Bulgarian Chemical Communications, Volume 51, Issue 1, (pp. 48 – 53) 2019

The effects of epoxyacrylate coating on printability of bio/synthetic-based fabrics in a thermal transfer printing system

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Received December 27, 2017; Accepted October 25, 2018

This study was aimed to determine the effect of epoxyacrylate oligomer on the print quality. For this purpose, the test print image, transferred on polyester film using a digital printing system, was applied on three different textile fabrics using thermal transfer printing system at three different temperatures. Then, epoxyacrylate based coating formulation was applied on the printed textile fabrics. In order to determine the printability parameters, print colors L*, a*, b* and gloss values were measured on uncoated and epoxyacrylate coated printed textile fabrics. Then a standard washing process was applied on uncoated and epoxyacrylate coated printed textile fabrics in order to estimate the washing fastness of the coating and printing processes. Results showed that print chroma values of epoxyacrylate coated fabrics decreased whilst print gloss values increased. But, after the washing step, print gloss values of uncoated and epoxyacrylate coated printed textile fabrics all remained unchanged. Furthermore, epoxyacrylate coating has no significant effect on print lightness values of printed textile fabrics. The change in textile fabrics' structures did not show a distinct effect on printability parameters.

Keywords: Epoxyacrylate coating, Thermal transfer printing, Print gloss

INTRODUCTION

Epoxy polymers exhibit excellent chemical stability and thermal resistance, showing good adhesion properties on a great variety of surfaces. They have good mechanical properties and can be used in composite materials as the matrix phase. Although having all these advantages, epoxies have some drawbacks such as low impact resistance, high brittleness, and poor UV-resistance. In order to eliminate these drawbacks, epoxies should be modified using some chemical reactions or inorganic fillers. The most widely used method in modification of epoxies is the acrylation process. The reaction of an epoxy with acrylic acid gives the epoxyacrylate (EA) oligomer which can be used for various coating purposes such as corrosion and UV protection, resistance to flame, acid and organic solvents, etc. [1-7]. In the literature there are just a few studies considering the usage of EA based coatings in printing industry. In a previous study, a urethane acrylate oligomer has been synthesized and used in a blue light curable ink formulation for jet printing on cotton fabrics [8].

Today, an aspect of graphic industry that is becoming more and more interesting is printing of textile materials. Printing of textile materials can be most appropriately described as an art and a science of desired design transfer onto the textile surface. Textile materials can be printed using screen-printing technique, digital printing technique, and thermal transfer printing [9]. In thermal transfer printing, firstly the image is transferred onto the transfer paper using digital printing technique, then a binder is printed on the printed transfer paper using digital or screen printing system. Finally, the images on prepared test samples are transferred onto textile fabric by using heat in the range of 140-220°C depending on textile fabric structure [10].

In this study, EA oligomer was synthesized and then applied on printed textile fabrics by dip-coating for protection of the image quality in a thermal transfer printing system. The effects of EA coating layer on print lightness, print chroma, and print gloss values were investigated. Printed and EA coated fabrics were also tested after double washings to assess the water resistance of printing color and EA layers.

MATERIALS AND METHODS

Materials

In this study, three different kinds of textile fabrics (cotton 113 g/m^2, 30 warp/cm, 22 weft/cm, polyamide 168 g/m^2, knitted fabric, polyester 84 g/m^2, 64 warp/cm, 40 weft/cm) were used. Bisphenol-A based epoxy (EPIKOTE 162, EEW:167-171 g/equiv.), triphenyl phosphine (TPP), acrylic acid (AA), methyl ethyl ketone (MEK), hydroquinone (HQ), photoinitiator

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(Irgacure-184), and dipropylene glycol diacrylate (DPGDA) were all purchased from Sigma-Aldrich.

Preparation and Application of the Printing Master Film via Thermal Printing System

Printing master films were prepared and then they were printed on polyester film by an HP Indigo 5500 digital printing machine. In order to prevent spreading of the image, the surfaces of printed polyester films were coated with white dye using a semi-automatic screen-printing machine. The mesh number was 140 threads/cm (tpc). After print, they were dried at 60°C. Then, they were coated with water-based adhesive for giving binder feature using a screen-printing system. The mesh number was 68 threads/cm (tpc) [11-13]

The obtained printing master films were transferred on cotton, polyamide and polyester textile fabrics using Sahok Sh 49BD thermal transfer printing machine at 140°C, 170°C and 200°C. In this process, printing pressure and printing time were kept constant.

