by using the dye based inkjet printer, EPSON PM-A920.

Measurement of Physical Properties

<Paper samples>

The optical density with the solid cyan pattern was measured by using GretagMacbeth, RD-19 with a red filter. The paper gloss at 20° was measured with the Murakami-shikisai, GM-26Pro.

＜Interaction between Inks and Paper samples＞

The change in ink absorption volume into the coating layer was measured by Kyowaseiko, K350 TypeD based on the Bristow's method. The ink set of samples was evaluated by the optical density of coated papers that were piled and pressed immediately with the paper samples printed with solid cyan patterns. The higher optical density of the coated paper meant the poorer ink set of the paper samples because larger amount of ink was transferred to the coated paper in that case.

Evaluation of 'Cyan bronzing'

The surface of paper samples with the solid cyan pattern were observed by a microscope and measured the cyan area ratio as an index of 'Cyan bronzing' by using image analysis software provided by ImageXpert Inc.

Results and Discussion
Characteristics of Samples with 'Cyan bronzing'
Physical Properties of Samples

The formulation of paper samples prepared and the physical properties for the samples were shown in Table 1. The ratio of small size (22 nm) and large size (45 nm) colloidal silica in the top layer was changed to make different samples about an ability of the ink absorption. The measurement results for the change of ink absorption by the Bristow's method were shown in Figure 2 [3]. The ink absorption rate of Sample A was the highest, and the top layer including the small size colloidal silica brought lower rate of the ink absorption. It was because the top layer with small size colloidal silica prevented inks from being absorbed into the coatings due to formation of a dense top layer.

Table 1 Formulation and print quality of paper samples

Sample		A	B	C
Under layer	Fumed Silica	100		
Formula	Poly Vinyl Alcohol	13		
	Cation Polymer	0.5		
Top layer	Colloidal Silica (Large)	100	30	0
Formula	Colloidal Silica (Small)	0	70	100
	Poly Vinyl Alcohol	13	13	13
	Cation Polymer	0.5	0.5	0.5
Basis weight	g/m^2	193.5	192.9	192.7
Coating amount	g/m^2	16.5	15.9	15.7
Gloss 20°	%	23.8	26.6	25.9
ISO brightness	%	97.1	97.0	97.0
Optical density	Cyan solid	2.20	2.25	2.34

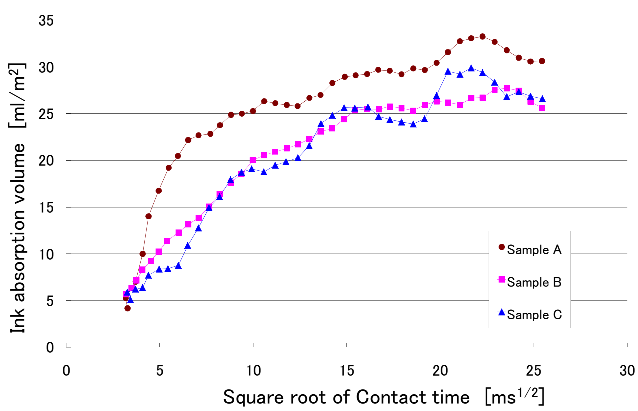


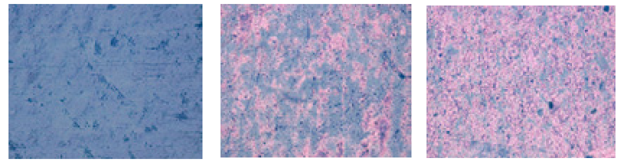
Figure 2 Change in ink absorption volume measured by Bristow's method

Observation of sample surfaces with the 'Cyan Bronzing'

The surfaces of samples printed with cyan solid patterns were observed by a microscope and the micrographs were shown in Figure 3. Sample A could be seen blue just like the shiny sky. On the other hand, there appeared the 'Cyan bronzing' phenomena for Sample B and C.

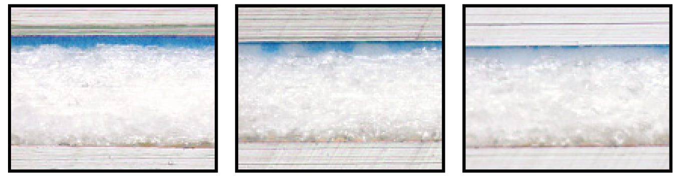
Characteristics of Ink Penetration

The micrographs of cross section for each sample were shown in Figure 4. They confirmed that the ink penetration depth of the sample with the 'Cyan bronzing' (Sample B, C) was shallower than that without the 'Cyan bronzing' (Sample A). In addition, the ink set of the sample with 'Cyan bronzing' was poorer than the sample without the 'Cyan bronzing' as shown in Table 2.



