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Effects of Polyols Solvents on Rheological Properties of Reactive Dye Inks for Textile Digital Inkjet Printing

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Abstract

Reactive dye inks are the basic consumables for textile digital inkjet printing and the definition of the printed patterns depends on their rheological property. In this research, the influence rules of polyols solvents on rheological behaviors of reactive dye inks were investigated in detail. The reactive dye inks were characterized in terms of dynamic surface tensions and viscosities. Results showed that the surface tensions of inks were affected greatly by the position of hydroxyl groups in polyols solvent molecules and their carbon chain length. The viscosities were influenced obviously by the Van der Waals forces and hydrogen bond forces among the ingredients of reactive dye inks.

Introduction

Digital inkjet printing technology is one of the key technologies of the textile industrial in the 21st century, due to its unparalleled advantages of high pattern resolution, simplified process flow, energy conservation, and environment protection [1,2]. The drop-on-demand (DOD) inkjet is most commonly used mode for textile printing application. Through this method, colorant ink droplets with the volume of 5~10 pL were precisely deposited on the surface of textiles [3]. Their rheological behaviors are closely related to the ink-jetting property and the droplet morphology [4,5], which determines the pattern resolution. Reactive dye inks are the basic consumables for cotton textile digital inkjet printing [6-8]. As the main ingredient of reactive dye inks, the polyol organic solvent accounts for 40%-60% in reactive dye inks. They usually function as moisturizer and viscosity modifier. But few researches were reported on the influence mechanism of polyol solvent on rheological properties. Through this research we hope to explore the influence rules of polyol solvents on the rheological behavior of reactive dye inks.

Experimental section

Materials

Ethylene glycol, 1,3-propanediol, 1,4-butanediol, 1,3-butanediol, and 2,3-butanediol were purchased from the Sinopharm Chemical Reagent Co., Ltd. All of the above chemicals were of analytical pure grade and used without further purification. Reactive blue 49 dye was obtained from Everlight Chemical Industrial Corporation, Taiwan. All the aqueous solutions were prepared with redistilled water.

Preparation of reactive dye inks

A certain amount of polyol agents were dissolved in the redistilled water. Then the reactive blue 49 dyes were dissolved in the mixed solvent of polyol and redistilled water. After being stirred for 120 min, the reactive dye inks were formed. For comparison, five different polyols including ethylene glycol, 1,3-propanediol, 1,4-butanediol, 1,3-butanediol, and 2,3-butanediol were chosen to be the organic agents. For all reactive dye ink samples, the concentration of reactive dyes were 80g/L and the concentration of polyols were 1 mol/L, 2 mol/L, 3mol/L, and 4 mol/L.

Characterization

The dynamic surface tensions of the reactive dye inks were detected on a bubble pressure tensiometer (T60, SITA, Germany). The viscosities of different samples were tested using a programmable rheometer (DV-III Ultra, Brookfield, USA).

Results and discussion

To investigate the effects of polyol on rheological properties of inks, five different dihydric alcohols including ethylene glycol, 1,3-propanediol, 1,4-butanediol, 1,3-butanediol, and 2,3-butanediol were used as organic solvents to prepared reactive dye inks. The chemical structure of dihydric alcohols were listed in Fig 1. Viscosity and surface tension, the critical parameters for rheological properties, were carefully tested as the main analyzing basis for reactive dye inks.

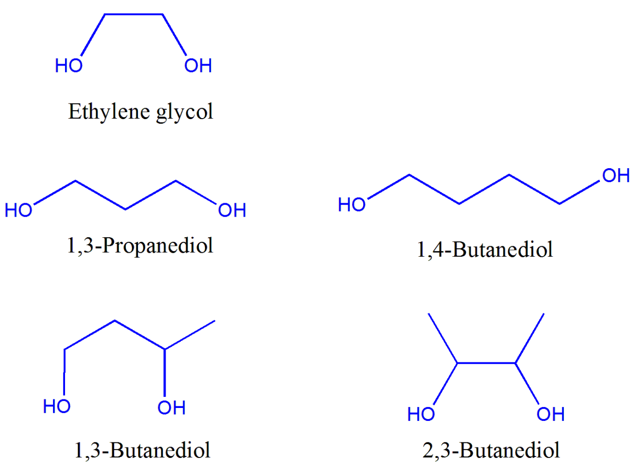

Figure 1. *The chemical structures of polyol agents used for reactive dye inks.*

The effects of the position of hydroxyl groups in polyol molecules on the rheological properties

