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Preparation of Microemulsion Based Disperse Dye Inks for Thermal Bubble Ink Jet Printing

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Abstract. *This study describes the preparation of microemulsion inks based on commercially available disperse dyes for thermal bubble ink jet printing. The approach to make the inks is by formulating to form water-soluble emulsions (o/w), which were then optimized to reach a dynamically stable isotropic condition. The dyes in three primary colors—cyan, magenta, and yellow—were systematically investigated. Different species and amounts of dispersants, emulsifiers, and dyes were selected to prepare microemulsions after intense stirring. The system, D50/963H/ Pannox140/glycerin/water, performed excellently in particle size reduction and size stabilization. The surface tension, pH value, viscosity, and stability of the microemulsion inks meet the requirement of the applied printhead to provide both good printing quality and excellent printing consistency without clogging in the nozzle. The interaction between dyes and the microemulsion system can be comprehensively understood based on the results of particle size analysis, lightfastness, water fastness, and the characterization of printing quality. The low particle size-reducing efficiency can be attributed to the compatibility between dye and dispersant structures as well as particle aggregation. The lightfastness could be enhanced with smaller particle size but decreased with dye content. However, the water fastness of the preformed sample was identically high without being affected by the dye particle size in the range between* 80 nm *and* 96 nm. *The printing performance was found to be closely correlated with the dye structure and ink concentration.* **©** *2007 Society for Imaging Science and Technology.*
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INTRODUCTION

With superiority in cost and manufacturing technique, the thermal bubble ink jet technology shares a valuable ink jet printing market with the piezo ink jet. To formulate water miscible inks with water insoluble colorants, the dyes or pigments must be processed via microparticle reduction and intensive dispersing to form stable jet inks. The present article focuses on applying microemulsion technology to render the ink of disperse dye base a homogeneous and thermally stable system for the thermal bubble printhead. As previously defined,[1] the microemulsion is formed by mixing oil phase, surfactant, cosurfactant, and water to provide a large oil-and-water interfacial area and low viscosity. Different surfactants and composition determine the microscopic structure of oil-in-water droplets, bicontinuous systems, and water-in-oil droplets. These small structures enable not only the reaction of oil-soluble phase and water-soluble phase but also the synthesis of ceramic pigments[2] as well as phase transfer catalysis.[3] Both categories of normal microemulsion and reverse microemulsion have been reported to have very low water solubility, and consequently, low solid content in the preparation of pigment containing inks,[4] although the nanoparticles were produced with narrow distribution and no agglomeration. That is because the microemulsion phase transforms to another state when the water amount exceeds a certain level. An effective ink, comprising high solid content and merits of microemulsions, should be formulated with a choice of a microemulsion or reverse microemulsion system, optimization of preparation conditions, and application of bicontinuous structure. However, most prior research work[5–10] focused only on the preparation and characteristics of well-dispersed nanoparticles by the reverse micoremulsion method, without experiments on practical application in the ink jet printer. Moreover, comparatively little information has been published on how ink jet printability of dyestuffs correlate with dyestuff structure and molecular weight, ink composition, concentration, and solvent used. Only by systematically exploring inherent possibilities and limitations of the technique can strategies be envisioned for printing with a large number of different compounds in future.[11]

In order to prepare an isotropic and highly disperse dye containing ink jet ink, this work first optimized the dye dispersion formulation to obtain well-dispersed and storage stable preink, followed by studying effects of dye structure on the microemulsion region in the quasi-ternary phase diagram. The particle site in extremely purified disperse dye presscake should be reduced, and the dye well suspended and free of impurities to be capably incorporated into a microemulsion. Then, conditions for the maximization of water-solubility were identified as the basis for the ink preparation. Precisely speaking, the microemulsion of disperse dyes in this work was prepared by forming droplets of water, containing dye, suspended and stabilized in an appropriate mixture of cosurfactant and cosolvent. Finally, the preferred ink physicochemical properties were determined according to printability tests. In addition to the effect of dye structure, the particle size of dyes and the concentration of inks influenced printing consistency and the light stability.

