Development of High Image Quality Inkjet Printing Paper

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Abstract

Inkjet photo glossy paper with a resin-coated paper support is now a main medium for photographic inkjet printing because of its whiteness and smooth surface, which closely resembles those of the conventional AgX photo print.

Inkjet photo glossy paper has two types; polymer type and porous type. Recently, porous type is becoming a major medium for photographic inkjet printing in the aspect of ink absorbing rate. But it was difficult to be compatible with high glossiness, high Dmax and ink absorbing rate.

In this report, we describe below two techniques developed to achieve high glossiness and high Dmax (wide color gamut) of porous type inkjet paper.

1. A new definition of glossiness of inkjet paper correlated with visual gloss evaluation.

2. A way to improve density of Dmax

1. Introduction

With the spread of personal computers and the Internet, inkjet printers are now widely used for home printing applications. Although the primary purpose is document printing, the amount of photo printing is increasing year by year, and demand is growing for the image-receiving paper that is used to print photo images (photo glossy paper). In particular photo glossy paper which uses resin coated paper (RC paper) as a support is close to AgX photo printing in terms of whiteness and smooth surface, and has become the main medium for photo-quality printing. The level of quality demanded by the users grows higher each year.

In this report, we describe the techniques which we developed in order to achieve high glossiness and high Dmax (wide color gamut).

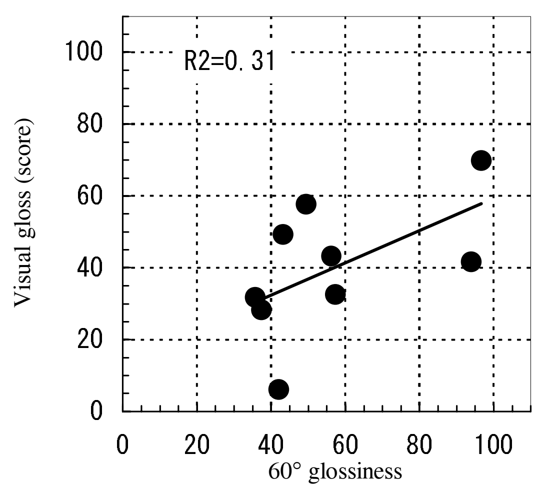
2. Improving the visual gloss

The conventional methods for evaluating visual gloss can be broadly divided into the following two types. (1) Regular reflected light strength (glossiness, etc.): A method which measures the strength of reflected light in the regular reflection direction. (2) Image clarity: A method which measures the clarity of an image projected on the sample surface. Of these, measurement of the regular reflected light strength (1) is the method most often used, and has been standardized by JIS (Japan Industrial Standards) [(1) (2)]. There is also a method that is similar to (1) and which measures the ratio between regular reflected light and diffuse reflected light. Three versions of this method have been reported [(3)]: one which finds the ratio of the surface reflected luminous flux at the angle of deviation to the total reflected luminous flux, one which is expressed as the ratio of the brightness in a specific direction to the brightness in the regular reflection direction, and one which is expressed as the ratio of the reflected luminous flux in the regular reflection direction when the light incidence angle is changed.

Of these measurement methods, the measurement of relative-specular glossiness has been commonly used, however because it does not always match the sense of visual gloss, there has been a recognized need for a method of quantitatively evaluating the visual gloss. Fig. 1 is a graph showing the correlation between 60 degree glossiness and a psychophysical evaluation of the visual gloss by multiple test subjects, using commercially available or experimental printing materials. It is clear that the correlation between 60 degree glossiness and the visual gloss is low.

When a fluorescent lamp is shined on print samples with different visual gloss, and the projected images are examined, then as Fig. 2 shows, the psychophysical evaluation score is high whenever either (1) the regular reflected light strength (glossiness) or (2) the image clarity is high. We then thought to express the visual gloss as a linear coupling of the regular reflected light strength and image clarity, and performed multiple regression analysis to create an evaluation formula for the visual gloss which corresponds extremely well with the visual gloss at the psychophysical evaluation.

