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Effect of atmospheric-pressure air/He plasma on the surface properties related to ink-jet printing polyester fabric

Chunming Zhang [a, b, *], Meihua Zhao [a], Libing Wang [a], Miao Yu [a]

[a] College of Textiles and Clothing, Qingdao University, Qingdao 266071, China
[b] Sunvim Grp Co Ltd, Gaomi 261500, China

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ABSTRACT

Pigment inkjet printing shows more environmental advantages and can potentially enable cost-effective short-run for production. However, patterns directly printed with pigment inks have poor color yields and easily bleed. In the present study, polyester fabrics were surface modified with atmospheric-pressure air/He plasma. The effect of plasma treatment on various fabric properties such as the surface morphology, chemical compositions, surface energy and dynamic contact angles was investigated. Color strength and edge definition were used to evaluate the ink-jet printing performance of samples. The changing of the surface fixation of pigments on polyester fibers was also analyzed by scanning electron microscopy (SEM). Atomic force microscope(AFM) and X-ray photoelectron spectroscopy (XPS) analyses indicated the increase in surface roughness and the oxygen-containing polar groups reinforced the fixation of pigments on the fiber surface. This work explores a novel approach for the atmospheric-pressure plasma, which can provide its important application in enhancing the surface properties and ink-jet printing performance of fabrics.

1. Introduction

Pigment-based inks are often used as inkjet printing media since they have no selection on fabrics. However, patterns directly printed on polyester fabrics often have low color strength and blurred edge definition [1,2]. Therefore, preprocessing of printing substrate must be done to acquire better performance of inkjet printing.

Chemicals solutions such as cationic reagents and thickeners are often used as conventional approach to size the fabrics [3–5]. This wet pretreatment which involves several steps is very complicated, with high energy and water consumption. In the mean time, waste water and harmful substances which results in serious environmental issues would be generated.

Compared to traditional methods for producing high-quality color reproduction, the advantages of plasma surface modification are: be particularly suitable for textile processing because most textile materials are heat sensitive polymers; no production of waste water; higher security and lower chemical consumption; environmentally friendly and matching the definition of ecological textile manufacturing [6–8].

The atmospheric pressure plasma has been reported to be effective to increases the dyeing rate of fabric [9]. In that case, the effect of plasma modification on the chemical property of ink-jet printing fabric deserves special attention.

Therefore, in this study, the influence of various parameters, including the surface morphology, chemical compositions, surface energy and dynamic contact angles of the control and plasma treated samples was investigated. AFM and XPS were used to characterize the influence of plasma treatment on surface morphology and chemical components of the specimens. The surface fixation of pigments on polyester fibers was also investigated by SEM. Color strength and edge definition were used to evaluate the ink-jet printing performance of samples.

2. Experimental

2.1. Raw materials

The fabric specimens were 100% polyester plain weave fabric (65 g/m^2) without chemical processing. Pigment-based ink without any binder (Key Laboratory for Eco-Textiles Ministry of Education, Jiangnan University) was used in all ink-jet printing experiments.

* Corresponding author.
E-mail address: zcm1229@126.com (C. Zhang).

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The average particle size of the pigment is about 180 ± 10 nm.

2.2. Plasma treatments

All surface modification in this study was carried out in ST/RI dielectric barrier discharge (DBD) plasma reactor manufactured by Shanghai Textile Research Institute, China. As schematically shown in Fig. 1, the main chamber which is made of stainless steel has a dimension of 40 cm × 40 cm × 40 cm. There is an approximately 25 cm × 25 cm active exposure area of between two copper electrodes, both of which is embedded in a 6 mm thick glass dielectric barrier. A rotary vane pump is attached to the gas outlet and the pressure in the chamber is maintained by a set of valves. The system was evacuated to 50 Pa before plasma treatment. Then the gas was admitted up to a pressure of 100 kPa. The entire DBD was performed at a mixed ambience of atmospheric air and 10% helium and lasted for 90s. The facility is conducted by a range of 0–500W power supply operating in the frequency of 1 kHz. The samples directly put into the reactor were treated at a total power of 300 W, dielectrics space 3 mm.

2.3. Inkjet printing procedure

The modified and control fabrics were digitally printed using a Mimaki JV4-180 ink-jet printer (Mimaki Company, Japan) and subsequently baked at 120 °C for 3 min with Minni thermo-350 baker (Roaches Company, England).