Epoxyacrylate Synthesis and Coating Process on Printed Fabrics

The synthesis of EA oligomer was carried out according to previous studies [12,13]. 300 ppm of HQ and 1000 ppm of TPP (out of the total AA and epoxy resin) were dissolved in AA by ultrasonication, then included in a round-bottom flask having the epoxy resin. The molar radio of AA and epoxy was set as 1:1. Magnetic stirrer condenser, and air inlet were used during the reaction. 10 % DPGDA was included in the reaction in order to decrease the viscosity of the resin. The reaction was performed at 100ºC for 2 h and another 2 h at 120ºC. At the end of the reaction phosphonium betaine was formed *via* the ring opening reaction of epoxide group which is initiated by the nucleophilic attack of the catalyst (TPP). The obtained betaine group abstracts a proton from AA by giving a carboxylate anion that is effective on the electrophilic carbon of phosphorus, resulting an ester bonding.

The obtained EA oligomer was included in coating formulations with 3 % photoinitiator, and MEK. MEK was used to lower the viscosity of the resin and to give wettability property to the fabrics. The printed fabrics were dipped into the coating solution for 3 min and then were dried in an oven (70ºC, 10 min) in order to evaporate the MEK. Then the coating layer was cured on the fabric surface by using 300 W Osram Ultra-Vitalux UV-lamp.

The obtained printed, EA coated fabric samples were washed twice by using ECE non-ionic detergent (4 g/L) solution in water at 40ºC for ½ h [14]. The quality of the printing process was evaluated both before and after the washing step. Furthermore, the uncoated/coated fabric samples before and after washing steps were characterized by light microscopy (Olympus B×51) in order to observe the surface properties in details.

Evaluation of the Printability Properties

CIE *L**, *a**, and *b** values of the printed uncoated samples and the printed samples coated with EA oligomer were measured by the D50 illuminant/2° observer values using X-Rite eXact Densitometer [15, 16]. BYK Portable glossmeter (BYK-Gardner Gmbh, Geretsried, Germany) was used based on ISO 2813 (2014) to determine the gloss values of the printed uncoated samples and the printed samples coated with EA oligomer [15, 16]. Both CIE *L**, *a**, and *b** color values and gloss values of the printed samples were measured immediately after printing and after each washing.

RESULTS AND DISCUSSION

Print Lightness

The lightness value shows the saturation of the color and ranges from 0 to 100. If it is close to 0, it means the print is darker whilst close to 100 means the print becomes lighter [17].

In Figs. 1 and 2, the L* values of the printed uncoated and EA coated CO, PA and PES textile fabrics, before and after double washing steps are given depending on various temperatures. Accordingly, the print lightness values slightly decreased with EA coating layer. After double washing, no significant change in print lightness values was recorded in uncoated and EA coated PES textile fabric,whereas in CO and PA fabrics, the print lightness values decreased, especially at 140 ºC after double washing (Fig. 2).

Print Chroma

High color saturation is an important property for good quality prints. High chroma indicates high color saturation. The print chroma value (C_{ab}) was calculated by Eq. 1 [18].

$$C_{ab} = \sqrt{a^{*2} + b^{*2}} \quad (1)$$

For a*, negative values indicate green, while positive values indicate magenta. For b*, negative values indicate blue, and positive values indicate yellow.

The chroma values of uncoated and EA coated CO, PA, and PES printed samples before and after double washings are given in Figs. 3 and 4 depending on the temperature change. According to

Fig. 3, a noticeable decrease in print chroma values for all samples after EA coated was recorded. This decrease proved that color gamut of EA coated samples is smaller than color gamut of uncoated samples. After a double washing process (Fig. 4), the print chroma values of uncoated samples decreased whereas in EA coated printed samples the print chroma values were all enhanced especially for CO and PES textile fabrics.