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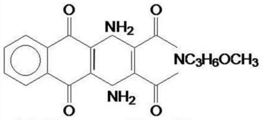
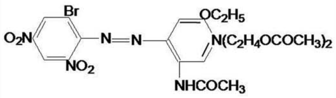
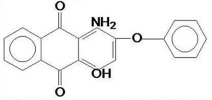
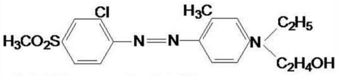
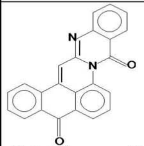
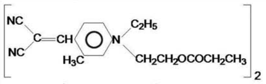
Table I. Preparations and particle sizes of stabilized disperse dye dispersions (dye content: 20%).

Structure of dyes	Dispersion formulation	Grinding time (hr) / Particle size (nm)	Viscosity (cps)	Surface tension (dyne/cm)
 C.I. Disperse Blue 60	<B60-a> D50 (4% wt.) /MT830L (3% wt.) / NL428 (0.5% wt.)	120 / 140.9	12.05	51.2
	<B60-b> PT 245L (4% wt.) / Triton X-100 (2% wt.) / NL428 (0.5% wt.)	168 / 164.4	12.91	50.8
 C.I. Disperse Blue 79	<B79-a> D50 (4% wt.) /MT830L (3% wt.) / NL428 (0.5% wt.)	120 / 104.1	13.93	56.5
	<B79-b> PT 245L (4% wt.) / Triton X-100 (3% wt.) / NL428 (0.5% wt.)	168 / 173.3	14.62	57.8
 C.I. Disperse Red 60	<R60-a> D50 (4% wt.) /MT830L (4% wt.) / NL428 (0.5% wt.)	120 / 53.2	8.02	53.1
	<R60-b> PT 245L (4% wt.) / Triton X-100 (3% wt.) / NL428 (0.5% wt.)	168 / 95.6	8.13	55.5
 C.I. Disperse Red 109	<R109-a> D50 (4% wt.) /MT830L (4% wt.) / NL428 (0.5% wt.)	120 / 103.8	7.36	52.7
	<R109-b> PT 245L (4% wt.) / Triton X-100 (3% wt.) / NL428 (0.5% wt.)	168 / 108.7	7.64	54.2
 C.I. Disperse Yellow 77	<Y77-a> D50 (4% wt.) /MT830L (1% wt.) / NL428 (0.1% wt.)	120 / 149.8	10.52	52.0
	<Y77-b> PT 245L (4% wt.) / Triton X-100 (3% wt.) / NL428 (0.2% wt.)	168 / 106.5	10.98	54.0
 C.I. Disperse Yellow 99	<Y99-a> D50 (4% wt.) /MT830L (1% wt.) / NL428 (0.1% wt.)	120 / 124.2	10.34	51.8
	<Y99-b> PT 245L (4% wt.) / Triton X-100 (3% wt.) / NL428 (0.2% wt.)	168 / 187.6	10.83	53.5