We chose three butanediols with different hydroxyl group positions to investigate their effects on the rheological properties of inks. The dynamic surface tensions of different reactive dye inks are shown in Fig 2. The surface tension of all samples decreased as the bubble lifetime extended. This is because the butanediol molecules have certain surface activity. They transferred gradually from the inside of inks to the bubble interfaces and functioned as surfactants to low the surface tension. The methyl and hydroxyl in butanediol molecules have hydrophobicity and hydrophilicity, separately. When the hydroxyl groups were located in the middle position of the carbon chain, the butanediol molecules have more obvious hydrophilic and hydrophobic end. 2,3-butanediol exhibit the strongest surface activity and 1,4-butanediol has the weakest surface activity. Therefore, the reactive dye ink containing 2,3-butanediol showed the minimum surface tension. The viscosities of the reactive dye inks with different organic solvent concentration are shown in Fig 3. Due to the same molecular weight, there's no significant difference in their viscosities at low concentrations of butanediol. When the concentration was above 2 mol/L, the viscosity difference of the different inks appeared. The reactive dye inks containing 2,3-butanediol had the highest viscosity, while the sample prepared with 1,4-butanediol exhibited the lowest viscosity. There are two reasons for this results. On the one hand, it's easier for 2,3-butanediol and 1,3-butanediol to form intermolecular hydrogen bonds and the intramolecular hydrogen bonds between butanediol and water molecules were weakened. On the other hand, the two methyl groups in 2,3-butanediol caused stronger hydrophobic interactions among these organic molecules resulting in higher viscosity of reactive dye inks.

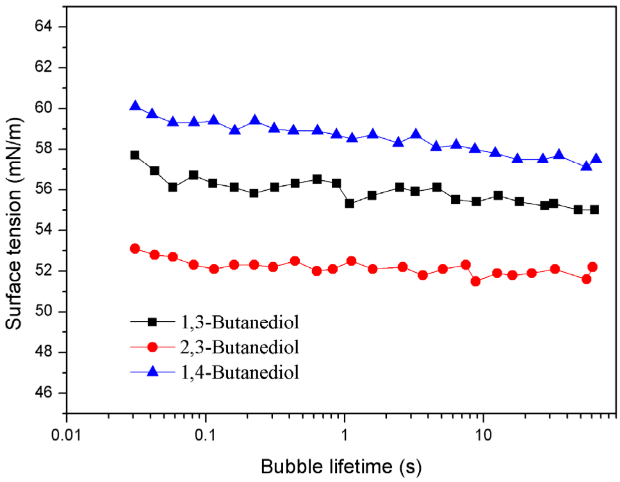

***Figure 2**. The surface tensions of reactive dye inks prepared with three different butanediol including 1,3-butanediol (2 mol/L), 2,3-butanediol (2 mol/L), and 1,4-butanediol (2 mol/L).*

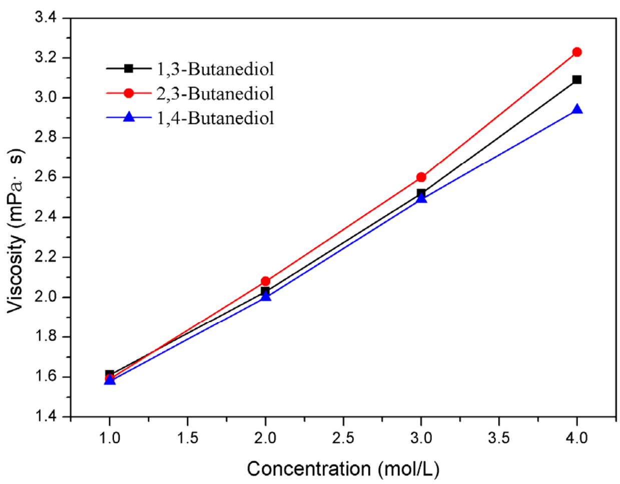

***Figure 3**. The viscosities of reactive dye inks prepared with three different butanediol including 1,3-butanediol, 2,3-butanediol, and 1,4-butanediol.*

The effects of the carbon chain length of polyol organic solvents on the rheological properties

