Carbohydrate Polymers 91 (2013) 560–567

Contents lists available at SciVerse ScienceDirect

Carbohydrate Polymers

journal homepage: www.elsevier.com/locate/carbpol

Hydrophilic modification of polyester fabric by applying nanocrystalline cellulose containing surface finish

Masuduz Zaman[a,*], Hongbin Liu[a,b], Huning Xiao[a], Felipe Chibante[c], Yonghao Ni[a,b,**]

[a] Limerick Pulp and Paper Research Center, University of New Brunswick, Fredericton, New Brunswick, Canada E3B5A3
[b] Key Laboratory of Pulp & Paper, Tianjin University of Science & Technology, Tianjin 300457, China
[c] Applied Nanotechnology Laboratory, University of New Brunswick, Fredericton, New Brunswick, Canada E3B5A3

ARTICLE INFO

Article history:
Received 6 July 2012
Received in revised form 7 August 2012
Accepted 19 August 2012
Available online 28 August 2012

Keywords:
Polyethylene terephthalate
Cationic nanocrystalline cellulose
Hydrophilic polyester
Surface coatings
Rolling–drying–curing process

ABSTRACT

In this study, polyethylene terephthalate (PET) fabric was modified by applying a hydrophilic surface finishing agent that contains nanocrystalline cellulose (NCC). To impart superior hydrophilicity, NCC was further cationically modified through quaternization by grafting glycidyl tri-methyl ammonium chloride (GTMAC). A textile binder, PrintRite595®, was added to the finishing system. The surface finish was applied on the fabric using a rolling–drying–curing process. The modified fabric was characterized in terms of coating durability, moisture regain, and wettability. The durability of the surface finish was tested by six repeated washing steps. The surface properties of the fabric changed from hydrophobic to hydrophilic after heat treatment with the NCC-containing surface finishing agent. The results from the washing fastness, SEM, FTIR, and EDX analyses confirmed that the cationic NCC-containing textile surface finish showed superior adhesion onto the cationic dyeable (anionic) PET surface over the unmodified NCC. Furthermore, the cationic textile surface finish was capable of withstanding multiple washing cycles.

1. Introduction

Polyester is one of the fastest growing synthetic fibers in the textile industry due to its excellent properties, such as excellent wash and wear, good dimensional stability, anti-wrinkle, and quick drying properties. However, 100% polyester has an extremely poor moisture management (transport of moisture vapor and liquid away from the body) property, as compared to natural fibers, such as cotton. Polyester has a moisture regain of only 0.42% (measured at a relative humidity of 65% and 20 °C for 24 h) (Alakara, Karakisla, & Sacak, 2008), while cotton has a moisture regain of about 8.5% (Su, Fang, Chen, & Wu, 2007). The poor water and moisture absorption of PET make it less desirable material in many textile applications, such as sportswear, under garment, furniture, and bedding.

The origin of hydrophobicity of polyester is the lack of polar groups (—OH, COOH, —NH_2, etc.) on its polymer backbone. When one perspires, the polyester tends to keep the perspiration trapped against the body. Due to the hydrophobicity, polyester is also more electrostatic compared to the natural fibers. Electrostatic nature of the polyester is highly undesirable as it causes clothes to cling to each other.

Surface modifications using various methods have been performed to improve the water and moisture absorption properties of polyester fabric (Alakara et al., 2008; He, Gu, & Tian, 2003; Kim & Song, 2006, 2008; Lee et al., 2007; Lee & Song, 2010; Parvinzadeh & Ebrahimi, 2011; Ploymalee, Charuchinda, & Srikulkit, 2010; Siriviriyanun, O'Rear, & Yanumet, 2007). The Denier reduction by aminolysis or hydrolysis is a widely used technique for improving the hydrophilicity of polyester (Bech, Meylheuc, Lepoittevin, & Roger, 2007; Bide et al., 2003; Croll, O'Connor, Stevens, & Cooper-White, 2004; Elsaeed & Farag, 2009; Hall & Whinfield, 1952; Latta & Pensa, 1976; Mangovska, BogoevaGaceva, & Pohlers, 1996). This method involves polymer chain scission at the ester linkage and produces water compatible functional groups, such as —COOH, —OH, —NH_2 on the polyester fiber surface. However, the denier reduction suffers from the loss of mechanical strength of the fabric and also produces waste in the effluent, therefore increasing the cost for textile effluent treatment. Multi-component and composite fibers also attracted significant attention to improve the hydrophilicity of the polyester (Backwell, 1997; Bolon & Boldebuck, 1983; Mathes, Lange, & Gerlach, 1983; Su et al., 2007). However, the production of this kind of fibers needs a sophisticated technology

