The Study of the Relation Image Quality the Physical Properties of Inkjet Ink

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Abstract

The optical density could be increased by controlling the ink viscosity during the imaging process in which inks were more concentrated and by controlling the dynamic surface tension. By using inks that showed a faster increase in viscosity during the imaging process, more pigments remained on the paper surface. The higher viscosity of the ink appeared to reduce the forces that caused the ink to penetrate deeply into the paper fibers. On the other hand, non-printed areas on the paper reduced when the dynamic surface tension of the ink was lower. It appeared that the lower dynamic surface tension of the ink increased the forces that caused the ink dot expansion on the paper. The dot size on the printed paper was found to have the correlation with the dynamic surface tension in short time range (10^{-3}s range). However, no correlation could be seen between the static surface tension and the dot size. It is thought that the ink layer is formed in several micro seconds after the ink drops contact on paper.

Introduction

Recently, inkjet systems have been used in the field of commercial printings because of their reasonable cost, environmental friendliness, and adaptability for print-on-demand.

Consequently, high quality printings on non-treated papers will be value due to cost performance.

On the other hand, the commercial printing market has been dominated mainly by offset printing systems that have been providing higher image qualities. Inkjet printing systems require the improvement of the image quality with higher optical density to satisfy the demand of commercial printings. Some improvement methods of the image quality were previously studied. For example, the composition of co-solvent [1], the property of pigment dispersant [2], and the effect of particle size were reported [3,4]. However, the relevance between ink physical properties and image qualities has not been studied yet.

In this paper, the relations between the physical properties and the image qualities are studied. Generally, optical density is determined by pigment layers status on the paper surface. Higher optical density can be achieved by increasing amounts of the pigment on the paper surface and by decreasing color heterogeneity (streakiness). Thus, it is important for inkjet inks to design the physical properties to control the pigment status on the paper surface.

The aim of this study is to understand mechanisms that control the pigment status on a paper surface and to understand the factor of color heterogeneity.

Experimental

Preparation of encapsulated pigment dispersion

To prepare the encapsulated pigment dispersion, the water-insoluble acrylic polymer was adopted. First of all, 20g of the neutralized polymer and 80g of Pigment Black 7 (carbon black) were mixed with 500g of MEK and water. The mixture was dispersed with a homogenizer. The dispersion was concentrated with an evaporator by removing MEK and some water, and centrifuged to remove the large size particles. The content of the dispersion was adjusted to 20wt% by ion exchanged water.

Printing condition

Print tests were carried out by an EPSON ink jet printer (EM930C). Print modes are described below.

Paper mode of printer: plain paper, Print speed: fast, Printed paper: NPI55 (Nippon paper).

Measurement

Measurement of image quality and observation of colorant status on printed papers

Image quality was evaluated by the optical density. Optical density was measured by SpectroEye (Gretag Macbeth: GMB).

Pigment status on the paper surface was determined by the pigment amounts observed in the paper cross-section by digital micro scope (Keyence VH-2500). Color heterogeneity of the printed area was observed by DDC micro camera (PIAS-2). Those images were analyzed by Image-J software.

Measurement of physical properties

Ink drop contact angle on paper was measured by microscopic contact angle meter MCA-3(Kyowa Interface Science Co. Ltd.)

Inks which have various solid contents were prepared by a vacuum dry oven as concentrated inks. Those concentrated inks were the models to simulate ink viscous behavior during drying process on the paper surface. The rheological properties of the concentrated inks were measured by rheometer physica MCR301 (Anton Paal). Static surface tensions were measured by Wilhemy type surface densitometer FACE CBUP-Z (kyowa Interface Science Co. Ltd.). Dynamic surface tensions were measured by maximum pressure tensiometer MPT2 (LAUDA).

Results and Discussion

Effect of co-solvent for image quality

First, the effects of co-solvents in the ink were investigated. Five types of inks were prepared. Those inks contained 5% of

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organic solvents. In this case, those organic solvents were selected from mono-alkyl ether ester type (solvent A), amide type (solvent B), alcohol type (solvent C), and polyethyleneglycol type (solvent D) respectively. The details of the ink compositions are shown in Table 1. The initial viscosities of those inks were adjusted 4cP by glycerol as a viscous control agent. Figure 1 shows the optical density on the printed paper with each solvent. The ink containing solvent A showed the highest optical density in all inks.

