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A coating of silane modified silica nanoparticles on PET substrate film for inkjet printing

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ABSTRACT

The paper aims to design nanoporous coatings for inkjet printing and study its microstructure influence on the ink absorption. In the present work, two inkjet materials were prepared: one with unmodified nano-SiO_2 (S_1), the other with silica coupling agent modified nano-SiO_2 (S_2). The surface characteristic changing after modification was investigated by scanning electron microscopy (SEM), atomic force microscopy (AFM). Wetting with contact angles was determined by the dynamic contact angle analysis test (DCAT). Through measurements, the dispersion of modified nano-SiO_2 particles in the coating was superior to the dispersion of unmodified nano-SiO_2 particles, surface roughness value (Ra) of S_1 was significantly higher than that of S_2, dynamic contact angle of S_2 is smaller than that of S_1 and ink droplet absorption in S_2 was much faster than in S_1. These results also reveal that the modification method is effective and offers a potential way to fabricate inkjet material with the advantages of microstructure and ink absorption over traditional methods.

1. Introduction

The inkjet printing is one of the most prospective technologies because of its versatility, large color gamut, sharp detail rendering, and excellent long-term fastness properties [1,2]. Currently, small-scale color printing and low-cost variable data printing by using inkjet printing are receiving strong research interest [3]. Inkjet print has shown its potential application in 3D printing, electronics and biomedical materials [2,4]. These applications require that ink receptive coatings fixed the colorant and quickly absorbed it, commonly without the use of drying process [5]. The inkjet print quality depends on the properties of inks and inkjet recording materials and their mutual interactions [6–8]. Interactions between inkjet recording material and ink, such as wetting and penetration, can primarily govern the setting and drying of the liquid ink on the surface of the material. Conventional coatings, such as $CaCO_3$-based coatings, have a relatively low interaction between inkjet colorants and the coating pigments, and their inability to absorb fluid inkjet inks, because of their small pore volume and surface area, as well as low chemical material–ink interactions [9]. In recent years, silica-based mesoporous adsorbents have generated more interests due to their large specific surface area, regular pore structure and highly controllable surface properties [10]. The silica-based coatings and substrate materials are adhered by water-soluble hydrophilic polymers, such as polyvinyl acetate (PVAc), polyvinyl pyrrolidone (PVP), and polyvinyl alcohol (PVA) [11]. However, the disadvantages of silica particles that clump together by water-soluble hydrophilic polymers are easily formed aggregates and even agglomerations, and have decreased micro-porosity. The inkjet print quality depends on the microstructure of the coating [7,12]. Therefore, the micro-porosity should be increased in order to enhance inkjet print quality. To date, there are only few papers focusing on the design of nanoporous receptive coatings.

The aims of the present work are to fabricate a modified nanoporous SiO_2-based coatings on a polymeric substrate and investigate the influence of microstructure of the coating on the ink absorption.

2. Materials and experimental procedure

2.1. Raw materials

An uncoated film (PET) produced by Shanghai Zeafee Digital Inkjet Composite Material Co., Ltd., China was used as substrate for the coating. Its thickness was 150 μm. Silane coupling agent was a production of Dow Corning, American and its chemical structure was $(CH_3O)_3SiCH_2CH_2CH_2NH_2$. Nano-$SiO_2$ (as pigment) was a production of Degussa, Germany. The average particle size was in the

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ranges of 12–20 nm. PVA (as binder) was obtained from Changchun Chemical Factory, China.

2.2. Preparation of inkjet material

2.2.1. Preparation of nano-SiO_2 dispersed solutions

Nano-SiO_2 was directly added into H_2O ($W_{\text{nano-SiO}_2} : W_{H_2O} = 1 : 4$) followed by stirring for 60–120 min (named as S_1 solution). Silane coupling agent and H_2O ($W_{\text{silane coupling agent}} : W_{H_2O} = 0.5\text{–}2 : 100$) were mixed and stirred at room temperature for 30 min. The nano-SiO_2 was added into the precursor solution ($W_{\text{nano-SiO}_2} : W_{\text{precursor solution}} = 1 : 4$) followed by stirring for 60–120 min (named as S_2 solution).

The *weight ratio* of the nano-SiO_2 and H_2O (named as S_1 solution) was 20:100.

2.2.2. Preparation of PVA adhesive

PVA and H_2O ($W_{PVA} : W_{H_2O} = 1 : 3$) were stirred at room temperature for 30–40 min and then gradually heated to 95 °C for 50 min in water bath. Then the PVA adhesive was cooled to room temperature.