EXPERIMENTAL

Preparation of Dispersion of Disperse Dye

Disperse dyes in the form of presscake with high purity is a prerequisite in the ink formulation to ensure an accurate reaction system unaffected by side products of the synthesized dye. The dyes applicable for ink jet ink should be exhibited with neutral color shade and demonstrated dyeing fastness. In the interest of our investigation, we selected the dyes resembling the process colors in commercial ink jet printing and analyzed the effects of different dyes on the ink formulation. We selected C.I. Disperse Blue 60 (bright greenish blue, C.I. Constitution No. 61104, Widetex, Taiwan) for cyan by comparing to C.I. Disperse Blue 79 (dark reddish blue, C.I. Constitution No. 11345, Widetex, Taiwan), C.I. Disperse Red 60 (bright bluish red, C.I. Constitution No. 60756, Widetex, Taiwan) for magenta in contrast with C.I. Disperse Red 109 (bright yellowish red, C.I. Constitution No. 11192, Widetex, Taiwan), and C.I. Disperse Yellow 77 (bright greenish yellow, C.I. Constitution No. 70150, Widetex, Taiwan) for yellow by analogy with C.I. Disperse Yellow 99 (bright greenish yellow, C.I. Constitution No. 48420, Widetex, Taiwan). A combination of dispersants and wetting agents applicable for disperse dyes in ink formulation were divided into two systems of alkyl polynaphthalene formaldehyde sulfonate (D50, Pleasant and Best Chemical Co.) with the sodium salt of di-butyl naphthalene sulfonic acid (MT 830L, Pleasant and Best Chemical Co.), and maleic anhydride diisobutylene copolymer (PT 245L, Pleasant and Best Chemical Co.) with Triton X-100 (PerkinElmer). Those disperse dye dispersions with particles of small size, i.e., precursors of microemulsion, were prepared by grinding with a planetary micromill (Pulverisette 7″, Fritsch) where zirconium oxide grinding bowls and 0.5 mm beads were adopted to effectively degrade particle size. Each sample was ground at 400 rpm for different times to obtain the derived particle size. Then, the dispersion liquid was filtered to remove contamination, such as particles derived from unwanted wear of the grinding elements, and finally stabilized with an antiprecipitating agent, NL428 (Jintex Co., Taiwan). Preferred dye dispersing methods are listed in Table I, where systems have been optimized to achieve extraordinary stability when particle size dropped below 200 nm. Although such preink obtained was well dispersed and stable, its physicochemical properties did not meet the demands of ink jet printing and immediately clogged printing nozzles because of high dye content (20%), high surface tension (50–60 dyne/cm), and high viscosity (7–15 cps), whereas the relative values for thermal bubble ink jet inks were 3–10% of dye content, 20–40 dyne/cm surface tension,

Table II. Composition of disperse dye microemulsion (microemulsion system: Sinopol 80:Sinopol 963H:Pannox 140:Glycerin:Deionized water=2.4%:4.8%:7.2%: 26.4%:49.2%–54.2%).

Ink Number	Maximum Amount of Dye in Microemulsion (%)	Balanced Amount of Deionized Water (%)	Particle Size (nm)	Particle Size after Stability test (three cycles of 5 °C for 3 h and 70 °C for 3 h) (nm)
B60-am	8.0	50.2[a]	80.9	80.1
B60-bm	5.0	53.2[a]	129.7	131.4
B79-am	6.0	52.2[a]	88.6	88.1
B79-bm	6.0	52.2[a]	128.3	130.2
R60-am	10.0	49.2	49.5	48.5
R60-bm	8.0	51.2	89.5	91.6
R109-am	7.0	52.2	86.2	86.8
R109-bm	6.0	53.2	96.5	98.4
Y77-am	5.0	54.2	97.5	99.3
Y77-bm	10.0	49.2	99.6	98.7
Y99-am	8.0	51.2	83.8	84.2
Y99-bm	5.0	54.2	102.2	104.5

[a] The addition of 1% diethylene glycol monoethyl ether.

and 2–5 cps viscosity. The results of surface tension and viscosity were shown in Table I.

Determination of Microemulsion System

The microemulsions of disperse dyes were obtained by intensively mixing the dye dispersion with an emulsifier (Sinopol 963H, polyoxyethylene nonyl phenyl ether, HLB=12.0, Sino-Japan Chemical), a coemulsifier (Pannox 140, nonyl phenol polyethylene glycol ether, HLB=17.7, Pan Asia Chemical), a cosolvent (glycerin, Ferak), sorbitan oleate (Sinopol 80, HLB=4.3, Sino-Japan Chemical), and deionized water. The mixture was homogenized (1500 rpm for 10 min) to disperse the dye into very small emulsion droplets, whereby the microemulsion spontaneously formed. The system achieved its stability due to unique size compatibility and adhesion of the dye particles inside the oil phase of the microemulsion. Microemulsions of magenta and yellow dyes were thermodynamically stable for an indefinite period of time and an survive freezing and thawing cycles. However, the cyan dye samples were observed precipitating in the storage stability test (three cycles of 5°C for 3 h and 70°C for 3 h) whereas others did not. Despite the stabilization of microemulsion structure by coemulsifier, hydrotropic amphiphiles (Diethylene glycol monoethyl ether, Riedel–de Haen AG Seelze–Hannover) were needed for cyan dyes to surround each microemulsion droplet in order to prevent the microscopic droplets from coalescing. In order to determine the maximum amount of water content for each system, the quasiternary phase diagram was used to establish the largest microemulsion regime, where the ratios of emulsifier, coemulsifier, and cosolvent formed the upper region of the boundary between the total mass of dye phase, water phase, and emulsifiers. The optimized compositions for each dye microemulsion are summarized in Table II.