Figure 1. Correlation between 60 degree Glossiness and visual gloss evaluation



[Evaluation formula (multiple regression formula) for visual gloss]

Visual gloss C* = 0.3 × (Regular reflected light strength) + 0.4 × (Image clarity C value)

Correlation coefficient = 0.96 Contributing ratio = 0.92

Regular reflected light strength:

Maximum strength of reflected light measured with a goniophotometer

Image clarity C value:

Sum of measured values with band widths of 2 mm, 1 mm, 0.5 mm, 0.25 mm, and 0.125 mm

Fig. 2 Fluorescent light image on the printed paper

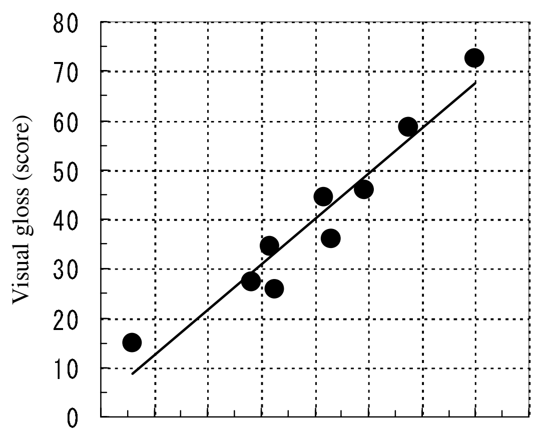
Visual gloss: poor | Visual gloss: excellent | Visual gloss: poor

Image clarity: good, Regular reflected light strength: poor | Image clarity: good, Regular reflected light strength: good | Image clarity: poor, Regular reflected light strength: good

Using this evaluation formula, we determined that the users evaluate the visual gloss of a photo print based on its regular reflected light strength and image clarity. We also determined that the weighting of the two factors is (Regular reflected light strength):(Image clarity) ≈ 3:4. In other words, the users place more importance on the image clarity than on the regular reflected light strength (glossiness) when evaluating visual gloss.

Based on this idea, we carried out studies which were primarily aimed at increasing image clarity.

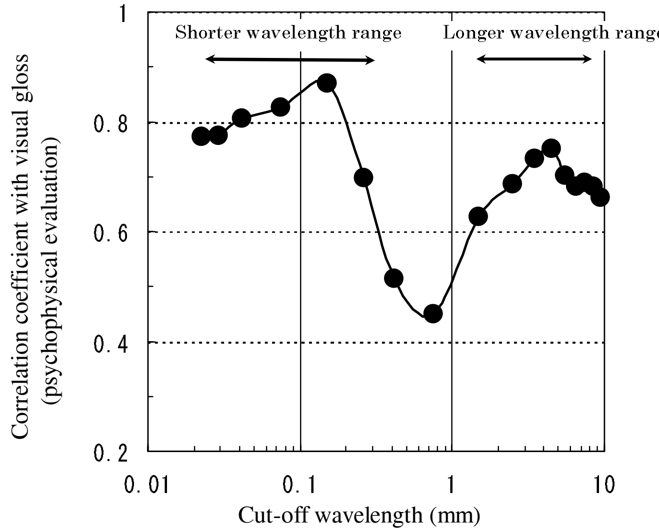
Fig. 3 Correlation between new gloss value(C＊)and visual gloss value



When we again examined fluorescent light images projected onto the print samples, we found that even with images of approximately the same brightness, some images appeared blurred or distorted. We hypothesized that this sort of image blurring or distortion was due to differences in the roughness of the image-receiving surface (the surface roughness wavelength). We therefore examined the relationship between image clarity and the surface roughness wavelength.

We first used a 3-dimensional roughness gauge and measured the surface roughness of the image-receiving paper at a variety of cut-off wavelengths in order to determine the correlation with the visual gloss (psychophysical evaluation). The results showed that there were roughness wavelengths which correlated highly with the visual gloss (Fig. 4). As shown in Fig. 4, the roughness wavelength ranges which correlated highly with the visual gloss were a shorter wavelength range of 0.1 - 0.2 mm, and a longer wavelength range of 3 - 4 mm.