Sample A Sample B Sample C

Figure 3 Micrographs of sample surfaces printed with cyan ink



Sample A Sample B Sample C

Figure 4 Micrographs of cross section

Table 2 Results of ink set measurements

Sample	A	B	C
Ink Set			
	Good	Poor	Very Poor

As a result, it can be considered that the thin cyan ink layer might be existed on surfaces of the sample with 'Cyan bronzing' as shown in Figure 5. That hypothesis was supported by the results of a XPS analysis shown in Figure 6 because it confirmed that copper, one of a main component of the cyan colorant, was detected only from the surfaces of the sample with 'Cyan bronzing'.

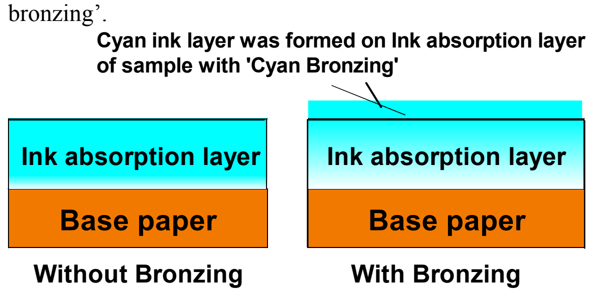
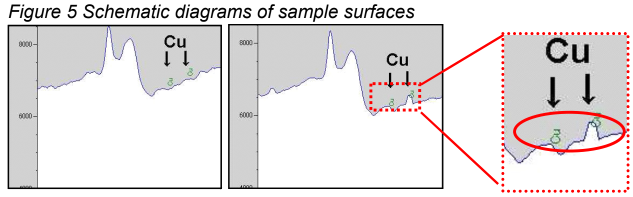


Figure 5 Schematic diagrams of sample surfaces



Without Bronzing With Bronzing

Figure 6 Results of XPS analysis on sample surfaces (depth of 5 nm)

Explanation for 'Cyan bronzing' appearance

Interference of lights for 'Cyan bronzing' Phenomena

If the thin ink layer was existed on the sample surface, the 'Cyan bronzing' phenomena might be explained by the light interference theory. The interference is the addition more waves that result in a new wave pattern as shown in Figure 7. It usually refers to the interaction of waves that are correlated (constructively or destructively) with each other [4].

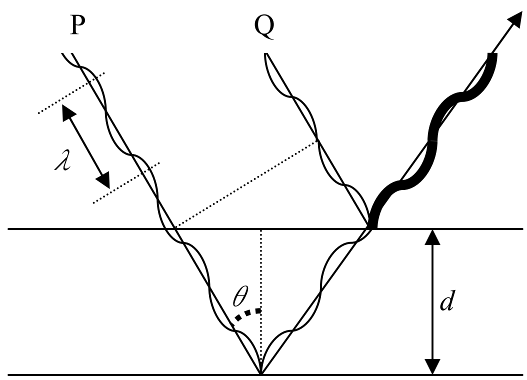


Figure 7 Schematic diagrams of interference phenomena (Constructive)

As shown in Figure 7, the difference of distance of ways between P and Q can be expressed as 2dcosθ. Therefore, the two waves are correlated constructively in case of Eq. (1), on the other hand, the waves are destructed each other in case of Eq. (2).

$2d\cos\theta = n\lambda$ (Two light waves in phase) (1)

$2d\cos\theta = (n + 1/2)\lambda$ (Two light waves 180° out of phase) (2)

Where d is the thickness of the ink layer on the sample surfaces, θ is the angle of incidence to the surface, λ is the wavelength of the light, and n is the natural number respectively.

From the results shown in Figure 8, colorants in cyan inks had properties to be penetrated by red light as well as blue light. Therefore, two of them could be interfered at the thin ink layer on the sample surfaces.

