The Development of New Disperse Dye Inks for Inkjet Textile Printing

Yasuhiko Kawashima, Hitoshi Morimoto, Toshiya Takagi, and Takao Abe
Inkjet Technology R&D Center, Konica Technology Center Corporation
Tokyo, Japan

Abstract

Disperse dye inks are used in the inkjet textile printing of polyester fabrics. We aimed at developing a black disperse dye ink consisting of yellow, magenta, and cyan dyes that met the exacting requirements of safety, image durability, and storage stability. One difficulty we met was dye particles tending to aggregate/agglomerate, leading to sedimentation and the threat of head clogging and/or inferior color reproduction. We discovered that rapid adsorption and desorption exchange of dispersants and the wetting ability of the dyes' surfaces appeared to control the system's stability. Based on this, we succeeded in developing a stable black disperse dye ink.

Introduction

Inkjet printing, with its low printer and running costs, its wide variety of compatible recording media, and its many other attractions, has proliferated in consumer and commercial markets alike. Of special note among emerging commercial applications is textile inkjet printing as a digital method of printing samples, designs, and coupons, as well as for outdoor usage with signage, flags, and banners.[1]

Although textile and paper inkjet printing share the same basic technologies, textile inkjet printing inks must be designed specifically for the substrates and delivery mechanisms with which they are matched. This means fiber-specific colorants chosen for such fabrics as cotton, silk, and polyester.

Preferred with polyester fabrics are disperse dye inks in the form of hydrophobic dyes dispersed to small crystalline form in an aqueous medium. After printing with such dye inks, polyester fabrics are heated and the dyes melt, sublime, and/or dissolve into the fabric's fibers, where they fix.

For this application, dispersed dyes must meet three requirements. First, image stability requires that the dyes provide images that resist such agents of degradation as light, water, sweat, and abrasion. Second, safety requires that dyes providing image stability also not be toxic, carcinogenic, or otherwise hazardous to health, especially because these dyes will often come into direct contact with human skin. Third, ink storage stability requires that these stable and safe dyes remain in dispersed form, without aggregation and/or agglomeration, for a matter of years. If dispersed dye particles were to aggregate or agglomerate during storage, the larger particles thus formed would settle into a sediment, leading to filter and print head clogging and to inferior color reproduction.

But while the weight of satisfying these demands falls directly on the design of the dyes involved, only a small range of dyes exist to be chosen from, and therein lies the challenge. In this paper, we present our efforts to develop a safe and stable black disperse dye ink.

Experimental

Preparation of Black Inks

Yellow, magenta, and cyan dyes were dispersed independently with a beads-mill disperser to yield commensurate dispersions. The three dispersions were then mixed as in Table 1 to produce three black inks.

Table 1. Composition of three black inks

Ink #	Dispersant/carrier medium	Auxiliary agent
1	Optimized for each dye	Not added
2	Same for all dyes	Not added
3	Same for all dyes	Added

Evaluation of Mutagenicity

The mutagenicity of the inks was tested through conventional AMES testing with *Salmonella typhimurium* TA98, *Salmonella typhimurium* TA100, and *E.Coli WP2uvrA*/pKM101.

Evaluation of Dye Surface Energies

Each dye was palletized, and its contact angles with water, nitromethane, and diiodometane were measured with a CA-V contact angle meter (Kyowa Interface Science Co., Ltd.). The surface energies of the dyes' were calculated from the contact angles via Young-Fowkes equilibrium.

Evaluation of Ink Properties

Each ink was centrifuged at a common speed and the absorbance of the supernatant measured at intervals with a U-3200 spectrophotometer (Hitachi). The sedimentation property of the inks was expressed as the ratio between the initial and the centrifuged absorbencies.

The viscoelasticity of the inks were measured with an MCR 300 modular rheometer (Physica Messtechnik GmbH).

Electron microscopic images were obtained with an S-800 scanning electron microscope (Hitachi).

Light fastness, water fastness, and the fastness of color to perspiration, to washing and laundering, and to abrasion were evaluated according to corresponding Japan Industrial Standards.

Results and Discussion

Image Durability

A dye's stability and durability against light, water, sweat, and abrasion controls the stability and durability of the inkjet-printed textile image. We examined the dyes' stability ratings in conventional screen-printing systems, and chose stable yellow, magenta, cyan, and black dyes. We then confirmed their stability and durability in inkjet textile prints.