* Corresponding author. Tel.: +1 506 4516857; fax: +1 506 4534767.
** Corresponding author at: Limerick Pulp and Paper Research Center, University of New Brunswick, Fredericton, New Brunswick, Canada E3B5A3. Tel.: +1 506 4516857; fax: +1 506 4534767.
E-mail addresses: zaman.masuduz@gmail.com (M. Zaman), yonghao@unb.ca (Y. Ni).

0144-8617/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.carbpol.2012.08.070

(Ploymalee et al., 2010). Several studies have also been reported in the literature on the hydrophilic improvement of polyester through co-polymerization and graft co-polymerization (Alakara et al., 2008; Maity, Kartha, & Srivastava, 1984) of hydrophilic monomers in the presence of an initiator. However, considering the high cost and lengthy processing time, such treatments are not commercially viable for applying to polyester fabrics in the textile industry. In recent years, application of plasma process for the modification of textile fabrics has received attention (Morent et al., 2008), which has the advantage of being an environmental friendly technique. However, this is a sophisticated technology and selection of the plasma source and treatment conditions are crucial for the non-destructive treatment of the fabric.

The application of surface finish is a commercially viable alternative to improve the hydrophilic properties of polyester fabric. Significant amount of research has been conducted on the development of smart textiles by applying surface finish, such as (1) antimicrobial fabric (El-Rafie, Mohamed, Shaheen, & Hebeish, 2010; Kim, Choi, & Yoon, 1998), (2) ammonia decomposing fabric (Dong, Bai, Liu, & Zhu, 2007), fragrance-containing textile (Sohn et al., 2007; Voncina, Vivod, & Chen, 2009), UV-protective fabric (Zohdy, El Hossamy, El-Naggar, Fathalla, & Ali, 2009), etc. Several studies have been reported in the literature on the application of surface finish to improve the hydrophilicity of polyester fabrics (Adler & Walsh, 1984; Eom, 2001; Ferguson, 1982; Ploymalee et al., 2010; Xiao, Chen, Wei, & Wu, 2009). The surface finishing agent usually contains hydrophilic polymer or fluorinated compounds. The benefit of this technology is that it can be easily adapted to any existing textile facility at a relatively low cost.

Nanocrystalline cellulose (NCC) has received much attention recently (Araki, Wada, Kuga, & Okano, 1998; Beck-Candanedo, Roman, & Gray, 2005; Cranston & Gray, 2006; Jahan, Saeed, He, & Ni, 2011), due to many unique characteristics, including: (1) high strength, Young's modulus and tensile strength of NCC can be up to 145 GPa and 7.5 GPa, respectively (Lahiji, Reifenberger, Raman, Rudie, & Moon, 2008); (2) high aspect ratio (up to 100) (Cranston & Gray, 2006); (3) high specific surface area (up to several hundred m^2/g) (Chazeau, Cavaille, Canova, Dendievel, & Boutherin, 1999); (4) polar groups (—OH) enriched surface, which provide excellent means of moisture adsorption and surface reactivity. The above unique characteristics give them improved material properties, therefore, a large variety of applications in various industries, such as pulp and paper, textile, biomedical, personal care products, plastics, electronics.

In this study, the authors used cationically modified nanocrystalline cellulose (NCC), which was prepared based on an early procedure (Zaman, Xiao, Chibante, & Ni, 2012), as part of the surface treatment agents, and applied to the plain weaved polyester fabric based on a rolling–drying–curing process. The hypothesis is that the surface finishing system consists of cationic NCC would render superior hydrophilicity and affinity toward the cationic dyeable polyester fabric (anionic PET). The goal of this study was to develop a durable hydrophilic surface finishing system to improve the hydrophilic properties of polyester.