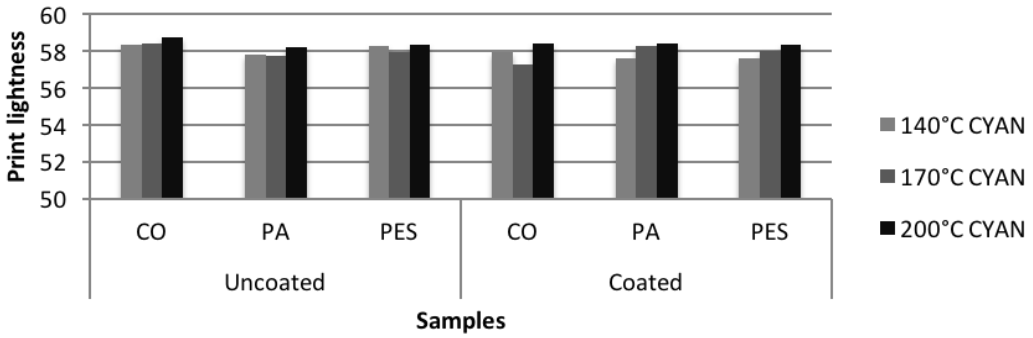

Fig. 1. Print lightness of uncoated and EA coated samples before washing

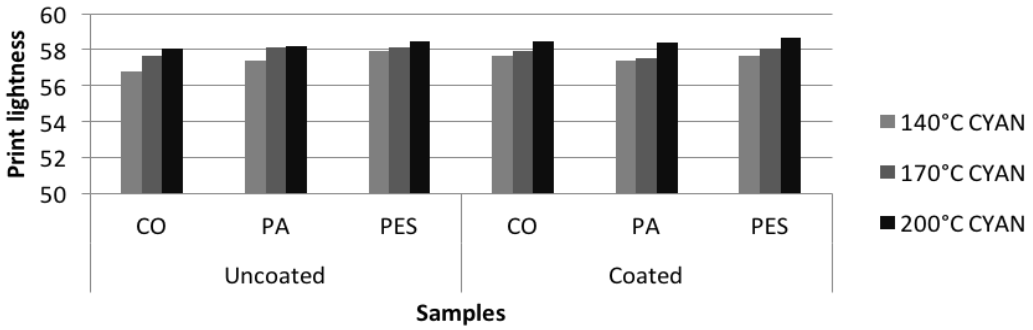

Fig. 2. Print lightness of uncoated and EA coated samples after double washing.

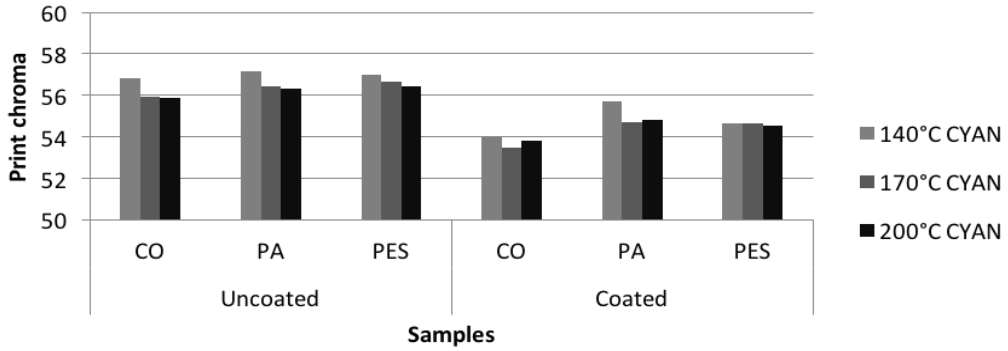

Fig. 3. Print chroma of uncoated and EA coated samples before washing.

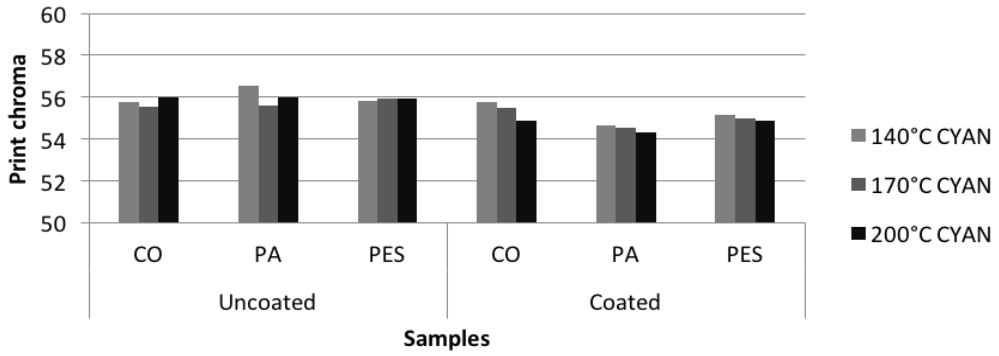

Fig. 4. Print chroma of uncoated and EA coated samples after double washing.