Besides the position of hydroxyl groups, the carbon chain length of polyol organic solvent is also an important factor for rheological properties of inks. Three dihydric alcohol, ethylene glycol, 1,3-propanediol, and 1,4-butanediol were chosen to investigate the effects of carbon chain length. The surface tensions of reactive dye inks are shown in Fig 4. The surface tensions of inks declined with the increase of carbon chain length in dihydric alcohol molecules from ethylene glycol, 1,3-propanediol to 1,4-butanediol. For ethylene glycol and 1,3-propanediol samples, the surface tensions had no remarkable changes as the bubble lifetimes extended. By comparison, the surface tension of inks prepared with 1,4-butanediol decreased gradually along with the extending of bubble lifetime. These results can be attributed to the differences of chemical structure among the dihydric alcohols. The ethylene glycol molecule without obvious hydrophobic structure has no surface activity, resulting in high surface tension. In contrast, 1,4-butanediol has hydrophobic and hydrophilic groups and exhibits surface activity. They can absorb at interface to low the surface tension of reactive dye inks. The viscosities of reactive dye inks containing three different dihydric alcohol were listed in Fig 5. It showed that the viscosities increased greatly with the increase of carbon chain length in dihydric alcohol molecules. The main reason is that the higher molecular weights lead to the stronger intermolecular forces, which make the higher viscosities.

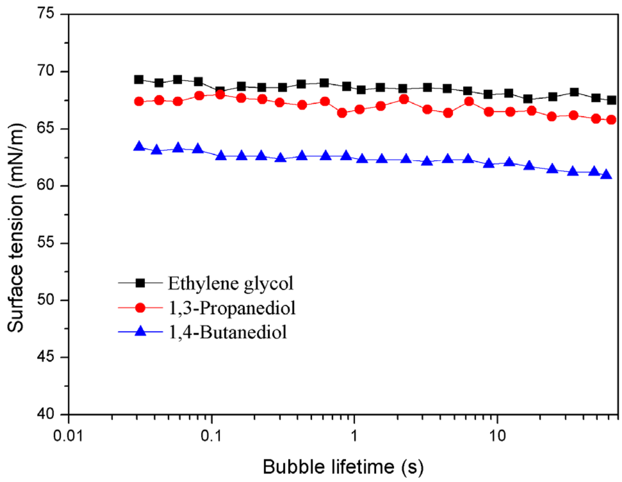

***Figure 4**. The surface tensions of reactive dye inks prepared with three different dihydric alcohol including ethylene glycol (1 mol/L), 1,3-propanediol (1 mol/L), and 1,4-butanediol (1 mol/L).*

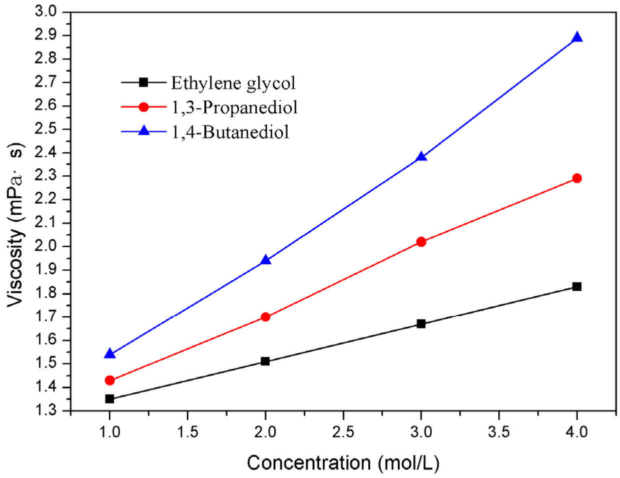

Figure 5. *The viscosities of reactive dye inks prepared with three different dihydric alcohol including ethylene glycol, 1,3-propanediol, and 1,4-butanediol.*

Conclusions

The results indicated that the molecular structure of polyols have obvious effects on the rheological properties of reactive dye inks. When hydroxyl groups are located in the middle of carbon chain, dihydric alcohol molecules exhibit better surface activity and can low the surface tension of inks. The position of hydroxyl groups have no significant influence on viscosities of inks at low concentration of dihydric alcohol. For the dihydric alcohol with hydroxyl groups at both ends, the longer carbon chain makes surface tension of inks lower. Meanwhile the dihydric alcohols with relatively long carbon chain can result in high viscosity than those with short carbon chain due to the stronger intermolecular forces. When preparing reactive dye inks, we can choose the appropriate solvent to adjust the rheological behavior to achieve the best printing effects.

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