Table 1. Ink composition

Pigment (carbon black 7)	7%
Acrylic polymer dispersant	5%
Co-solvent	5%
Surfynol 104PG50	0.1%
Glycerol (Viscous Cont. agent)	Balance
Water	Balance

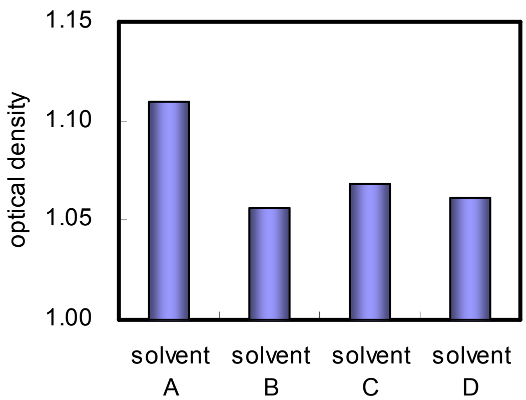

***Figure 1.** Effect of co-solvents on optical density*

Next, the ink layer status of printed area was investigated to understand the working mechanism of solvent A system. Figure 2 shows the cross section pictures of the papers printed with solvent A ink and solvent C one. The more pigments existed on the surface of the paper printed with the solvent A-containing ink than that with the solvent C one.

Figure 3 shows the scale-up pictures of the printed paper surface printed with solvent A ink and solvent C one. The solvent A ink showed less color heterogeneity than the solvent C ink.

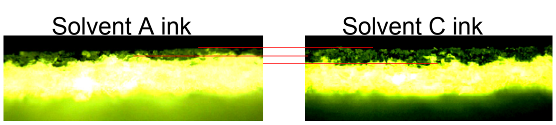

***Figure 2.** Pigment remaining conditions in the paper*

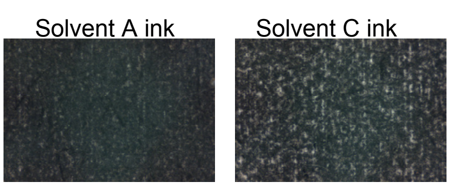

***Figure 3.** Color heterogeneity*

These results indicate that the pigment remaining status on the paper and the color heterogeneity were the important effects for optical density.

Influence of viscosity on optical density

The ink solid content dropped on the paper surface increases during the ink layer forming process. This phenomenon was modeled by using the concentrated inks.

Figure 4 shows the viscosity changes during the ink concentrating process.

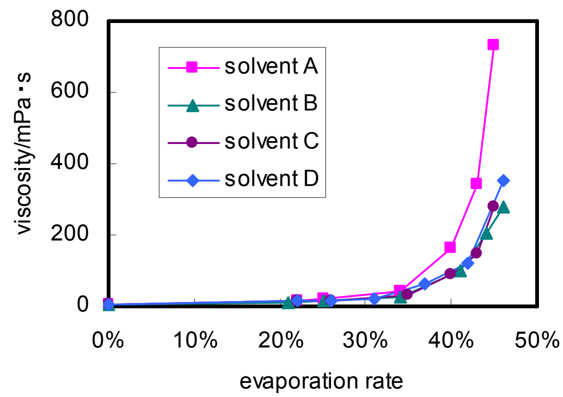

***Figure 4.** Viscosity properties during concentrating process*

The viscosity of the solvent A ink increased faster than those of the other inks during the concentrating process. It is believed that if the ink viscosity increases faster, more pigment remains on the surface of the paper because the viscous forces prevent the ink liquid to penetrates into the paper inside. Therefore in the case of the ink with solvent A, more pigments existing on surface of the paper contributed to the high optical density.

It was suggested that these viscosity change properties were caused by the interaction between solvent and colorant. To control the viscosity during the concentrating process, the interaction forces between dispersed pigment particles and co-solvent must be controlled. Accordingly, this interaction force should be taken into account in the design of inkjet inks.

Influence of surface tension for optical density

The color heterogeneity was reported to relate to ink dots size [5]. Graininess score which corresponds to color heterogeneity and 1dot diameter is shown in Table2. Graininess score refers to irregular fluctuations of optical density at a specified printed area. Graininess score is calculated according to the ISO-13660 International Print Quality protocol, which uses a area size of 1.27mm. In this case, the lower score means the lower color heterogeneity.

Table 2. Summery of Graininess and dot diameter

	Graininess	Dot diameter
Printed by solvent A ink	0.050	130 μm
Printed by solvent C ink	0.084	116 μm

Figure 3 and Table 2 suggest that the dot expansion might decrease color heterogeneity. Then, the dominant factor of the dot size was investigated. As printing dots might form when the ink drops contact to the paper surface, an ink drop contact angle to paper is one of the important factors of the dot size. Therefore, contact angle of solvent A ink and solvent C ink were measured (Figure 5).

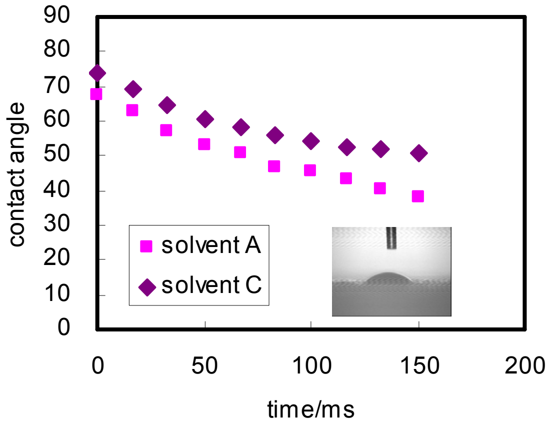

Figure 5. *Contact angles of ink drop of solvent A ink and solvent C ink.*

These results indicate the solvent A ink drops expand faster than the solvent C ink. Thus, the color heterogeneity of the solvent A ink was thought to be improved by the dot diameter due to the lower dynamic contact angle, which would correspond to the better wettability of the ink on the paper.