Dye Safety[2]

Dye safety was of paramount concern. We evaluated the mutagenicity of selected stable dyes, and most tested positive in AMES testing. Unfortunately, no black dye tested negative, but we did find yellow, magenta, and cyan dyes that satisfied dye safety as well as specifications of color and image stability and durability. Thus we were resigned to using a combination of yellow, magenta, and cyan dyes.

Storage Stability

The sedimentation properties of the inks are presented in Fig. 1, where the horizontal axis indicates relative centrifugal force and the vertical axis indicates relative absorbance. The viscoelasticities of Ink 1, Ink 2, and Ink 3 are summarized in Fig. 2, where the horizontal axis indicates shear rate, and the vertical axis indicates viscosity.

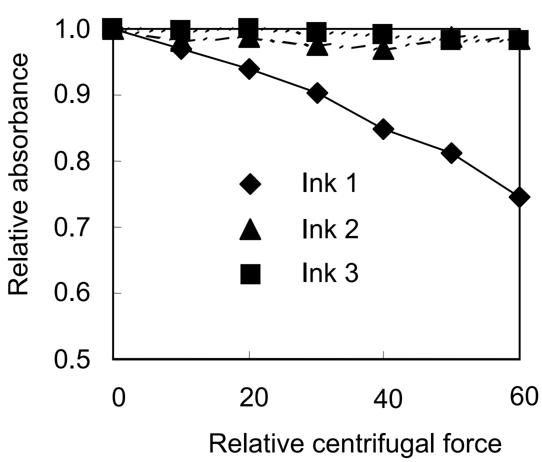

Figure 1. Sedimentation properties of three inks

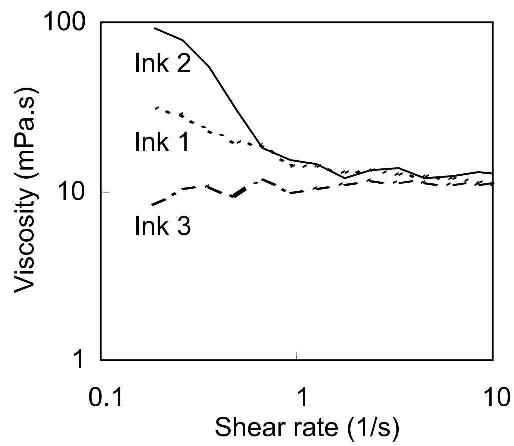

Figure 2. Viscoelasticities of three inks

Figure 1 shows the relative absorbance of Ink 1 decreasing as centrifugal force increases, reflecting sedimentation in Ink 1. In fact, Ink 1 yielded particles large enough to be captured in a mesh filter. The flocculation seen in the Fig. 3 SEM image shows small primary particles aggregated/agglomerated to form larger particles. To clarify the mechanism involved, we analyzed the change in dispersant adsorption in the supernatant over time. Measuring the concentration of Ink 1's unadsorbed dispersant over a number of days, we calculated the ratio of the initial concentration to subsequent concentrations. As seen in Fig. 4, the concentration of the unadsorbed dispersant decreased.

We optimized dispersants and carrier media for each dye in order to control dispersion speed, and so could not use the same dispersant for all three dyes. We assumed that a rapid adsorption and desorption exchange of the dispersant occurred at the surface, making the system unstable, resulting in dye aggregation/agglomeration that formed larger particles, which finally led to sedimentation.

