

Study on color ink-jet printing paper coating with nano-SiO₂ as pigment

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Abstract. With many years of research, color ink-jet printing technology has reached the requirements of color ink-jet printing. The significance of this experiment is to find a suitable method to improve the quality of color ink-jet printing paper. In this work, the dispersion effect and types of sodium polyacrylate (PAAS) on nano-SiO₂ solution are discussed, and the most suitable PAAS dosage is selected. When the dosage of PAAS is 8%, the dispersibility of nano-SiO₂ solution is much better, with an average color density of 1.60, a gloss of 59% and an ink absorption value of 10.2 cm. Adhesives also have a great influence on color ink-jet printing paper. When the amount of PVA is 30% of nano-SiO₂, the average color density is 1.62. Glossiness and ink absorption are also the best.

1 INTRODUCTION

With the rapid development and popularization of ink-jet printers, scanners and digital cameras, ink-jet printing, as one of the important ways of image and text output, has become more and more popular among customers due to its low price and high quality printing. As a result, ink-jet printing paper, which is used in conjunction with it, has developed rapidly and its demand has doubled. Ink-jet printing paper is a special paper used to print exquisite and high-quality pictures by coating a layer of porous ink-absorbing pigments on the surface of base paper to form a good ink acceptance layer on the surface of paper to meet the requirements of color ink-jet printing^[1].

As we all known, ordinary ink-jet printing paper, namely uncoated paper, has very poor ink absorbency. When printing, the ink diffuses quickly, the ink droplets are big, the image is rough, there is no sense of hierarchy, the clarity is poor, the drying speed is slow, the density is low, and the water resistance is not good. The color ink-jet printing paper is a special processed paper coated. This coating can not only absorb water-based ink quickly, but also ensure the non-proliferation of ink^[2]. This coating can prevent ink from penetrating too deep and too fast, and can also control the diffusion degree and width of ink particles, and separate water-soluble organic dyes from water carriers, leaving pigments on the surface without penetration, thus reducing capillary phenomena, wrinkling and color migration phenomena, thus greatly improving printing. The resolution and clarity of the image are very high^[3]. At the same time, it can also improve printing efficiency and speed up the drying of paper ink.

The coating of color spray paper is mainly composed of nano-scale pigments, adhesives, water retaining agents, fixing agents, dispersants, fluorescent whitening agents and defoamers^[4]. The main pigment of color ink-jet paper is nano-SiO₂^[5]. Although silicon dioxide has a series of excellent properties, nano-SiO₂ tends to be aggregated, which greatly affects its performance and application. The agglomeration of nano-SiO₂ is due to the large surface area and high surface energy of nano-SiO₂. Because of the easy agglomeration between nano-SiO₂, the nano-SiO₂ will still be reunited after dispersion, and it is difficult to form stable dispersion solution^[6]. Therefore, improving the dispersibility of in aqueous solution has become the key to the preparation of nano-SiO₂.

2 MATERIALS AND METHODS

2.1 Raw materials

An uncoated film (Printing paper) produced by Anne Ltd., China, was used as substrate for the coating. Its thickness was 150 μm. Nano-SiO₂ (as pigment) was a production of Hong Li Long Chemical Co. Ltd., China. The average particle size was in the 15~40 nm. PAAS (as dispersant) was obtained from TA Mao Chemical Co., Ltd., China. PVA-1799 (as binder) was obtained from Changchun Chemical Factory, China.

2.2 Preparation of coatings

2.2.1 Pigment dispersing

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The dispersing concentration of pigment used in this experiment was 8%. The nano-SiO₂ and dispersant were added to the beaker and stirred with glass rods. The pigment dispersion was dispersed with ultrasonic wave pulverizing apparatus or a high-speed dispersing machine. The dispersed pigment was a stable semi-transparent emulsion.

2.2.2 Preparation of adhesives

The adhesive concentration used in this experiment is 8%. 30 g PVA-1799 was dispersed in 345 g water and were placed in 60 °C thermostat water bath, magnetically stirred for 1 h, flowed by heating at 90 °C until a completely transparent solution was obtained. Subsequently, the mixer was slowly opened and the temperature was raised to for thermal insulation. The stirring speed could be properly increased. xx mL defoamer was added to remove bubbles in the solution. After cooling the solution, evaporated water was added to ensure the concentration of PVA solutions..

2.2.3 Dispersion of paints

The pigment and adhesive were mixed in a certain proportion, then the container was placed under the high speed dispersion and the high speed dispersion was slowly opened. Then carboxymethyl cellulose, defoamer and cationic fixing agent were added in turn, and the dispersing time was about 30 min.

