Interaction between Acid Dyes and Surfactants in Inkjet Ink for Textiles

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1. INTRODUCTION

Recently, various inkjet ink for textiles has been developed, but more improvement of the ink is necessary. For example, the fixing ratio of dyes for textiles and the color fastness to washing, sweat, and light is found to be low, even though vivid color can be shown.

The inkjet ink composition is very complicated due to the complex nature and very challenging requirements of inkjet inks. The ink must have physicochemical properties which are specific to the various printing devices [1]. To formulate inkjet ink, not only dyes or pigments but also additives are needed and the types and amounts of additives are the most important factors.

Commonly, the additives are added to the ink to adjust pysical properties of ink such as viscosity, surface tension, droplet form and so on [2]. Also various types of additives such as surfactants and inorganic salts have been used in the inkjet ink for textiles in order to solve the other problems which occur in printing processes [3].

Moreover, the additives affect the improvement of fastness properties, color strength, dye fixation and ink penetration. For example, the surfactants in inkjet ink are used to adsorb the colorants uniformly on the surface of the textile after the printing, and improve the permeability of the ink and can penetrate into the textiles in a short time. Furthermore, the nonionic surfactant is effective in improving level dyeing ability and in preventing feathering or bleeding [4]. Therefore, the study on the additives is worthwhile to improve the inkjet ink.

In the present study, the additives used to formulate the inkjet ink for textiles were investigated. Especially, the interaction between dyes and additives such as surfactants were investigated.

To investigate the binding of three acid dyes (C. I. Acid Red 88, 13, and 27) with sodium dodecyl sulfate (SDS), octaethylene glycol monododecyl ether (OGDE), and surfynol 465, the visible absorption spectra of aqueous dye solutions in the absence and presence of the surfactants were measured.

2. EXPERIMENTAL

Materials

Three acid dyes containing the different number of sulfonate groups, C. I. Acid Red 88 (R-1), C. I. Acid Red 13 (R-2), and C. I. Acid Red 27 (R-3) were used after purification. As the additives, an anionic surfactant, sodium dodecyl sulphate (SDS) and nonionic surfactants, octaethylene glycol mono-dodecyl ether (OGDE) and surfynol 465 (S465) (Fig.1) were used without further purification.

Visible absorption spectrum measurements

The visible absorption spectra of aqueous solutions having various surfactants concentrations and a constant dye concentration (R-1, 2.97×10^{-5} mol dm^{-3}; R-2, 2.81×10^{-5} mol dm^{-3}; R-3, 2.83×10^{-5} mol dm^{-3}) were recorded using a JASCO UV-530 spectrophotometer at 15, 25, 35 and 45 °C.
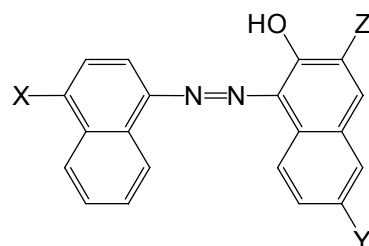
R-1: X = SO$_3$Na, Y = H, Z = H
R-2: X = SO$_3$Na, Y = SO$_3$Na, Z = H
R-3: X = SO$_3$Na, Y = SO$_3$Na, Z = SO$_3$Na
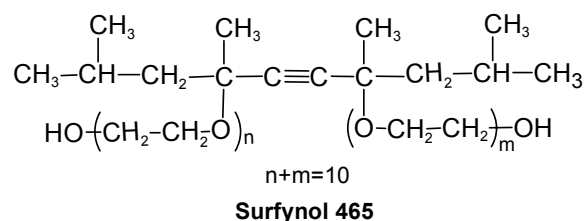
Dyes

n+m=10
Surfynol 465

Fig. 1. Chemical structure of three acid dyes and Surfynol 465.

3. RESULTS AND DISCUSSION

As shown in Fig. 2, the extinction coefficients for the dyes at the wavelength where the largest difference was observed decreased with increasing surfactant concentration for all the dye/surfactant systems except R-3/SDS system. This indicates that the dyes bind with the surfactant micelles in the aqueous solutions. In the case of R-3/SDS system, the extinction coefficients hardly changed in the presence of SDS, suggesting that R-3 does not interact with the SDS micelle owing to its water solubility and the electrostatic repulsion.

