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Printing properties of the red reactive dyes with different number sulfonate groups on cotton fabric

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ABSTRACT

Cellulose fabric is an important printing substrate. Four red azo reactive dyes based on 1-naphthol-8-amino-3,6-disulfonic acid for cotton fabric printing were designed. Their UV–Vis spectra and printing properties for cotton were investigated. The relationship between the chemical structures of the dyes and their printing properties on cotton fabric was discussed. The results show that the color yield (*K*/*S*) values of the printed fabrics decreased with the increase of sulfonate groups, but the fixation and penetration of the reactive dyes on cotton fabric increased. The reactive dyes with fewer number sulfonate groups were sensitive to alkaline and urea. Whereas, the reactive dyes with numerous sulfonate groups were not sensitive to urea and had good leveling properties, penetration uniformity, and good wet fastness for cotton fabric. Surface wettability of all cotton fabrics printed with four dyes was excellent. It is possible to print cotton fabric urea-free using the reactive dyes with numerous sulfonate groups.

1. Introduction

Cellulose fabric is one of the excellent natural materials and it is the most commonly printed substrate. Printed fabrics have wide applications in the different productions, such as garment, home textile, and composite materials (Hou & Sun, 2013; Jung, Wolters, & Berlin, 2007; Xie, Gao, & Zhang, 2013). Reactive dyes, mainly monochloro-triazine reactive dyes, is one kind of the most commonly used dyes for cellulose fabric printing because of its high wet fastness and brilliant color (Hebeish, Ragheb, Nassar, Allam, & Abd El Thalouth, 2006; Kanik & Hauser, 2003; Lewis, 2001). Reactive dyes for printing cotton must exhibit the properties, such as high solubility, low affinity, high diffusion and high printing paste stability. Red color for printing fabric is one of the most important color hues. Reactive Red K-2BP (C. I. Reactive Red 24) is an important commercial red reactive dye for cotton fabric printing in the dyestuff market.

Reactive Red K-2BP is derived from 1-naphthol-8-amino-3,6-disulfonic acid (H-acid) as the coupling component. The chemical structure has monochloro-triazine reactive group. The monochloro-triazine reactive group can react with cellulose fiber under the alkaline condition. It is widely used to print cellulose fabric and can be applied to match color as the red component in the reactive black dyes (El-Shishtawy, Nassar, & Ahmed, 2007; Nateri & Ekrami, 2010; Shams-Nateri, 2010). However, there are some problems in the practical application for cellulose fabric. Its solubility and diffusion in the printing paste is not satisfactory (Chen, 2006; Kantouch, Kantouch, & El-Sayed, 2006; Xie, Liu, & Wang, 2009). Deep red color in the high dye concentration for printing fabric may pose quality problem. Meantime, the fixation yield of Reactive Red K-2BP on cotton material is only about 70–80%. Furthermore, unfixed reactive dyes in wastewater may pose an environmental hazard (Hamaky, Tawfeek, Ibrahim, Maamoun, & Gaber, 2007; Kanik & Hauser, 2002; Wang & Wu, 2009).

In this paper, four red reactive dyes with different number sulfonate groups based on 1-naphthol-8-amino-3,6-disulfonic acid were synthesized. Their chemical structures and printing properties for cotton fabric were investigated and compared.

2. Experimental

2.1. Materials

1-Naphthol-8-amino-3,6-disulfonic acid (H-acid), 2-sulfonic acid aniline, and trichlorotriazine were obtained from Wujiang Taoyuan Chemical Company, Suzhou, China. Desized, scoured and bleached cotton fabric, weight 230 g/m^2, was obtained from Shaoxing Jinqiu Textile Company, Shaoxing, China. Other chemicals used were obtained from Shanghai Chemical Reagent Plant, Shanghai, China.

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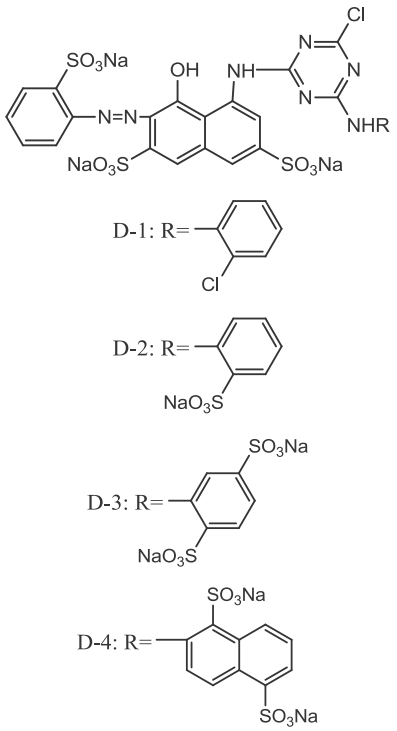

Scheme 1. Chemical structures of the designed red reactive dyes.

2.2. Synthesis of the reactive dyes

Chemical structures of the designed red reactive dyes with different number sulfonate groups are shown in Scheme 1.

