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Insight into multifunctional polyester fabrics finished by one-step eco-friendly strategy

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HIGHLIGHTS

- The excellent and durable antimicrobial and anti-mite polyester fabrics are fabricated.
- The finished PET fabrics exhibit excellent hydrophilic and antistatic properties.
- Non-leaching antimicrobial PET fabrics exhibit no skin stimulation and toxicity.
- The improved cohesive force between the fibers leading to enhanced tear strength.
- The finished PET fabrics maintain mechanical properties and vapor/air permeability.

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ABSTRACT

Polyethylene terephthalate (PET) has been widely used in fabrics owing to its great mechanical properties, easy processability and quick drying. However, PET-based products always suffer from uncomfortable low sweat uptake and electrostatic charge buildup mainly due to its bad surface wettability. Moreover, porous fabrics may induce unfavorable mite and microorganism reproduction. Due to lack of reactive groups on the PET skeleton, it was very difficult to endow its surface hydrophilicity, antistatic properties, perdurable antimicrobial and anti-mite properties by conventional methods. In this work, we develop a one-step eco-friendly finishing strategy for PET fabrics through photochemical reaction using benzophenone group terminated quaternary ammonium salt (BP-QAS) as the finishing reagent. The as-finished PET fibers changed from incompact state to compact state due to the increased cohesive forces within individual fibers, resulting in improved tearing strength. The PET fabrics show significantly improved hydrophilicity, and antistatic properties. Furthermore, the as-finished PET fabrics exhibit excellent, durable broad-spectrum antimicrobial activities against gram-negative, gram-positive, drug-resistant bacteria and fungi. Moreover, our fabric shows long-lasting antimicrobial properties above AAA requirements after 50 laundering cycles. Usual PET fabrics generally have difficulty achieving AAA standards after 10 laundering cycles. In addition, our as-prepared fabrics showed excellent anti-mite activities against house dust mites based on disruption of the microbial and mite membrane due to oxidation stress, while no negative effects were observed for mouse and rabbit. The finished PET fabrics can be applied to multiple industries to prevent infectious diseases and improve public health, including but not limited to packaging, clothes, water treatment, and medical appliances.

1. Introduction

The most commonly used polyester, polyethylene terephthalate (PET), has been broadly used in multiple industries especially textiles owing to its excellent strength, chemical resistance, processability, quick drying and dimensional stability [1,2]. However, surface

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hydrophilicity and water absorption of PET fabrics are poor, resulting in uncomfortably low sweat uptake, electrostatic-charge buildup and pilling [2,3]. Additionally, microorganisms can proliferate in porous PET fabrics due to the abundant adsorption of metabolic products from the skin s sweat/sebaceous glands [4–6], resulting in unfavorable odor, stains, and discoloration, the reduction of the textiles' mechanical properties and cause cross-contamination [7]. Furthermore, 50% of the patients with asthma are sensitized to house dust mites, and the allergic reaction from exposure to mites is a leading cause of a severe world-wide health problem [8]. House dust mites exist widely in bed, pillow, and mattress fabrics where they can breed and colonize. Anti-mite fabrics are therefore urgently needed for the control of the disease and the protection of human health [9]. However, the anti-mite fabrics are barely studied and the anti-mite mechanisms are not yet clarified [10,11]. Therefore, the development of hydrophilic, antistatic, antimicrobial and anti-mite finishing methods for PET fabrics is highly desired and is the focus of this work.