The K_{bind}^{Surf} values determined for all the dyes with surfactants are shown in Fig. 3 as van't Hoff plots (the plots of ln K_{bind}^{surf} against the reciprocal of temperature). The K_{bind}^{Surf} values decreased in the order of R-1 > R-2 > R-3 at every temperature, which is comparable to the order of the number of sulfonate groups. It is worthwhile to mention that the introduction of sulfonate groups into the dye molecule increases the solubility in water, i.e. the solubility increases in the order of R-1 < R-2 < R-3, which corresponds to the decreasing order of $K_{bind}^{Surf.}$. This means that the binding affinity to all the surfactants decreases with increasing water solubility. Thus the hydrophobicity (water solubility) is one of the most important factors in the binding process of the dyes with surfactant micelle.

As van't Hoff plots gave good linearity, the enthalpy change, ΔH_{bind}^{surf}, and the entropy change, ΔS_{bind}^{surf}, were calculated from the slope and intercept of these plots, respectively. The ΔH_{bind}^{PVP} values for all the dyes with SDS and OGDE were negative, showing that the binding processes are exothermic. However, in the case of the ΔH_{bind}^{PVP} values for all the dyes with S465 were positive, showing that the binding processes are endothermic.

Furthermore, the increasing in the number of sulfonate groups of the dyes for the binding with
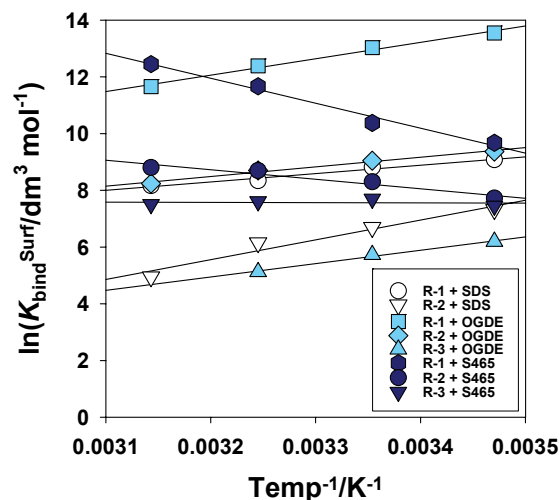

Fig. 3. Van't Hoff plot (ln Kbind^Surf vs. 1/T) for the three dyes with surfactants.

SDS made the binding reaction more enthalpic and less entropic, whereas in the case of OGDE the opposite results were obtained.

4. ACKNOWLEDGEMENTS

5. REFERENCES

[1] S. Magdassi; "The chemistry of inkjet inks", (S. Magdassi, Ed.), World Scientific, Ltd., 2008.
[2] J. S. Bae, Y. A. Son; *J. of Res. Ins. of Industrial Technology*. **21(1)**, 33 (2006)
[3] Y. Ikutani; *Dyeing Industry*. **38**, 200 (1990)
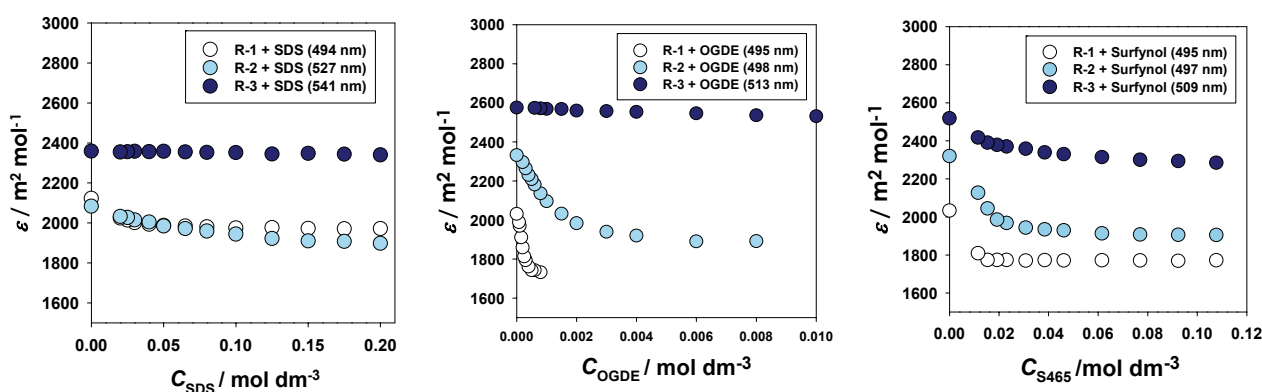[4] P. Gregory; *Optics & Laser Technology*, **38,** 306 -314 (2006).

Fig. 2. Dependence of ε on SDS, OGDE, and S465 concentration at 25 °C.