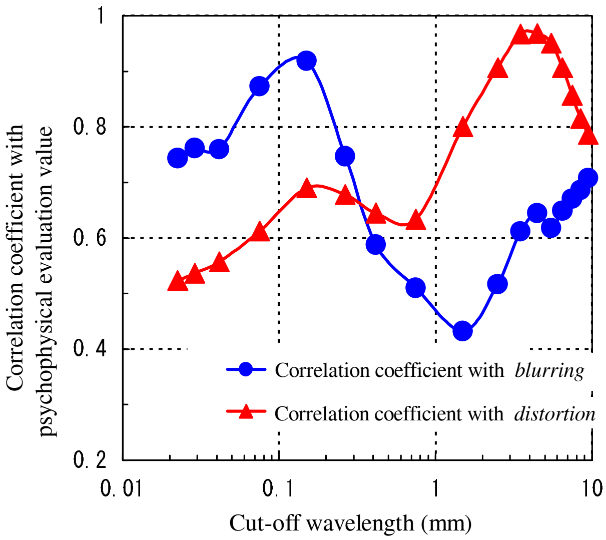
Fig. 4 Correlation between surface roughness wavelength and visual gloss value – 1



Next we separated the psychophysical evaluation values for the visual gloss into blurring and distortion, as described above, and again examined the correlation with the surface roughness of the image-receiving paper. The results showed that blurring correlated highly with the shorter wavelength range, and that distortion correlated highly with the longer wavelength range (Fig. 5).

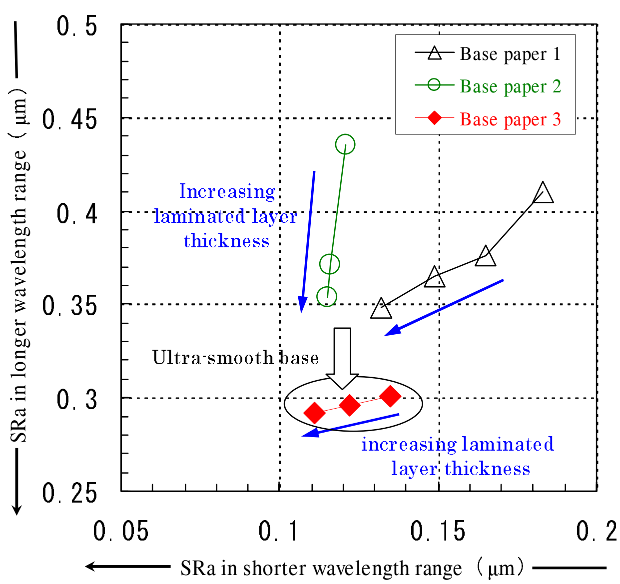
In order to improve the visual gloss (psychophysical evaluation) of the image-receiving paper in this way, it is necessary to smooth the roughness in the shorter wavelength range of 0.02 - 0.5 mm and in the longer wavelength range of 3 - 4 mm.

Fig. 5 Correlation between surface roughnesswavelength and visual gloss value – 2



We then performed a study concerning methods for reducing the roughness in the shorter wavelength and longer wavelength ranges of the RC paper which is used to receive the images. Fig. 6 shows how the base paper and laminate layer in the RC paper affect the surface roughness (SRa) in the shorter wavelength and longer wavelength ranges. We found that increasing the thickness of the laminate layer was highly effective in smoothing the roughness of the base paper and reducing roughness in all wavelength ranges.

Fig. 6 Effect on SRa of the base paper and laminate layer



3. Improving printing density (Dmax) and color reproducibility

We next developed techniques which would achieve high black density (Dmax) and a wide color gamut.

Fig. 7 shows a cross-section model of the inkjet image-receiving paper after black printing. After printing, the dye penetrates to a certain depth in the image-receiving layer. When the printed photo is viewed, a part of the incident light is scattered by the surface of the image-receiving layer, and the light which penetrates the image-receiving layer is also scattered by nano particles which form voids. As a result, with nano-porous type image-receiving paper, the printing density (Dmax) and color reproducibility are largely affected by the depth to which the dye penetrates, and by the scattering of light on the surface and inside of the light-receiving layer.