Print Gloss

Although surface properties of materials have an important effect on gloss value, the ink properties and its ingredients are effective to determine the final gloss value [19].

The gloss values of the printed samples of uncoated and EA coated CO, PA and PES textile fabrics at 60° before and after double washing depending on the temperature change are illustrated in Figures 5 and 6. Results showed that the print gloss values of the uncoated samples were all almost at the same levels. After EA coating, the print gloss values of PA textile fabric increased at 140°C, whilst decreased at 170°C and 200°C. The print gloss values of CO and PES textile fabrics all increased with EA coating step at all temperatures (Fig. 5). An increase in the print gloss value is an important property of the printability parameters, as the visual quality is enhanced by the print gloss value. After double washing process (Fig. 6), the print gloss values of uncoated and EA coated samples all decreased. The decrease in EA coated samples was greater than in uncoated samples.

Light Microscopy Images of Printed Samples

Fig. 7 shows the light microscopy images of printed-uncoated, printed-EA coated fabrics, and fabrics after abrasion resistance test. Accordingly, EA coating process caused a rough surface for all samples. The least roughness was observed in PA fabric samples. The roughness may be formed due to the shrinkage of EA layer after the UV-curing stage resulting in puckering of the textile fabric. After 50,000 cycle-abrasion test, the fabric images retained almost the same look in printed-EA coated samples.

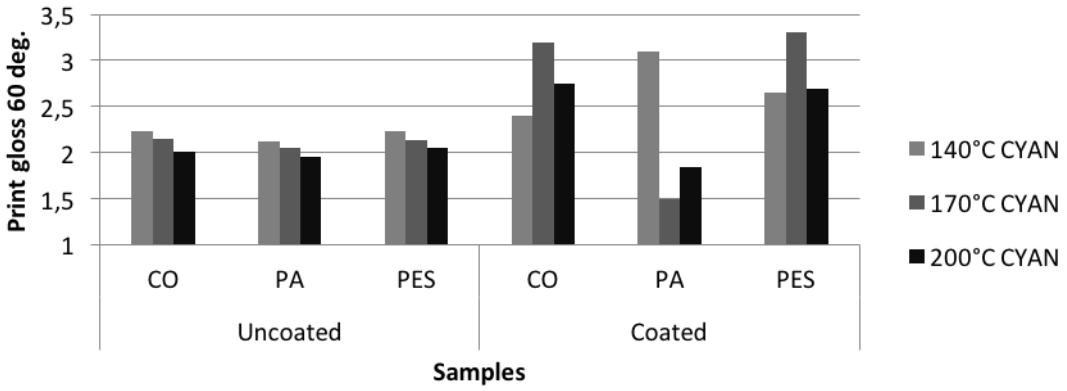

Fig. 5. Print gloss of uncoated and EA coated samples before washing.

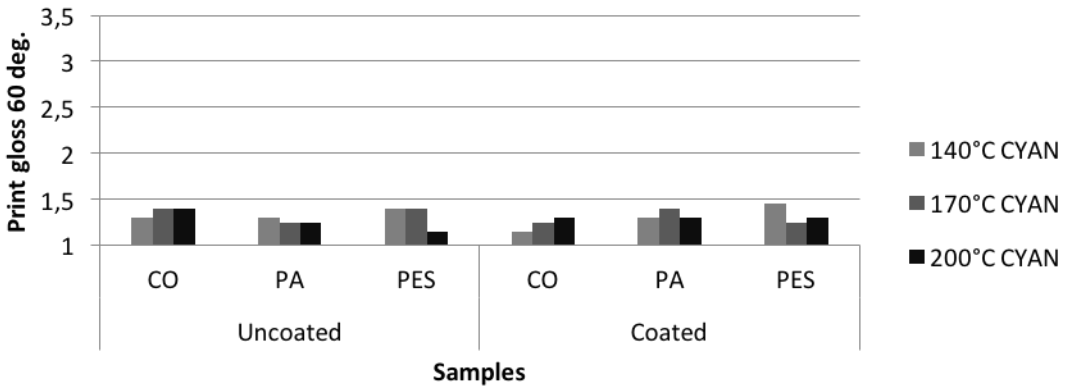

Fig. 6. Print gloss of uncoated and EA coated samples after double washing.