2.3 Characterization

2.3.1 Dispersion

For nano-SiO₂ which remain stable in water, it is difficult to characterize the dispersion effect by conventional static precipitation. Ultraviolet spectrophotometer is used to determine the absorbance of suspension under certain wavelength incident light, which was employed to characterize the dispersion of suspension. The relationship between absorbance and particle concentration can be referred to Bill-Lambert's law: when the incident light is irradiated on the absorbing medium, the transmission intensity will be weakened when the medium absorbs part of the light energy compared with the incident light. The greater the media concentration and the greater the thickness of the medium, the greater the incident light intensity will be.

$$A = \lg \left(\frac{1}{T} \right) = \epsilon bc \quad (1)$$

Where A is the absorbance; T is the transmittance of the solution, which is the absorbance constant; b is the thickness of the solution; c is the concentration of the solution^[7]. The absorbance is directly proportional to the concentration of the solution. The larger the absorbance, the smaller the transmittance, which indicates that the

higher the particle concentration in the suspension, the better the particle dispersion performance in the suspension system. As time progressed, nano-SiO₂ particles continue to settle, and the transmittance increases. In this study, the difference of transmittance is used to indicate the settlement of nano-SiO₂.

2.3.2 Color density

On coated paper, four 100% full color blocks, C, M, Y and K, were printed with Konica Minolta printer. The color density of different color blocks was then measured using X-Rite 530 densitometer. The measurement was conducted with at least three parallels, and the average value was obtained.

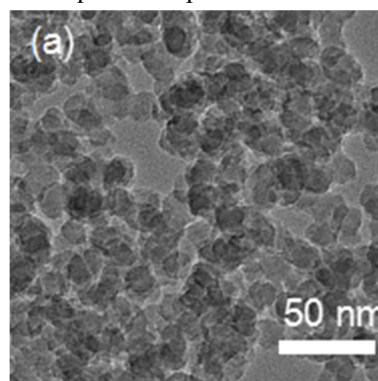
2.3.3 Ink absorption

After dropping a drop of ink on the quantitative roll with a syringe on the coating machine, the paper was immediately pressed at a fixed pressure speed. Then the length of the mark left by the color ink on the paper is measured, which is expressed in cm, representing the ink absorption performance of the paper^[8]. The big value indicates that the ink absorption speed of the pattern is slow and the ink absorption ability is poor. The small value indicates that the ink absorption speed is fast and the ink absorption is good.

3 Results and Discussion

3.1 Characterization of nano-SiO₂

Fig. 1a shows the SEM image of the nano-SiO₂. It can be seen from the diagram that the size of nano-SiO₂ is very small, only 20 nm. Fig. 1b shows that the TEM image of SiO₂, SiO₂ agglomerates seriously and forms 1–20 micron particles, which greatly limits the unique properties and applications of the original nano-SiO₂. Ultrasonic dispersion is commonly used to disperse nano-SiO₂ in aqueous suspensions.



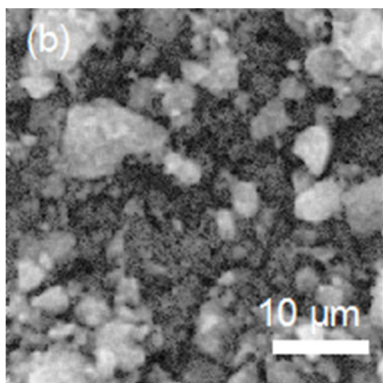


Fig. 1.(a)SEM image of SiO₂. (b) TEM image of SiO₂

3.2 Dispersion of nano-SiO₂

Fig. 2 a shows the dispersibility of nano-SiO₂ in water with and without the addition of PAAS. Without the addition of any dispersant, the supernatant of nano-SiO₂ dispersed in water is more transparent than the nano-SiO₂ suspension with the addition of PAAS. And the sedimentation height of the former is much higher than the latter, indicating PAAS is good candidate as nano-SiO₂ dispersant. As shown in Fig. 2b, the absorption peak at 3428 cm⁻¹ was assigned to the stretching vibration absorption peak of OH on the silicon surface, and peaks at 804 cm⁻¹ and 1108 cm⁻¹ were attributed to the Si-O-Si stretching vibration. There are no new characteristic peaks in the spectra of silica with PAAS, indicating the physical adsorption of PAAS on silica surface.