Generally, the wettability on a media surface is determined by surface tension of the liquid. Therefore, the relationship between the surface tension and the print quality was studied. In this time, five type inks were prepared. The detail of ink compositions are shown in Table 3. Surface tensions of those inks were adjusted using nonionic surfactants.

Table 3. Ink composition

Pigment (carbon black 7)	7%
Acrylic polymer dispersant	5%
Surfactant	0.1%-1.0%
Glycerol (Viscous Cont. agent)	Balance
Water	Balance

Dynamic surface tensions of those inks are shown in figure 6.

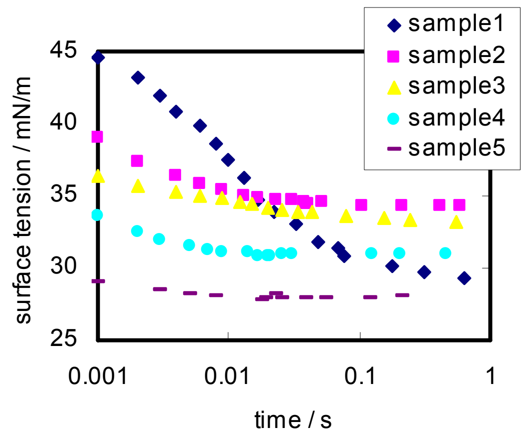

Figure 6. *Dynamic surface tension*

Table 4 summarizes optical densities, static surface tensions and dynamic surface tensions of these inks

Table 4. Properties of inks containing variant surfactant

	Optical density	Static γ	Dynamic γ
Sample1	1.02	28	45
Sample2	1.04	34	39
Sample3	1.05	32	36
Sample4	1.07	30	34
Sample5	1.09	28	29

Figure 7 shows the relationship between the surface tension and the optical density. The optical density scores of those inks were found to have the correlation with the dynamic surface tension in short time range (10^{-3}s): red points. However, no correlation could be observed between the static surface tension and the optical density: blue points. It is thought that the ink layer is formed in several micro second after the ink drops contact on paper.

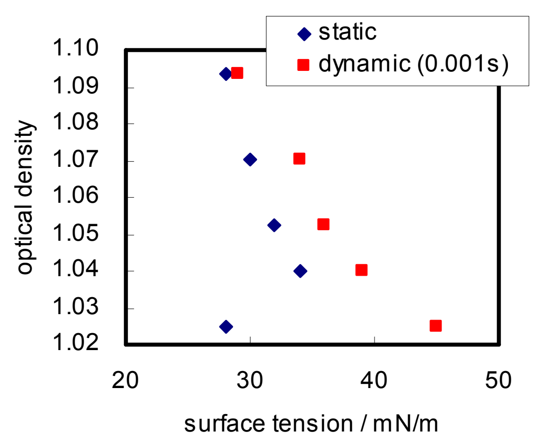

Figure 7. *Relationship between surface tension and optical density*

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Figure 8 shows the relationship between the dynamic surface tensions and the dot diameter. The Correlation between the dynamic surface tension and the dot diameter could also be observed Thus the dynamic surface tension in short time range is thought to be the dominant factor of the ink dot size, resulting in the higher optical density.

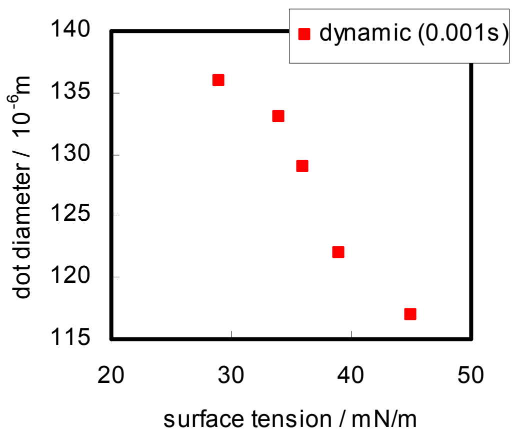

Figure 8. *Relationship between dynamic surface tension and dot diameter*

Based on these results, the control of dynamic surface tension is the important factor for optical density.

Conclusions

The image quality was found to be influenced by surface tension and by viscosity. The results showed that optical density could be increased by controlling the viscosity behavior during the drying process and by controlling the dynamic surface tension.

Therefore, the interaction force between dispersed pigment and co-solvent as well as the dynamic surface tension are needed to be considered for the inkjet ink design.

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