Fig. 7 Light Scattering in & on the ink absorbing layer

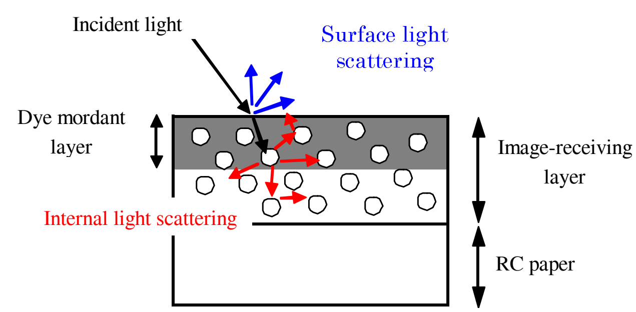
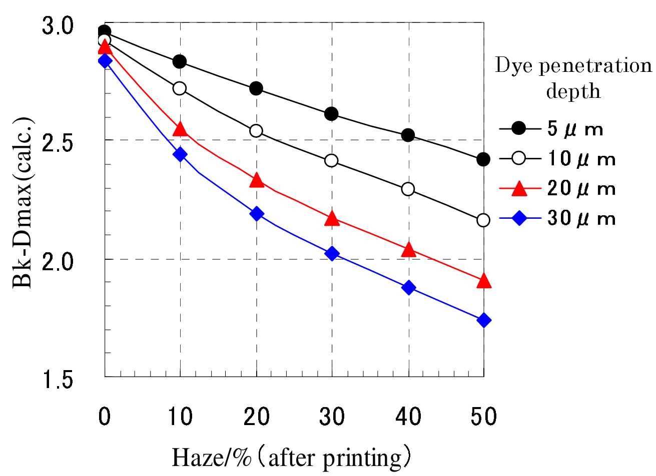


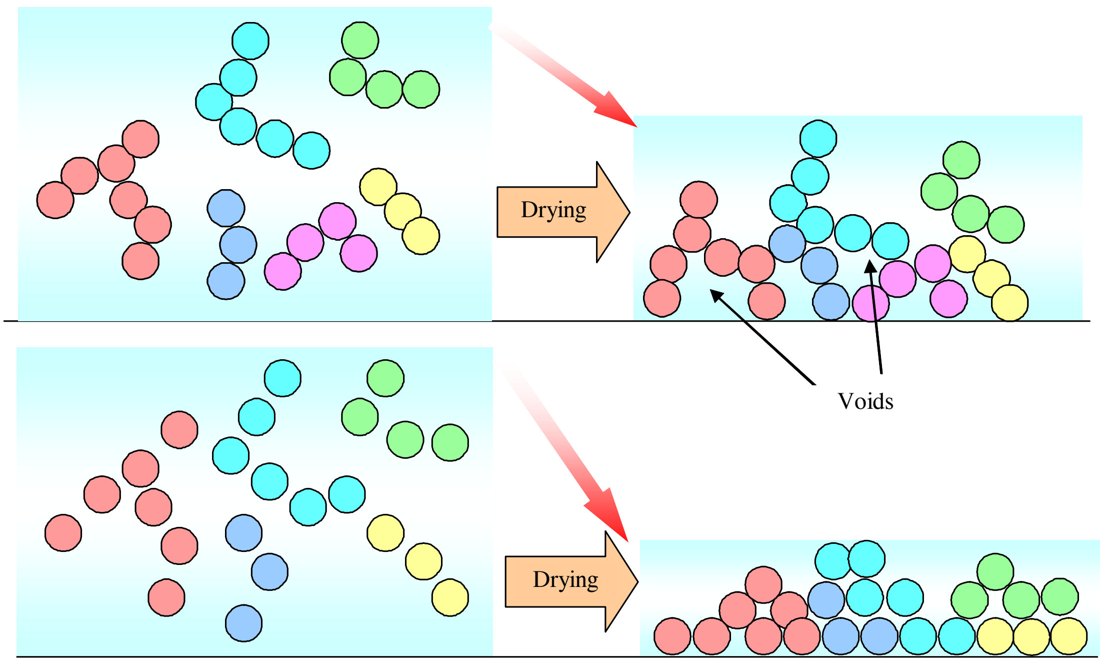
Fig. 8 shows the results from a simulation of the relationship between the haze value of the image-receiving layer (after printing) and the printing density (Dmax) when the depth which the dye penetrates to in the image-receiving layer is changed. The results showed that the effects of the haze value increase with deeper penetration of the dye.