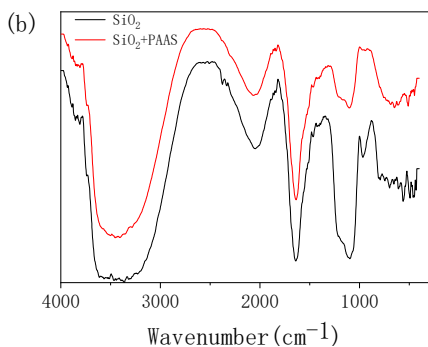
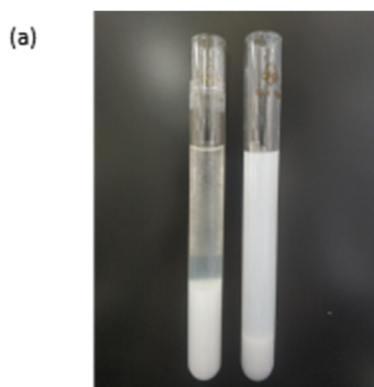


Fig. 2. (a) Photographs of SiO₂ dispersed in water without (left) and with (right) the addition of PAAS.(b) FT-IR of SiO₂ and SiO₂ with PAAS

PAAS, a commonly used polyelectrolyte dispersant, functions well through electrostatic stabilization and steric hindrance in suspension (ref.). As shown in Fig. 3a, the increase of dosage of PAAS, there will be many anionic groups in PAAS molecule after ionization, which leads to the growth of molecular chains and the formation of steric hindrance and electrostatic mechanism. When the dosage is 0.8%, the effect is the best. Continue to increase the amount of PAAS, PAAS layer is too thick, resulting in reduced steric effect, so nano-SiO₂ particles settling more. The dispersing performance of PAAS can be tailored by adjusting the pH value of slurries. When pH is 11, the dispersing effect is the best.

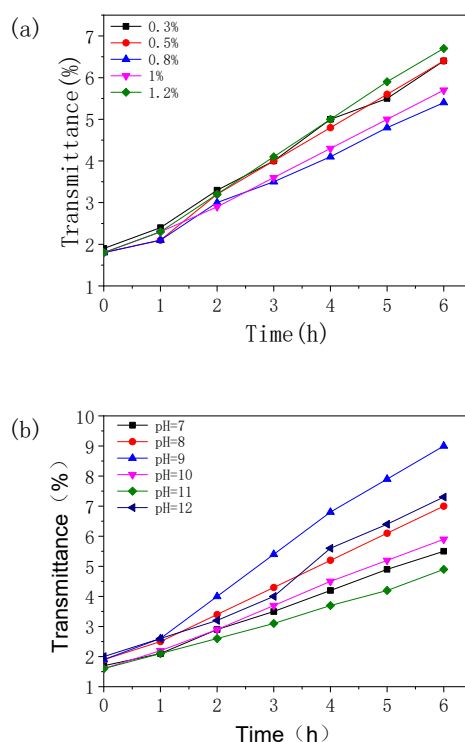


Fig. 3. (a) Effect of the dosage of PAAS on dispersion. (b) Effect of pH on dispersion.

3.3 Performance of paper

From the scanning electron microscopy (SEM) of the base paper shown in Fig. 4a, it can be clearly seen that the uncoated base paper fibers interweave with each other and form a three-dimensional network structure. There are a large number of pores in the paper, which is not conducive to the rapid absorption of ink and has a negative impact on the color density and printing performance of the color jet paper. From the SEM image of the coated paper as shown in Figure 4 b, it can be seen that after coating, a large number of pores are filled by coating particles, forming a large number of capillaries. The coating particles are small, and were compactly arranged in the structure of paper, which boosts the speed of ink absorption, improves the color

density, and then makes ink-jet beating. The color of the printed image is brighter.

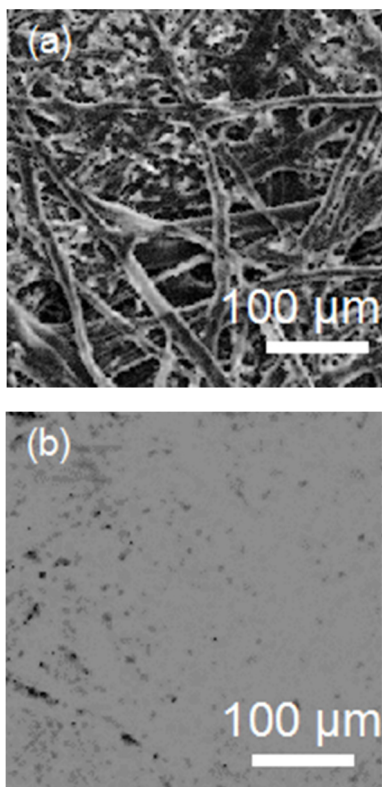


Fig. 4. SEM images of (a) uncoated paper and (b) coated paper.

As illustrated in Fig. 5a, the paper color density is linearly related to the dosage of PAAS. When PAAS dosage is 0.8%, the average color density can be up to 1.60. With the better dispersion of SiO₂ suspension, nano-SiO₂ particles evenly distribute on the surface of paper. Water in water-based ink are quickly and evenly absorbed into the paper, fixing the ink on the coating surface and dries quickly, thus the color density is relatively high. Similarly, with the increase of dosage of PAAS, the gloss of paper is greatly enhanced due to the highly dispersing of nano-SiO₂ particles in the pigment, as shown in Fig. 5b. Furthermore, ink can be quickly fixed on the surface of the coating, and the ink absorbency is larger than that of the pristine paper.