< B79-a > < R109-b > < B79-b >

Figure 1. Good dispersion of B79-a and R109-b in comparison to B79-b under an electronic microscope (Scope: 10×0.25).

Preparation of Disperse Dye Inks

The dye microemulsions met the viscosity requirements for thermal ink jet printing, i.e., 2–6 cps., measured by Brookfield, LVDV-III. However, other additives, e.g., fungicide and buffer solution (ammonium solution), employed in ink to optimize ink performance, decreased the viscosity without affecting other properties of the microemulsion. In general, the lower the viscosity the greater the velocity and amount of fluid propelled forward, which usually leads to the formation of long tails behind the head of the drop. Glycerin was therefore added additionally about 0.5–2 wt. % to restore the viscosity and optimize printing consistency. The characteristics of the inks were determined using a Horbita *p*H meter for *p*H measurement, Face CBVP-A3 for surface tension measurement, and ZetaPlus™ particle analyzer for particle size evaluation. Phase separation was determined by visual observation. The printing quality of line sharpness, edge acuity, successiveness, and nozzle clogging was evaluated by printing on a Lexmark Z43 printer on paper. The lightfastness of inks printed on fabric (100% polyester) was evaluated according to AATCC16-1998A.

RESULTS AND DISCUSSION

Effects of Disperse Dye on Dispersion Preparation

The effect of different disperse dyes on particle size were displayed in Table I. The dispersion formulations with D50/MT830L have revealed smaller particle size with shorter grinding time except for Y77-a. The samples thereof, B79-a and R109-a, achieved average particle size of <105 nm, and moreover, R60-a achieved the nanoparticle size of 53.2 nm, which might be due to D50, polynaphthalene formaldehyde sulfonate, having better wetting and deagglomeration than PT245L, maleic anhydride copolymer, under the mechanical force of micromilling. B79-b presented the largest particle size with agglomerates, indicating an unsuitable combination with PT245L/Triton X-100 (Figure 1), and then further failed to form microemulsion. By comparing B79-b to R109-b, more alkyl groups in the diazo structure decreased the efficiency of particle size reduction and consequently required more time or more active surfactants to accomplish the desired result. Among the systems of PT245L/Triton X-100, only the structure of Y77-b had more satisfactory compatibility with the copolymer allowing reduction in particle size to 106.5 nm in 120 h. The slight difference in