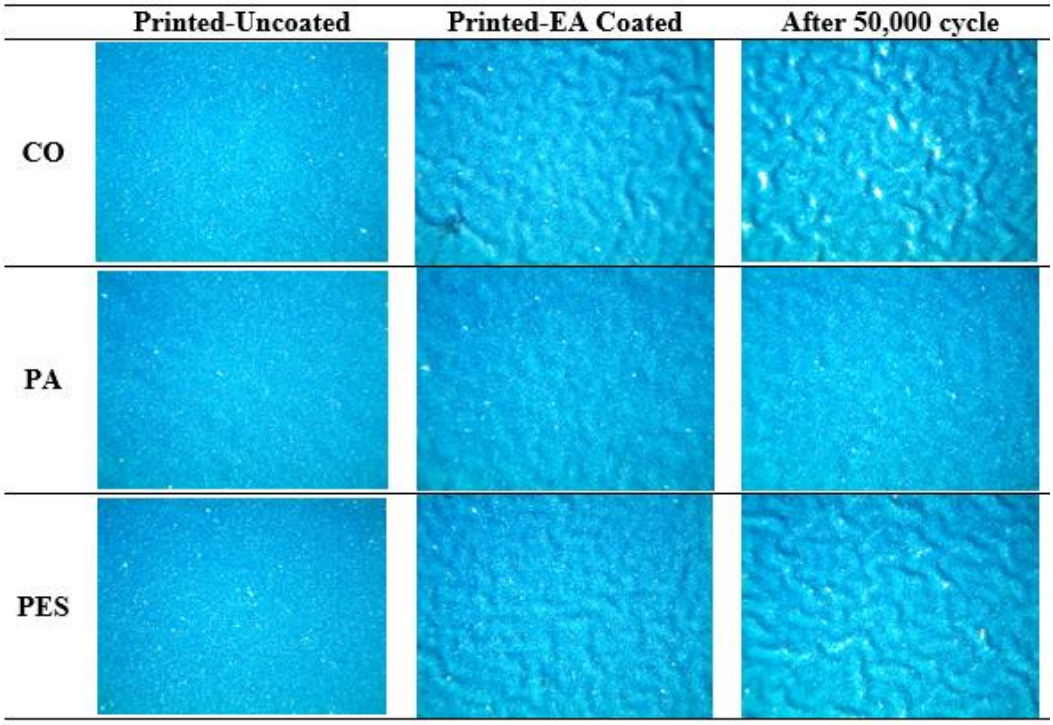

Fig. 7. Light microscopy images of printed, EA coated fabric samples after 50,000 cycles.

CONCLUSIONS

This study aimed to enhance the printing quality of the thermal transfer printing process in various textile fabrics. For this purpose the printing process was performed at three different temperatures. In order to enhance the printing quality an EA oligomer was synthesized and applied on the printed fabrics *via* dip-coating following the UV-curing step. Results proved that the EA coating layer enhanced the gloss values of printed fabrics.

1. The print lightness values of printed CO, PA, and PES textile fabrics decreased after the EA coating process. Considering the printing temperatures, the print lightness value of PES fabric was not affected after double washing, whilst the print lightness values of uncoated and EA coated CO and PA textile fabrics decreased, especially at 140 °C.

2. The print chroma value of printed CO, PA, and PES fabrics decreased after the EA coating process. After double washing process, the print chroma values of printed, EA coated CO and PES textile fabrics increased, whereas the print chroma values of uncoated printed fabrics decreased after double washing. Temperature changes during the printing process did not affect the print chroma values.

3. Before the washing process, the print gloss values of printed-EA coated CO, PA, and PES textile fabrics were higher than of printed-uncoated CO, PA and PES textile fabrics. However, after double washing process, the print gloss values of printed-EA coated CO, PA, and PES textile fabrics decreased and were at the same level as uncoated.

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