Fig. 5c shows that with the increase of the dosage of PVA in the pigments, the color density of the samples shows an overall upward trend. When the dosage of PVA is 10%–30%, the color density increases much faster while When the dosage is 30%–40%, the rising trend is very slow and the difference of color density is very small. This is because PVA absorbs ink in a swollen way, causing little ink to penetrate into the paper. Therefore, the color density has been rising. When the ink is absorbed by PVA, the color density is relatively small. Fig. 5d shows that the gloss increases slowly as the percentage of PVA in pigments increases. This is because PVA has good film forming property and certain plasticity. However, as the dosage increased, it begins to slow down. With the increase of PVA dosage, the ink absorbency of the pattern decreases, and the ink absorption performance is better. However, as the amount of PVA increases, the ink absorbency of the

pattern becomes worse. This is mainly because PVA is a hydrophilic and has a good swelling effect on water-based ink. However, with the further increase of the amount of PVA, the micropore of nano-coatings will be reduced due its strong cohesion,, thus prolonging the drying time of ink. The color ink-jet printing paper has the best performance in synthesizing all the indexes, when the dosage of PVA is 30%.

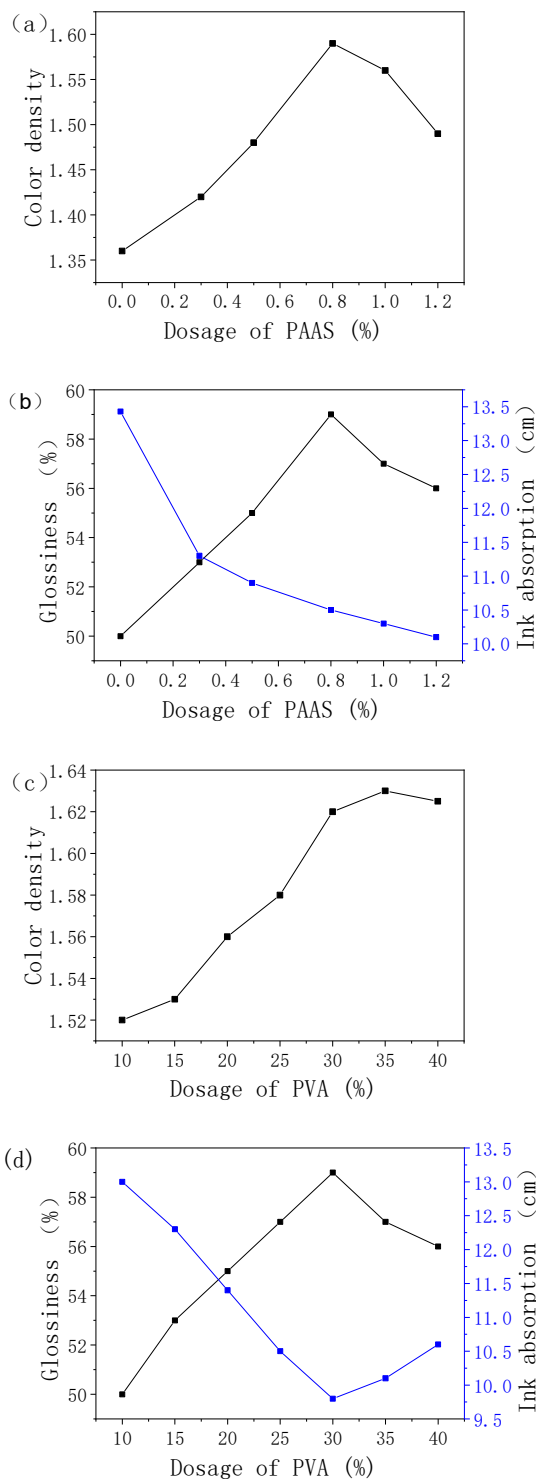


Fig. 5. (a) Effect of PAAS dosage on color density. (b) Effect of PAAS dosage on glossiness and ink absorption. (c) Effect of PVA dosage on color density. (d) Effect of PVA dosage on glossiness and ink absorption.

4 CONCLUSIONS

The dispersion of pigment and the amount of adhesives have a great influence on the printing quality of color ink-jet printing paper. Nano-SiO₂ has excellent properties and can improve the printing quality of color ink-jet paper. However, nano-SiO₂ is easy to agglomerate and disperse. When the dosage of PAAS is 8%, the color density, gloss and ink absorption of PAAS increased by 0.25% and 9%, respectively, compared with those without dispersant. When the ratio of pigment to adhesive is 10:3, the color density of the ink-jet printing paper is 1.62, the gloss is 59%, and the ink absorption value is the maximum.

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