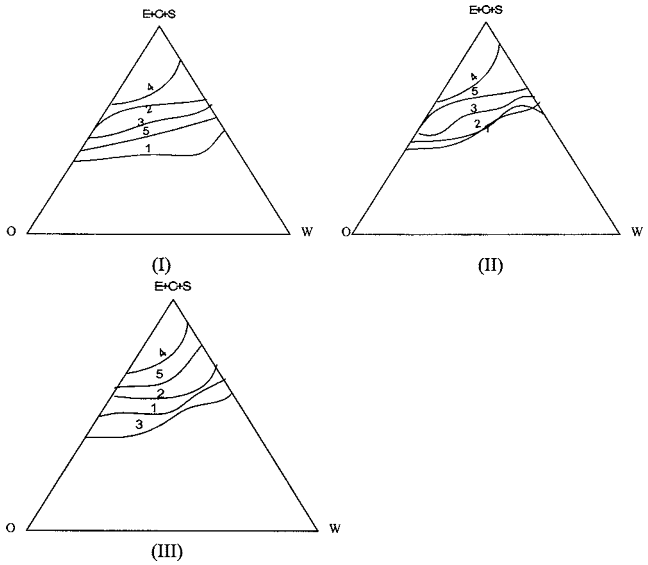


Figure 2. Quasi-ternary phase diagrams of the microemulsion systems, where E+C+S represents the total mass of emulsifier, coemulsifier and cosolvent, O is the mass of oil phase (Sinopol 80), and W is the mass of water. Lines 1–5 represent the ratio of emulsifier to coemulsifier and cosolvent (in mass) 2:3:11, 2:1:11, 3:2:11, 2:3:7, and 2:3:13. (I) is the system of Sinopol 963H (HLB=12.0)/Pannox 140 (HLB=17.7)/Glycerin. (II) is the system of Sinopol 960H (HLB=10.0)/Pannox 119 (HLB=15.8)/Glycerin. (III) is the system of Sinopol 966H (HLB=14.1)/Pannox 150 (HLB=18.0)/Glycerin.

Table III. The physicochemical properties of microemulsion based disperse dye inks.

Ink-Dye Content (%)	Surface Tension (dyne/cm)	Viscosity (cps)	*p*H Value	Particle size (nm)	Lightfastness (AATCC16-1998A)	Printabiliy (h)
B60-am-4	34.9	4.28	7.7	82.6	4	>8
B60-am-8	33.7	4.58	7.6	80.8	5	>8
R109-am-3.5	36.0	3.51	7.7	90.2	4	>8
R109-am-7	41.2	3.57	7.6	84.4	5	6
Y77-bm-5	41.4	5.80	7.3	90.7	5	>8
Y77-bm-10	41.1	3.96	7.3	95.5	4	6
Y99-am-5	41.5	4.50	7.5	82.9	4	>8
Y99-am-8	40.6	4.43	7.6	83.2	4	>8

particle-reducing results between the two dispersion systems at both 120 h and 168 h occurred in samples of C.I. Disperse Blue 60 and C.I. Disperse Red 109 probably due to lower molecular weight and reduced steric hindrance of the dye structures. The antiprecipitating additive, NL428 was found to successfully prevent reaggregation in both dispersing systems.

Determination of Disperse Dye Microemulsion System

The microemulsion system of Sorbitan trioleate/polyoxyethylene nonyl phenyl ether/nonylphenol polyethylene glycol ether/glycerin/water had been chosen by comparing to other compositions in the quasi-ternary phase diagrams at 25°C, shown in Figure 2. The experimental results shown in Table II indicated that the system had good compatibility with most dispersing systems and could be optimized to prepare the disperse dye inks of different colors. Figure 2 demonstrated that the microemulsion could be formed if the HLB values of emulsifiers lay between 10.0 and 18.0. The microemulsion area, formed in the upper region of the boundary line, depends on the ratios of emulsifier to coemulsifier and cosolvent. A maximum ratio was found as 2:3:11 and decreased in the following sequences: 2:1:11, 3:2:11, 2:3:7, and 2:3:13. When the cosolvent was the ratio of 11, additional emulsifier (emulsifier:coemulsifier=2:3) enlarged the microemulsion area more than those (emulsifier:coemulsifier=2:1) with the three different HLB value combination systems. However, more emulsifier of HLB value 14.1 than coemulsifier of HLB value 18.0 was required in system (III) to form the largest microemulsion area. It could be inferred that the emulsifiers of HLB values of 10.0 and 12.0 had more affinity to the oil phase and emulsified effectively at the lower ratio of 2 than the emulsifiers of HLB value 14.1, but required more coemulsifier of HLB value 15.8 to form the largest microemulsion area, i.e., maximum water dissolving capacity. When the ratio of emulsifier to coemulsifier was accordingly set at 2:3, the cosolvent at ratio of 13 increased water solubility more than at the ratio of 7, especially in the system (I), where the HLB value was 12.0 for emulsifier and 17.7 for coemulsifier. Nevertheless, the cosolvent at the ratio of 11 was most preferred to form the maximum water solubility in three systems. Relatively, the ratio of 2:3:11 (emulsifier:coemulsifier:cosolvent) in system (I) presented the largest microemulsion area among other two systems. The Sinopol 963H/Pannox 140/Sinopol 80/Glycerin microemulsion system had a maximum microemulsion area, implying maximum solubility. This ratio dependence indicated that the interfacial area generated by the emulsion drops can be expanded with the increased amount of coemulsifier and cosolvent. The maximum dye amount of each dispersion formulation dissolved in the given microemulsion system was determined by particle size variation (<2.5%) after the storage stability test, as shown in Table II. The resulting microemulsions were referred to as disperse dye inks, listed in Table III. In short, the composition corresponding to the maximum solubility was Dye:Sinopol 80:Sinopol 963H:Pannox 140:Glycerin:Deionized water=5%:2.4%:4.8%:7.2%:26.4%:54.2%.

