Color Reproducibility of the Encapsulated Pigment

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Abstract

The pigmented ink jet inks became popular recently. But they are used knowing some limitation of color quality compared with dye-based inks. To elevate the pigment dispersion for ultimate ink jet colorant, the research for more sophisticated pigment dispersion and the cooperation of colorant, ink formulation and printing technology are essential.

To improve the color reproducibility of pigmented ink for ink jet colorants, we did investigation for desired encapsulated pigment with water-insoluble polymer (encapsulated colorant). We found that the encapsulated colorant was improved color sifting in comparison with conventional colorants, water-soluble polymer dispersed colorant (conventional A) and dispersion dispersed colorant (conventional B), using the goniospectrophotometer. By reducing the ratio of pigment in colorant, color sifting could be improved, too. It seemed that the interfacial mechanism was thought suitable for color reproducibility in this study.

Introduction

The high technology and the low price of ink jet printing system progressed very rapidly in the printing market for these several years. There have been a number of improvements in some computers, printers and inks. Therefore, some ink jet printers can print text as fast as personal laser printers can do. Some ink jet printers can easily obtain photographic images that could not be distinguished from silver halide photographs using the high technology of digital cameras. But ink jet printer has problems of waterfastness and lightfastness of color prints because water-soluble dye based inks are usually used.

The pigments are known to have advantage in waterfastness and lightfastness comparing with water-soluble dyes. For applying the color pigment to ink jet colorants, many investigations on pigment chemistry, polymer chemistry and dispersion chemistry have been made. On the pigment chemistry, crystal size and shape control technology and surface modification technology were investigated.[1] In the field of the dispersant chemistry, structured polymeric dispersant[2] and emulsion-based technology[3] were developed. The technology to attach a variety of nucleophilic materials to pigment surface chemically was also made.[4] From the dispersion technique, some new methods were proposed.[5] As the result of these investigations, many suitable pigment dispersions for ink jet inks became available and the pigmented inks are used to not only wide format printers but also personal printers today.

The pigmented inks are believed to become more popular for ink jet printers, but they have to be improved from the point of color quality. To improve the color quality of pigmented inks, the higher absorption profile and the decrease of light scattering from the pigment surface are important.

In this study, we analyzed the color shifting of the print by changing viewing angles using the encapsulated type and usual kinds of pigment dispersions with various pigment/ binder ratios. The encapsulated pigment became apparent to improve the color quality of printing.

Experimental

Materials

In the case of encapsulated colorant, the polymer of styrene, lauryl methacrylate and methacrylic acid was prepared by the solution polymerization in 2-butanone (St/LMA/MAA=40/40/20wt%, Mw=30,000) and was neutralized with sodium hydroxide. The 30g of the neutralized polymer and 70g of pigment (CI No. Pigment Blue 15:3 or Pigment Red 122) were mixed with 500g of water. The mixture was dispersed with the beads mill. Then the dispersion was concentrated to 20%. Conventional A which used water-soluble polymer (Johnson Polymer; HPD-96) and conventional B which used dispersion (KAO; Erectrostoripper F) were also prepared similar to the encapsulated colorant. Encapsulated colorant having different polymer/pigment ratio changed a ratio was prepared.

Inks for this study were made from 5% of pigment in the colorant, 10% of 2-pyrrolidinone, 10% of glycerin, and the rest of water. All inks were filtrated with membrane filter (1.2 μm) just before the experiments.

Measurement of Color Sifting

These inks were printed on coated paper (EPSON; PM photo paper) and the color reproducibility of prints was measured by changing viewing angles using the goniospectrophotometer (MURAKAMI COLOR RESEARCH LABORATORY; GCMS-4, incident angle: -45°, viewing angles: -15° ~ 75°).

Goniospectrophotometer

Goniospectrophotometer is an instrument designed for color measurement with multi-angle illuminating and viewing conditions by changing incident and viewing angles. It is ideal for study of coatings containing metallic, pearl-mica, light interference pigments and other materials whose colors change depending on illuminating and viewing angles. Figure 1 shows optical system of goniospectrophotometer, and Figure 2 shows color shifting of the print made from dye-based ink by changing viewing angles. All three colors, yellow, magenta and cyan, change towards the same color (a*≒0, b*≒60). This color shifting is similar to that of gray scale, so we recognize the change of the color is natural. The extrapolated color is thought to that of the media.