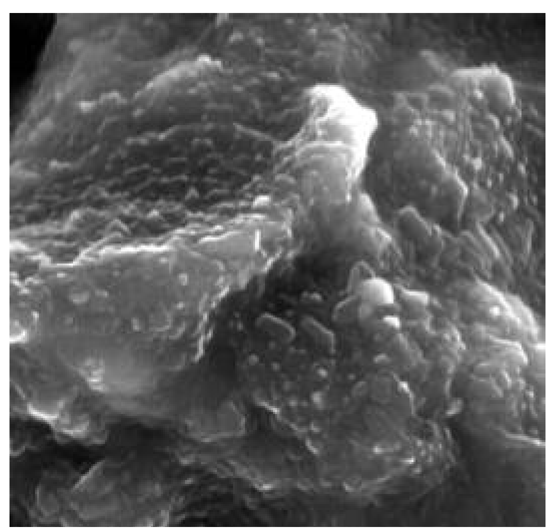

Figure 3. Ink 1 flocculation

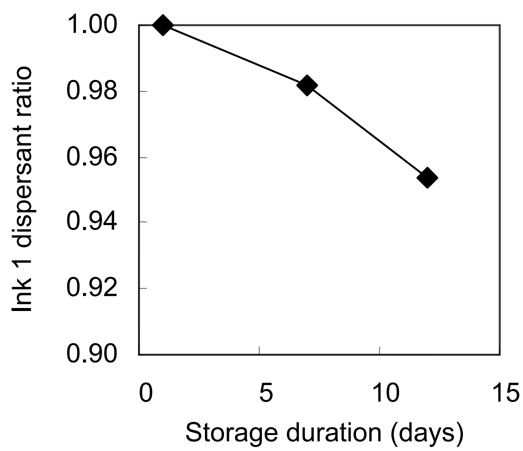

Figure 4. Ink 1, decrease of unadsorbed dispersant

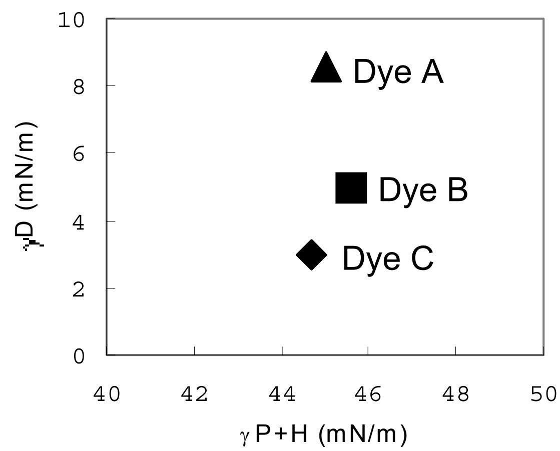

Figure 6. Ink 2 dye surface energies

In Fig. 2, the viscosity of Ink 2 was high at low shear rates, suggesting that Ink 2 possessed structural viscosity. Like Ink 1, Ink 2 developed particles that were large enough to be captured in a mesh filter, a SEM image of which is seen in Fig. 5. Spectroscopy identified these particles as the aggregation/agglomeration of Dye C. To investigate the mechanism involved, we measured the surface energies of Ink 2's three dyes. The results are summarized in Fig. 6, where the vertical axis indicates the wetting ability of the dyes: the bigger the value, the more easily it wets. Fig. 6 shows that Dye C had the poorest wetting ability of the dyes. From this we assumed that not enough dispersant could adsorb onto the surfaces of Dye C and of the particles of the dye aggregate/agglomerate.

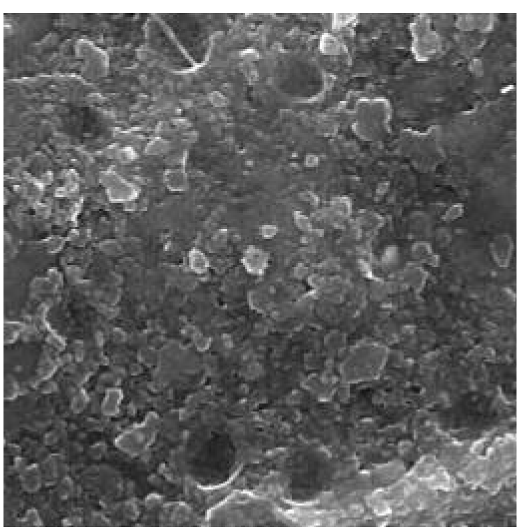

Figure 5. Ink 2 flocculation

In response to these results, we used the same dispersant for all the dyes to avoid the rapid adsorption and desorption exchange of the dispersant. Additionally, we used an auxiliary agent to compensate for the poor wetting ability of Dye C. This combination constituted Ink 3, and, as seen in Fig. 1 and Fig. 2, Ink 3 did not sediment or possess structural viscosity.

Conclusion

Our objective was a black disperse dye ink for textile inkjet printing that was safe, was highly resistant to light, water, sweat, and abrasion, and had high storage stability. Combining three dyes, we formulated several black disperse dye inks. We encountered the obstacles of rapid adsorption and desorption exchange of dispersants and poor dye surface wetting ability. However, after adopting an appropriate single dispersant and an auxiliary agent, we succeeded in developing black disperse dye ink that met our objective.

References

1. Taku Mitsuhashi, Takayuki Katoh, J. Imaging Soc. Jpn., 41, 189 (2002).
2. http://www.konica.co.jp/global/environment/report/02pdf/part5.pdf

Biography

Yasuhiko Kawashima received his B.S. in 1980 and his M.S. in 1982, both from Tohoku University. He joined Konica Corporation in 1982, where he synthesized new materials for color silver halide photographic systems and developed color silver halide photographic films. Since 1999, he has focused on the development of inkjet inks.