Effects of Disperse Dye on Microemulsion System

In Table II, the maximum amount of disperse dyes in a given microemulsion system was determined as the amount at which 2.5% or larger variation of the particle size was detected after the storage stability test. The samples of B60-am, R60-am, R60-bm, Y77-bm, and Y99-am could be incorporated more effectively inside the microemulsion droplets to allow the highest dye content, up to 8–10%. Other samples imply the maintenance of at least 5% of the dye, and all the required ink properties can also be met. Notably, to avoid the dye agglomeration mentioned above, 1% amount of amphiphile (diethylene glycol monoethyl ether) was added into samples of B60-a, B60-b, B79-a, and B79-b. The particle

< B60-am-8% > < R109-am-7% > < Y77-bm-5% >

Figure 3. The printing quality of inks, B60-am-8%, R109-am-7%, and Y77-bm-5%, which were ink jet printed with Lexmark Z43 printer.

size of dispersed dye was further reduced in the microemulsion after ball milling. In the storage stability test, the particle size of B79-am and R60-am decreased further while the R109-am, B60-am, Y77-bm, and Y99-am did not change apparently (nearly 0%). It could be concluded from the above analyses that when the ratio of Sinopol 963H/Pannox 140/Sinopol 80/Glycerin was 2:3:1:11, the system of disperse dye/D50/MT830L/water maintained good stability when the temperature changed from 5°C to 70°C.

Effects of Ink Concentration on Physicochemical Properties

With the superiority in particle stability, the samples of R109-am, B60-am, Y77-bm, and Y99-am were selected for further study on the effect of ink concentration. Since the process color of light cyan and light magenta are usually formulated in half concentration of cyan and magenta, the concentration effect on lightfastness, particle size, and printability therefore becomes important. In this work, sample B60-am-8% was investigated with the concentration of 4%, while the sample R109-am-7% is investigated with the concentration of 3.5%. Y77-bm-10% and Y99-am-8% are performed with the lowest dye content of 5% in microemulsion according to the above analyses. To be applicable as inks for the thermal bubble ink jet printing, each dye microemulsion was formulated with the added fungicide, the buffer solution to stabilize *p*H value of the system, and a little glycerin (the cosolvent applied in the above microemulsion system) to optimize viscosity. The above agents could all be incorporated into formulations without disrupting microemulsion stability. The inks for thermal ink jet printing were produced with acceptable physicochemical properties, summarized in Table III. The surface tension and viscosity of each sample met the demands of ink drop performance, to enable efflux through the capillary tube of the printer nozzle on to be able to print continuously and present good printing quality, sharp line, and accurate edge, either on paper or polyester fabric, without nozzle clogging and edge feathering (Figure 3). However, the inks of R109-am-7% and Y77-bm-10% had printing continuity of <8 h, but it can be extended much longer when the dye content was reduced, e.g., R109-am-3.5% and Y77-bm-5%. By comparing the particle size to other samples, the structure or formulation of R109-am-7% would not tolerate the temperature or vibration variation inside the thermal bubble printhead. The failure of Y77-bm-10%, however, could be attributed to the largest particle size causing inferior printability. The samples of B60-am-4% and R109-am-3.5% exhibited an increase in particle size and a slight decrease in lightfastness when the concentration was diluted in half. This implies that excessive amount of surfactant and solvent breaks up the microemulsion system and induces the primary particles to generate larger particles, i.e., agglomerates. Moreover, the greater amount of small dye particles on the medium surface would reflect more light and protect prevent the printed fabric from the effects of light exposure. Such particle effects are also seen in the yellow samples, although the differences are insignificant. The anthraquinone dyes performed better in lightfastness than the diazo ones, and their lightfastness grade can reach 5 by decreasing the particle size. No formulation in Table III performs less than grade 4, which demonstrates that all the formulated inks meet the requirement of light stability for thermal bubble ink jet printing.