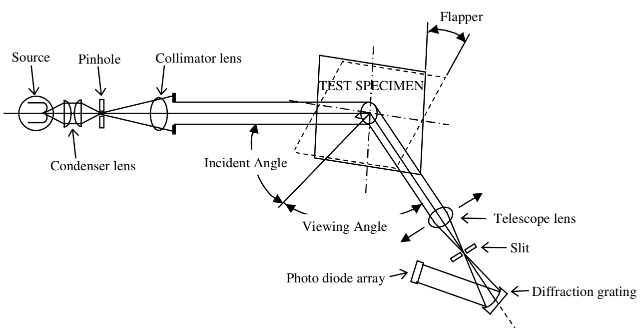

Figure 1. Optical system of goniospectrophotometer

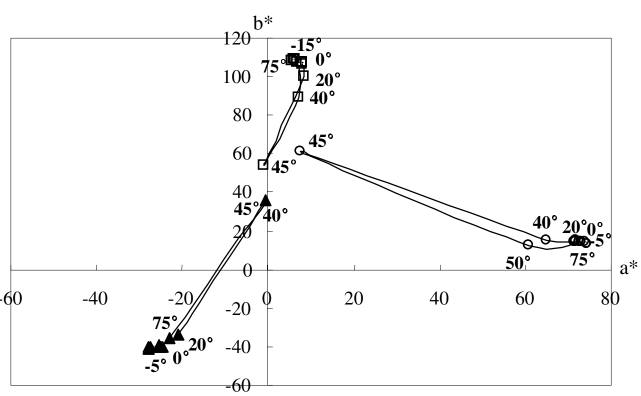

Figure 2. Color sifting of dye based ink (Magenta; white circle, Yellow; white square and Cyan; black triangle) by changing viewing angles

Result and Discussion

The Measurement of Color Sifting (Cyan)

Encapsulated colorant, conventional A and Conventional B (Pigment Blue 15:3) were estimated. Table 1 shows the particle size and the viscosity of the colorants, ink stability, and the optical densities of the prints.

Encapsulated colorant has the smaller particle diameter, lower viscosity, and better ink stability than two conventional colorants. This result suggests that encapsulated colorant is effective in formulating pigmented ink. Moreover, when using encapsulated colorant, the optical density on the plain paper was high. Encapsulated colorant has suggested having the tendency not to penetrate into the paper and remaining on the paper surface effectively.

Table 1. Physicochemical Properties and Print Quality of Cyan Pigment Colorants

Colorant type	Encapsulated colorant	Conventional A	Conventional B
Particle Diameter	97 nm	110 nm	126 nm
Viscosity (20%)	2.6 mPa.s	2.82 mPa.s	3.23 mPa.s
Stability (60°Cx3 months)	O	O	X
Optical density (Plain Paper)	1.11	1.05	1.03
Optical density (Photo Paper)	1.94	1.94	1.73
Rub resistance	O	Δ	X

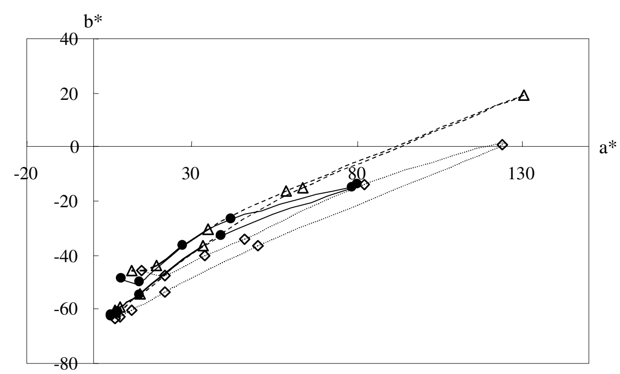

Figure 3. Color sifting of encapsulated colorant (black circle), conventional A (white square) and conventional B (white triangle) by changing viewing angles

Figure 3 shows the color shifting of the prints made from different kinds of dispersion by changing viewing angles. The color of all three kinds of prints shifts towards reddish at the angles near the specular. This phenomenon is known as "bronzing". The encapsulated colorant showed the smaller color shifting than two conventional colorants.