2.4. Measurments

Morphological and topographical modifications of the polyester fiber surface, resulting from plasma treatment, were investigated using a CSPM4000 AFM produced by Benyuan Company. The vertical resolution of the machine is 0.1 nm, while the horizontal resolution is 0.2 nm. Squares of 3.0 μm side were scanned in contact mode and all AFM images were collected at room temperature in atmosphere.

Surface chemical composition of fabric surface was determined by X-ray photoelectron spectroscopy (XPS), which is performed in a PHI-5000C ESCA (Perkin Elmer) system, using Mg Kα radiation (hν = 1253.6 eV) operated at 14.0 kV and 250W with a detection angle at 54°. The spectra were in reference to the C–C peak positioned at 284.6 eV.

The contact angles were investigated through the Wilhelmy plate technique by using a CDCD-100 F produced by Camtel Ltd Company of England. The Wilhelm method measures the pull force or the push force and the wetting force, to measure the contact angles [10]. The experiments were performed at room temperature and 65% relative humidity shortly after the plasma modification. Measurement velocity is 0.3 mm/s. Ethanediol and distilled water were selected as the probe liquid. Five different positions were measured and the average values were calculated. The data for the test liquid surface tension and surface tension components at 20 °C was as mentioned in literature [11,12].

Surface energy of the substrate can be counted from the contact angle values determined in previous study. Some calculation equations are listed as follow [11]. The total surface energy can be deemed as consisted of two parts, the Lifshitz-vander Waals and the acid-base component. The former indicates the dipole-dipole (Keesom), induction (Debye) and dispersion forces, and latter represents the H-bonding or acid-base interactions. Hence, for a solid phase S, the total surface energy can be expressed as:

$$\gamma_s = \gamma_s^p + \gamma_s^d \quad (1)$$

According to Fowkes, the total interaction between solid phase S and liquid phase L can be expressed as:

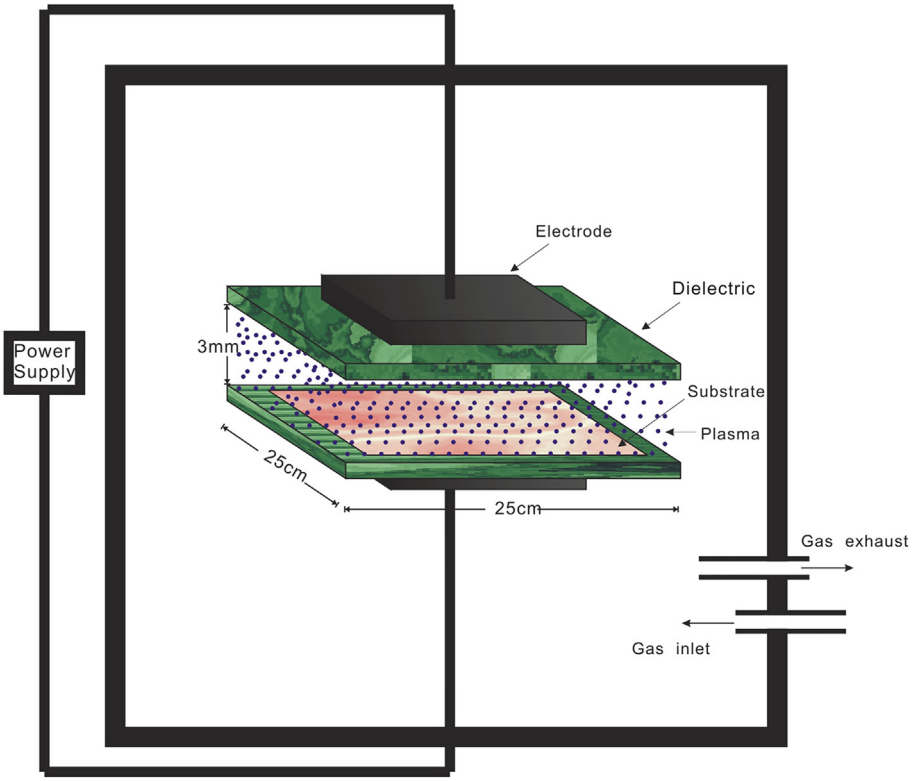

Fig. 1. Schematic view of experimental set-up.