Table IV. The water fastness of microemulsion based disperse dye inks.

	Water-fastness Test (AATCC-61-2003-2A)		
Ink-Dye Content (%)	Color Change	Staining on Cotton Fiber	Staining on Acrylic Fiber
B60-am-4	5	5	5
B60-am-8	5	5	5
R109-am-3.5	5	5	5
R109-am-7	5	5	5
Y77-bm-5	5	5	5
Y77-bm-10	5	5	5
Y99-am-5	5	5	5
Y99-am-8	5	5	5

The water fastness of each sample in Table IV was identically at grade 5, according to AATCC-61-2003-2A. There was no color change in shade and no staining on cotton and acrylic fiber. The cotton and acrylic fiber are usually easily stained by all kinds of dyes in the water-fastness test. It could be inferred that the microemulsion ink drops containing dyes (from 3.5% to 10%) were jetted on demand by the thermal bubble ink jet nozzle and fixed well on the polyester filament. Excessive dye that could be carried away by water did not occur on the fiber surface. Moreover, those dye particle sizes in the range between 80 nm and 96 nm did not affect the fastness to the fiber in water but slightly in the light. The high water fastness is thus another advantage of the studied microemulsion ink for the application of textile ink jet printing.

In the future, more systematic study of ink rheology in the dyestuff ink jet printability will be carried out to investigate the relationship between dye structure, ink composition and fluid viscoelasticity during ink jet printing.

CONCLUSIONS

The microemulsion system of Sinopol 80/Sinopol 963H/Pannox 140/Glycerin/Deionized water was determined to be compatible with the best dispersing composition of disperse dyes and exhibited excellent behavior in the quasi-ternary phase diagrams. It can be concluded that only C.I. Disperse

Yellow 77 had better compatibility with other ingredients to achieve printability of more than 8 h and lightfastness of grade 5. Moreover, the samples of B60-am, R109-am, Y77-bm, and Y99-am in the given microemulsion presented best stability without particle size variation in the storage stability test. Nevertheless, the samples of B79-am and R60-am demonstrated slightly decreased particle size in the microemulsion.

After the microemulsions were formulated into inks, the samples of R109-am-7% and Y77-bm-10% could not be printed with thermal bubble ink jet for more than 8 h, which is probably due to poor heat resistance of diazo structure or larger particle clogging in the nozzle after the ink has been frequently heated in the thermal bubble print head. When the ink concentration was diluted in half, B60-am-4% and R109-am-3.5% exhibited a particle size increase and slight decrease in lightfastness, which is due to the generation of agglomerates in the unbalanced system with higher amounts of surfactants and solvent. Notably, it was found that anthraquinone dyes yield higher lightfastness than diazo dyes to attain the lightfastness grade of 5.

The microemulsion inks of this study had many advantages over other inks containing just the dye dispersions. One advantage was that microemulsion ink was a microheterogeneous system that provided a large interfacial area to accommodate dye content up to 8–10% and low viscosity to effectively meet the demand of ink drop performance without adding other viscosity modifiers. Another advantage was that microemulsion inks produced printed dot sizes that were nearly independent of the surface properties of the medium; they could present good printing quality either on paper or 100% polyester fabric without nozzle clogging and edge feathering. The most important advantage was that dyes in the given microemulsion exhibited smaller particle size than in dispersion formulations and, thereby, good storage stability with very little particle size variation.

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