Some kinds of hypotheses of the mechanism in bronzing phenomenon were proposed. Buc, et. al. said a part of the pigments was pushed up to the print surface and the difference between the diffuse reflectance of the pigment in air and that in vanish was the cause of the bronzing.[6] The encapsulated colorant has the water-insoluble polymer on the surface of each pigment. As this polymer is thought to be less mobile than water-soluble polymer, the encapsulated colorant was thought to make less protruding pigment through the print surface and showed the reduced bronzing in comparison with conventional A.

The encapsulated colorant reduced color shifting with viewing angles, but when the ink contained large amount of colorant, the color shifting became larger (Figure 4). This phenomenon is unfavorable because there is the limitation of the pigment quantity in the ink to obtain the higher optical density.

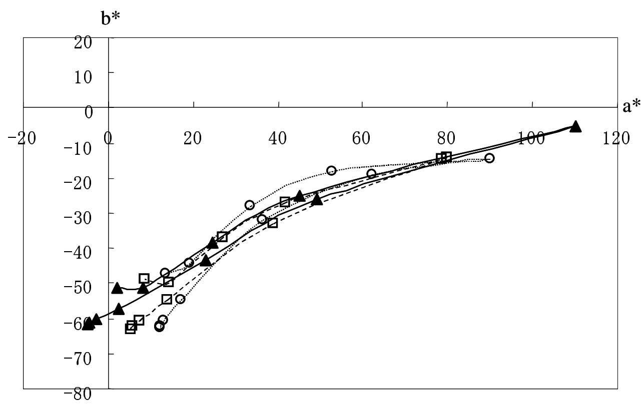

Figure 4. Color sifting of pigment contents (3% of pigment; white square, 5% of pigment; white circle and 7% of pigment; black triangle) by changing viewing angles

For getting more reduced color shifting property, the encapsulated colorants having different polymer/pigment ratio were investigated (polymer/pigment ratio = 30/70, 50/50, 70/30). Table 2 shows physicochemical properties and print quality of these colorants. When the polymer/pigment ratio exceeded 70/30, the color shifting became similar to that of dye based inks (Figure 5).

The facility of changing the polymer/pigment ratio without influencing to the dispersion viscosity is also important character of encapsulated colorant with water-insoluble polymers, which does not swell so much as the water-soluble polymers on the surface of the particle.

Table 2. Physicochemical Properties and Print Quality of Encapsulated Colorants (Cyan)

Polymer/Pigment	30/70	50/50	70/30
Particle Diameter	97 nm	97 nm	110 nm
Viscosity (20%)	2.6 mP.s	2.8 mPa.s	3.2 mPa.s
Optical density (Plain Paper)	1.11	1.10	1.12
Optical density (Photo Paper)	2.10	2.11	2.08

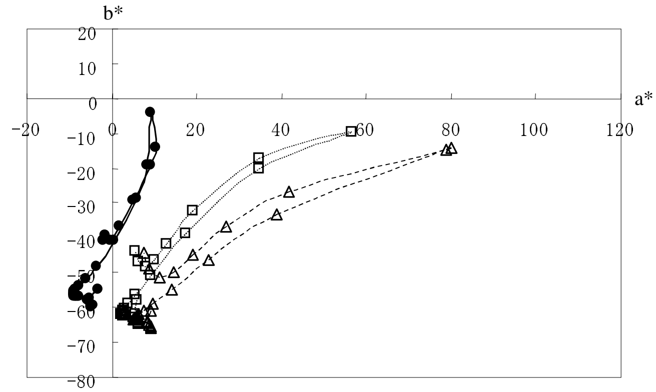

Figure 5. Color sifting of encapsulated colorants (Polymer/ Pigment=30/70; white triangle, 50/50; white square and 70/30; black circle) by changing viewing angles

The Measurement of Color Reproducibility (Magenta)

Similarly, polymer/pigment ratio effect was observed on the magenta colorant (Pigment Red 122). Bronzing phenomenon is well known on the cyan pigmented inks, but magenta pigmented inks also had the same color shifting with the viewing angles. The increase of the polymer/pigment ratio was effective to reduce the color shifting (Figure 6).