2. Experimental

2.1. Materials

100% (cationic dyeable) PET fabric (style#763), which was plain weaved, with the fabric weight of 163 g/m^2, was provided by Testfabrics, Inc., USA. A commercial textile binder, PrintRite595®, was obtained from Lubrizol, Inc., USA. A textile thicker (SC6477) was provided by StanChem, Inc., USA. NCC sample, prepared from the sulfuric acid hydrolysis process, was obtained from FPInnovations, Canada. GTMAC was used as a cationization agent and obtained from Sigma–Aldrich, Canada. Potassium poly vinyl sulfate (PVSK) with a MW of 100,000–200,000, 97.7% esterified, was provided by Wako Pure Chem. Ltd. Japan. Cellulose dialysis membrane (MW cut-off 12,400) was obtained from Sigma–Aldrich. Ethanol, sodium hydroxide were all analytical grade chemicals from Fisher Scientific Co., Canada.

2.2. Preparation of cationic NCC

A water based semi-dry process was used for the cationic modification of NCC (Fatehi, Ates, Ward, Ni, & Xiao, 2009; Liu, Ni, Fatehi, & Saeed, 2011; Zaman et al., 2012), which is given as follows: 1 g of water dispersible freeze dried NCC and 50 mg of powdered sodium hydroxide were mixed thoroughly using a mortar and pestle for 5 min at room temperature and left to cool to room temperature. The solid mixture was then transferred to a polyethylene bag followed by addition of the water. The cationization agent (GTMAC) was added dropwise to the previous mixture and mixed thoroughly by hand kneading. Subsequently, the reaction mixture was kept in a thermostated ultrasonic water bath at 65 °C. The reaction conditions were as follows: water content of the reaction system of 36 wt%, molar ratio of GTMAC to anhydroglucose units in NCC of 3:1, catalyst (NaOH) dosage of 5% (by weight of NCC), Temperature of 65 °C, reaction time of 4 h. The reaction mixture was hand kneaded every 15 min during the reaction. After 4 h, the reaction was stopped by precipitating the reaction mixture in 95% ethanol. The unreacted reagents and by-products were removed by centrifugation. After centrifugation, the sediment was kept and the supernatant was removed and replaced by fresh 95% ethanol and recentrifuged. After that, the product was redispersed in deionized and distilled water and diluted 4 times. The suspension was then dialyzed by using cellulose dialysis membrane against deionized and distilled water for 3 days to remove the last residue of any unreacted reagents and by-products. The distilled and deionized water was replaced every 2 h during the first day and twice a day in the following 2 days. The concentration of the product was then increased by evaporation in a rotary evaporator.

2.3. Application of NCC coating on polyester fabric

Two commercial textile additives, a self-crosslinking acrylic binder, PrintRite595®, and a SC6477 thickener, were employed to form the coating formulation. SC6477 is an alkali swellable acrylic copolymer emulsion which is widely used for thickening coating formulations. Aqueous suspension of NCC, the binder (at various binder to NCC mass ratio), the thickener (binder to thickener mass ratio is equal to 3), were mixed by an electromagnetic stirrer until the coating paste attained sufficient viscosity to be applied. A small amount of alkali was also added to start the thickening mechanism. Before applying the surface finish, a 3 in. × 3 in. fabric piece was etched with alkali, washed with distilled and deionized water, and dried in an oven. The coating paste was applied onto the fabric piece with a K303 Multicoater from RK Print Coat Instruments. The speed of the coater was adjusted to 2 m/min. Coating paste was applied to both surfaces of the fabric. The net weight addition due to coating was 30% by weight of dried fabric. After applying the coating, the fabric was dried at 80 °C for 20 min and cured at 160 °C for 15 min.

2.4. Characterization of NCC-coated polyester fabric

2.4.1. Evaluation of moisture regain properties

The moisture regain is the percent weight of moisture gain compared to the initial dry fabric weight. To determine the moisture regain properties, treated fabrics were kept in a conditioned room