First, H-acid reacted with trichlorotriazine at 0–5 °C, pH 2–3. Then the substituted product containing dichlorotriazine group was used as coupling ingredient. The diazotization and coupling reaction were carried out in the similar way as described in the previous study (Wang & Wu, 2009; Xie, Liu, & Li, 2007a). The obtained azo dyes containing dichlorotriazine as the intermediate further reacted with aniline derivates (Xie et al., 2007a; Xie, Liu, & Li, 2007b). The synthesized red reactive dyes based on different substituted compounds, 2-choloro-aniline, 2-sulfonic acid aniline, 2,5-disulfonic acid aniline, or 1,5-disulfonic acid-2-amino-naphthalene, were named as D-1, D-2, D-3, D-4, respectively. The purification was achieved by recrystallization with alcohol, and then dried. FTIR spectrum of the dyes was measured by a OMNI 98 Sampler of the Nexus-670 FTIR-Raman Spectrometer (Nicolet Analytical Instruments, Madison, WI). ^{1}H NMR spectrum was recorded on a Bruker Avance 400 (Bruker Co., Faellanden, Switzerland).

D-1: The yield was 91% and λ_{max} being 534 nm. IR (KBr, cm^{-1}): 3377, 2148, 1572, 1645, 1598, 1558, 1491, 1432, 1390, 1324, 1139, 1046, 993, 791, 753; ^{1}H NMR (D_2O, δ_H, ppm): 8.96 (s, H, —OH), 8.58(s, H, —NH), 8.14(s, H, —NH), 8.06–8.16 (m, 3H, H of naphthalene), 6.97–7.29 (m, 7H, Ar–H), 7.50–7.79 (m, 2H, Ar–H).

D-2: The yield was 87% and λ_{max} being 533 nm. IR (KBr, cm^{-1}): 3342, 2341, 2100, 1786, 1648, 1566, 1485, 1437, 1354, 1327, 1214, 1090, 1049 994, 797; ^{1}H NMR (D_2O, δ_H, ppm): 9.37 (s, H, —OH), 8.78(m, 2H, —NH), 7.89–8.06 (m, 3H, H of naphthalene), 7.08–7.40 (m, 7H, Ar–H), 7.55–7.89 (m, 2H, Ar–H).

D-3: The yield was 89% and λ_{max} being 533 nm. IR (KBr, cm^{-1}): 3372, 2259, 2094, 1670, 1545, 1485, 1325, 1250, 1122, 1056, 978, 800, 624; ^{1}H NMR (D_2O, δ_H, ppm): 9.17 (s, H, —OH), 8.24–8.25(m, H, —NH), 8.01–8.07 (m, 3H, H of naphthalene), 7.28–7.57 (m, 7H, Ar–H), 7.58–7.97 (m, 2H, Ar–H).

D-4: The yield was 84% and λ_{max} being 532 nm. IR (KBr, cm^{-1}): 3303, 2263, 2097, 1794, 1647, 1555, 1485, 1383, 1324, 1246, 1046, 978, 800, 764; ^{1}H NMR (D_2O, δ_H, ppm): 9.07 (s, H, —OH), 8.77–8.98(m, H, —NH), 8.08–8.13 (m, 3H, H of naphthalene), 7.16–7.46 (m, 7H, Ar–H), 7.66–7.99 (m, 2H, Ar–H).

2.3. Preparation of the printing paste

The printing paste of the reactive dyes was prepared according to the following recipe: sodium alginate 60 g, reactive dye 80 g, resists salt (sodium 3-nitrobenzenesulfonate) 10 g, urea 50 g, a certain amount of sodium bicarbonate and water, for a total recipe of 1000 g.

2.4. Printing technique

A screen printing technique according to the previous described method was applied to cotton fabric (Xie et al., 2009). The fixation of the printed samples was carried out by steaming using an automatic thermostatic oven, Mathis CH-8156 (Wenner Mathis Co., Switzerland). Steaming was conducted at 102–105 °C for 12 min.

The printed fabrics were washed according to the following washing procedure: cold rinsing 5 min at 20 °C; warm washing 5 min at 40 °C; hot washing 10 min at 85 °C with the addition of nonionic surfactant OP-10, 1 g/l; warm washing 5 min and neutralizing at 40 °C with the addition of acetic acid, 0.5 g/l; and cold rinsing 5 min at 20 °C. The liquor ratio was 1:10 for the entire washing procedure. The washed samples were dried.

In order to determine the extent of dye fixation, the printed fabrics after washing were further extracted with aqueous solution of 50% DMF at 100 °C for 15 min and then rinsed with water and dried.

2.5. Color yield analysis

The color yield (K/S) of the printed fabric was determined by Datacolor SP600$^+$ spectrophotometer (Datacolor, Switzerland). The tristimulus values X, Y and Z of the samples were measured under illuminant D_{65} using the 10° standard observer in the spectrum visible region 360–700 nm. The color parameters L, a, b, were calculated. The reflectance at the wavelength of maximum absorption (λ_{max}) was used to calculate the color yield of the printed fabrics by the Kubelka-Munk Equation (Eq. (1)).

$$\frac{K}{S} = \frac{(1-R)^2}{2R} \quad (1)$$

where K is the absorption coefficient of the substrate, S is the scattering coefficient of the substrate and R is the reflectance of the printed fabric at λ_{max}.

2.6. Measurements of dye fixation and penetration

The extent of reactive dye fixation (F%) was determined and calculated using Eq. (2) (Ahmed, Youssef, El-Shishtawy, & Mousa, 2006). The method assumes that K/S value is proportional to the concentration of dye on fabric at the dye concentration employed.

$$F\% = \frac{(K/S)\ \text{after}_{DMF}}{(K/S)\ \text{after}_{soaping}} \times 100\% \quad (2)$$

where K/S after$_{soaping}$ and K/S after$_{DMF}$ are the K/S values of the printed fabrics before and after extracted with aqueous solution of 50% DMF, respectively.