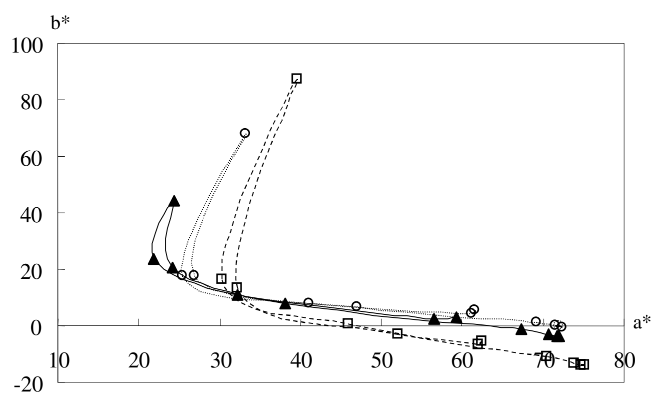

Figure 6. Color sifting of encapsulated colorant (Polymer/Pigment =30/70; white square, 40/60; white circle and 50/50; black triangle) by changing viewing angles

Bassemir, et. al. pointed out the interference bronzing mechanism, which was caused by the thin layer of vehicle on the pigment particles.[7] The influence of polymer/ pigment ratio on the color shifting was thought to support this mechanism. When the smaller pigment was examined with the same polymer/pigment ratio, the color shifting did not change (Figure 7). This result suggested that the color shifting was influenced by the amount of polymer. It seemed that the thickness of polymer layer around the pigment particle was no effective in color sifting. The mechanism of the color shifting was not clear yet but the interfacial mechanism was thought suitable for color reproducibility in this study.

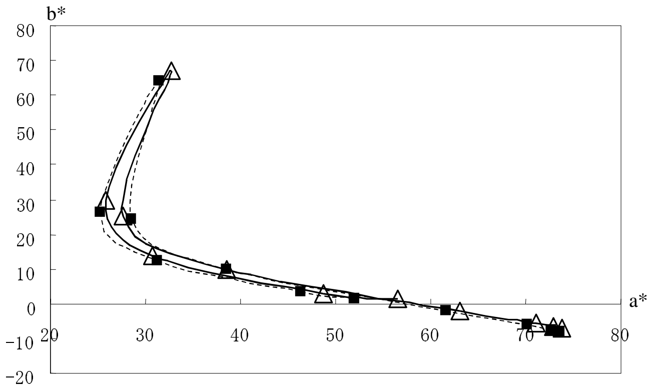

Figure 7. Color sifting of encapsulated colorants (Colorant particle diameter=80nm; whiter triangle and 100nm; black square) by changing viewing angles

Conclusion

The encapsulated colorant with water-insoluble polymer was recognized having smaller particle diameter, lower viscosity and better ink stability than colorants with water-soluble polymer and dispersion. Moreover, investigation in the color sifting of the prints by changing viewing angles with goniospectrophotometer revealed that encapsulated colorants showed reduced bronzing in comparison with that of the conventional colorants. Color shifting of cyan colorant could be improved by reducing the ratio of pigment in colorant. Similarly, in the case of Magenta, by reducing the ratio of pigment, color shifting of magenta colorants could be improved.

To improve the color reproducibility of pigmented ink for ink jet colorants, it is important to use the encapsulated pigment ink with water-insoluble polymer and to reduce the ratio of pigment in colorant.

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Biography

Isao Tsuru received his B.S. in Materials Science from Chiba University in 1994. He received his M.S. in Materials Science from Japan Advanced Institute of Science and Technology and he joined Kao Corporation in Materials Development Research Laboratories in Wakayama, Japan in 1996. Since 1998, he has been worked on polymer emulsions and ink jet ink colorants and inks. E-mail: tsuru.isao@kao.co.jp