Fig.8 Simulation of influence from Haze on Dmax



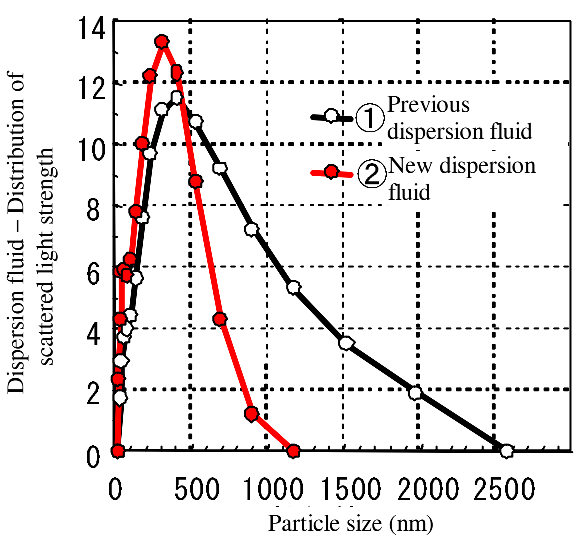
An effective method of reducing the haze value in the image-receiving layer is reducing the sizes of the voids, or of the particles which form the voids. However, reducing the size of the voids has a negative effect on ink absorbability (Fig. 9).

Fig. 9 Influence of pigment diameter for nano-porous structure



In order to resolve this trade-off relationship, we developed techniques to optimize the pigment dispersion for inkjet printing applications.

Fig. 10 Particle size distribution of our new dispersion



In order to reduce internal scattering of light as much as possible without lowering the ink absorbability, we promoted dispersion specifically of the pigments with large particle diameters (those which have a large effect on light scattering), while leaving the particle sizes that allow effective ink absorption unchanged, and performed monodispersion of the dispersion particles (Fig. 10).

When we actually measured the pore size distribution on the image-receiving paper using pigment dispersion fluid, we found that we were successful in reducing the number of large pores with sizes 50 nm or larger, which have a large effect on light scattering (Fig. 11), while leaving the 50 nm and smaller pore size distribution, which is the primary ink absorbing range, essentially unchanged. In doing so, we were able to significantly increase the black density (Dmax) (Fig. 12).