2.2.3. Preparation of coating solutions

S_1 solution was added to PVA adhesive ($W_{\text{S\_1 solution}}$:W_{PVA} = 1:1). A Continue stirring for 60–90 min was performed, until uniformly solution. Then the S_1 coating solution was remained for 24 h to eliminate bubble. The preparation method of S_2 coating solution was the same as that of S_1 coating solution.

2.2.4. Fabrication of nanoporous inkjet materials

The S_1 coating solution was coated on the PET substrate by using a Motorized Film Applicator (by Elcometer, Britain) at room temperature. The coating color was applied at a speed of 5.0 cm/s and layer thickness of 100 μm. The inkjet materials (named as S_1, respectively) were dried at room temperature for 5–10 min for leveling and then in an oven at 100 °C for 10 min to eliminate the solvent excess and to promote the gelation process [13–15]. The fabrication of S_2 was the same as that of S_1. The basic structure of nanoporous inkjet materials is shown in Fig. 1.

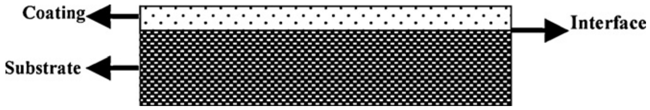

Fig. 1. Basic structures of inkjet material.

2.3. Measurements

The surface morphology of the coatings was carried out by a Russian solver P47 atomic force microscopy (AFM) in non-contact mode. A sample was fastened to a steel sample mount using double sided tape. All images were collected in air using the tapping mode with a silicon nitride probe. The scanning scope was 4 μm × 4 μm and the scan rate was 1.850 Hz.

A scanning electron microscope (SEM, by Philip Corporation, Netherlands) was used to observe the microstructure of the coatings. The samples mounted on a metal sample board were coated with gold using an ion sputter before being examined by SEM. The voltage of SEM was kept at 20 kV at all experiments.

Dynamic contact angles of samples and testing liquids were measured using Wilhelmy plate technique (DCAT21, Data Physics Corporation, Germany). Operative speed and sensibility of the measurement were 1 mm/min and 0.01 mg, respectively. Two dipping liquids, ultrapure water and 1-bromine naphthalene solution, were used.

In order to study the influence of its microstructure on the ink absorption, the absorption process was recorded by a super depth of field optical digital microscope (SDFODM). The ink was quickly dropped in samples and the dropping volume is 5 μl. When begin to drop, the absorption process was recorded by the SDFODM.

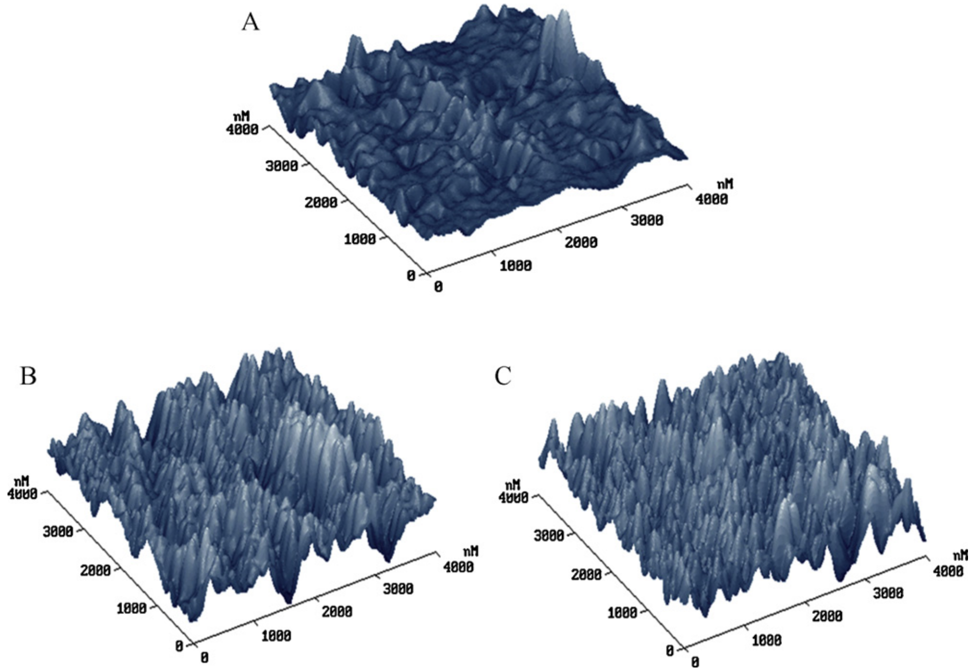

Fig. 2. AFM images of the surface of the substrate and inkjet materials: (A) substrate; (B) S_1; and (C) S_2.