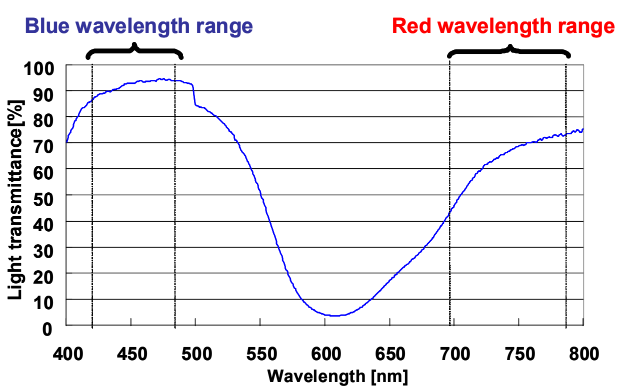


Figure 8 Transmittance of Cyan ink with the range of 400-800 nm

The phases of red light (wavelength of 780 nm) and blue light (wavelength of 450 nm) were shown in Figure 9. Because the wavelength of blue light is shorter than that of red light, each wave has different shapes and phases.

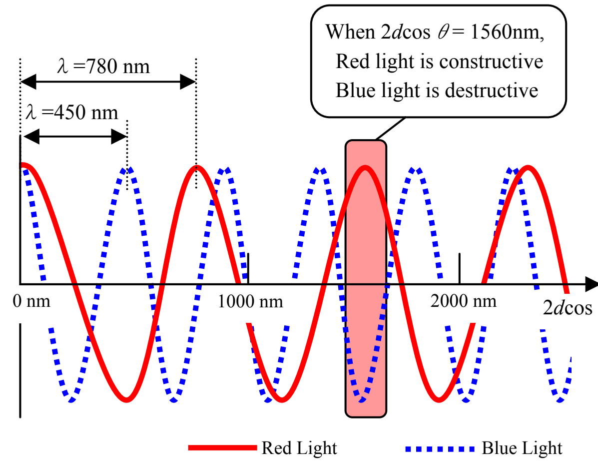


Figure 9 Phase of waves with red light and blue light

It can be considered that the sample surfaces with cyan solid patterns can be seen like red when the equation '2dcosθ=1560 nm (e.g. d=1000, θ=38°)' is valid because red light is constructive but blue light is destructive in that case (as shown in Figure 9). The analytical result of a confocal laser microscope for the cross section of the sample surfaces was shown in Figure 10. The area displayed with a red color in Figure 10 indicates a signal of the reflection of red light with a wavelength of around 780 nm that can be seen only from the surface of the sample with the 'Cyan bronzing'. According to the results mentioned above, the thickness of the layer which reflected red light was about 1000 nm or so. It can be concluded that the ink layer with thickness of around 1000 nm was existed on the surface of samples with 'Cyan bronzing'. Therefore, samples with cyan solid patterns could be seen like the red when red light was constructed selectively at the ink layer with the thickness of around 1000 nm in terms of interference phenomena.

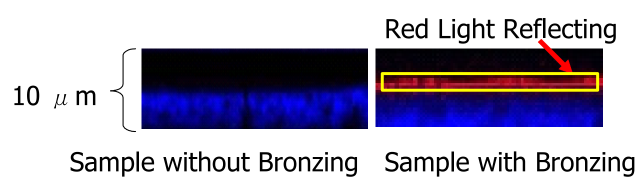


Figure10 Results of analysis on sample surfaces by confocal laser microscope

Conclusions

It is the 'Cyan bronzing' phenomena that the coated paper printed with cyan solid patterns like the blue sky can be seen red like the evening sky. The characteristics of coated paper samples with the 'Cyan bronzing' can be mentioned as shallow ink penetration depth and poor ink set due to slow ink absorption rate. These results as well as the XPS analysis confirmed that a thin ink layer was existed over the coated paper surface with the 'Cyan bronzing'.

Because colorants in cyan inks had properties to be penetrated by red light as well as blue light, two of them could be interfered at the thin ink layer on the sample surfaces. Therefore, it can be considered that the cyan solid patterns could be seen like red when red light was constructed selectively in terms of interference phenomena.

In order to avoid the ‘Cyan bronzing’ phenomena, the ink layer thickness on the sample surfaces should be controlled by enhancing the ink absorption rate and/or increasing the ink penetration depth due to employing pigments with proper size or size distribution in coatings.

References

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Takanori Otsuhata received his BS (1995) and his MS (1997) in chemical engineering from the Tokyo University of Agriculture and Technology. Since then he has worked in the Research and Development Division at Nippon Paper Industries Co., Ltd. in Tokyo, Japan. His work has focused on the development of various paper products related to inkjet printing techniques.