Fig. 11 Pore size distribution of the ink absorbing layer

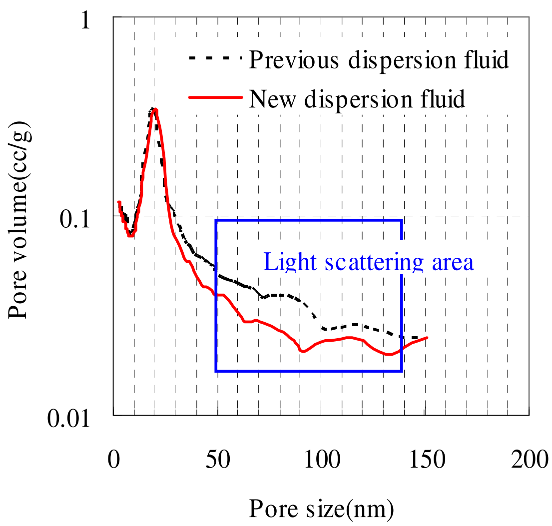
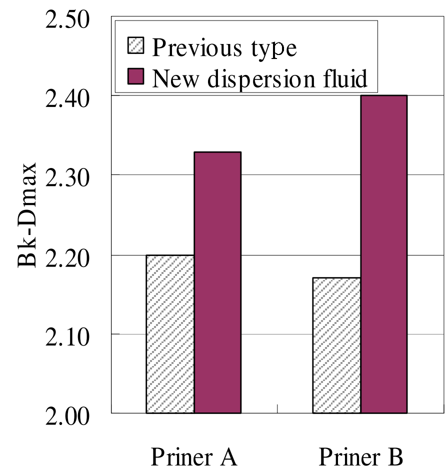
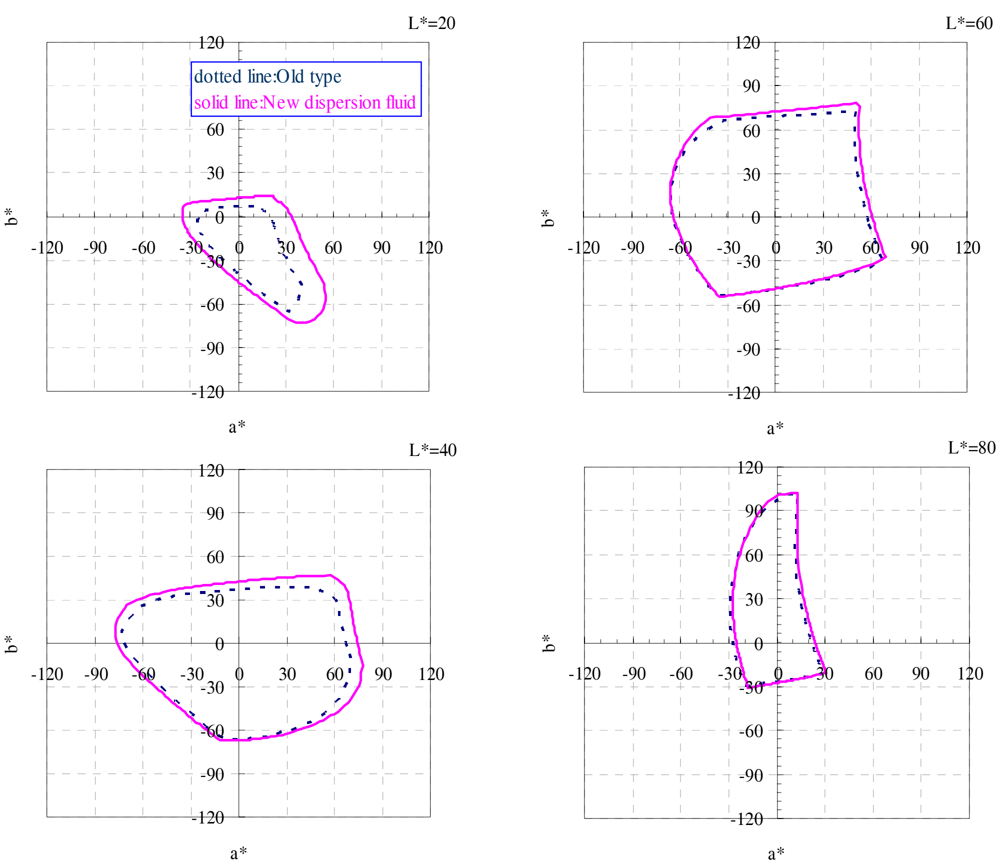


Fig. 12 Dmax of new dispersion method



As described above, reducing the haze value of the image-receiving layer has a greater effect on the color development when the dye penetrates more deeply, and the effect is particularly large on the sharpness of shadow parts where a large amount of ink is used. In addition, this technique is also effective in improving Dmax for other single colors besides black in the same way, and allows expanded color reproducibility over a wide range (Fig. 13).

Fig. 13 Color gamut of new dispersion method



4. Conclusion

We conducted a psychophysical evaluation of visual gloss which was pleasing to the users. From this evaluation, we found that so-called "image clarity" was of great importance to the users in their evaluations of visual gloss. Based on this index, we developed RC paper with the greatest possible smoothness, and achieved a high visual gloss for inkjet applications which is superior to previous types.

We also reduced the haze of the image-receiving layer without harming ink absorbability, resulting in much higher color density than with previous types. With the combined effects of a high-whiteness support, we achieved a wider color gamut.

5. References

[1] Method of Measurement for Specular Gloss -JIS Z 8741

[2] Testing Method for 75 Degree Specular Gloss of Paper and Paperboard-JIS P 8142

[3] The Color Science Association of Japan, *The handbook of color science* (University of Tokyo Press, 1998) pg.625-644

6. Author Biography

Ryoichi Nakano received his Master of Science in chemistry from the University of Tokyo (1997). Since then he has worked at FUJIFILM in Shizuoka, Japan. His work has focused on the development of inkjet paper