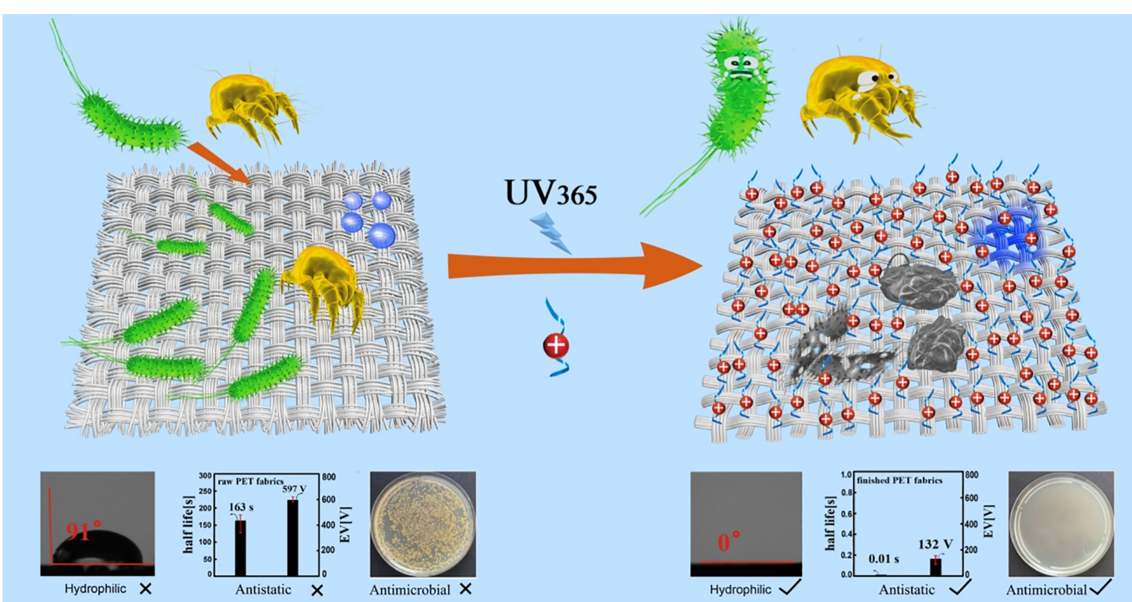
Many antimicrobials such as guanidinium [12,13], peptide [14–16], betaine [17–21], chitosan [22–24], nanofibrous membranes [25], nanoparticles [26–28], graphene [29,30] and cationic amino segments [6,31] have been developed to treat microbial and prevent infectious diseases transmission and infections. Among them, cationic quaternary ammonium salts (QAS) have attracted much attention in antimicrobial finishing of fabrics due to their excellent antimicrobial activities, low-cost and facile preparation process [32]. It is well known that QAS can interact with the cell membrane of bacteria [31] and create reactive oxygen species (ROS) that can cause cell death [33]. Additionally, hydrophilic and positively charged QAS could also endow PET fabrics with hydrophilic and antistatic properties to improve its wearing comfort.

Despite considerable efforts and recent advances in the fabrication of enhanced hydrophilic and antimicrobial cotton fabrics, an effective finishing method to obtain hydrophilic and antimicrobial PET fabrics is still far from optimal owing to no reactive group in the PET molecular skeleton [34]. To enhance the perdurable hydrophilicity or antimicrobial activity of PET fabrics, reactive groups such as OH, COOH, and NH_2 were introduced through alkaline hydrolysis [35,36], aminolysis [37–39], alcoholysis, plasma treatment [1], microwave irradiation [40], gamma-ray irradiation [41], or UV radiation [42], after then the hydrophilic and antimicrobial groups were bound to the PET molecular backbone after surface grafting [39], layer-by-layer self-assembly [35,36], or atom transfer radical polymerization [37,43]. However, those strategies would cause a local deterioration of the PET molecular backbone, leading to significantly decrease in the mechanical properties and surface roughness of PET fabrics [43]. Additionally, their hydrophilicity and durable antimicrobial properties are still not satisfactory [37,43,44]. Therefore, it is of great importance to develop a new finishing technology to fabricate PET fabrics with excellent hydrophilicity, broad-spectrum antimicrobial and anti-mite properties as well as enhanced stability against long-term laundering without compromising its superiority.

A novel benzophenone containing polyethylenimines has reported to be covalently bonded onto polymer surfaces using mild photo-cross-linking, imparting non-leaching thin antimicrobial coatings for fabrics [45]. However, the preparation process is relatively complicated, and the final yield is not satisfactory. Especially, no investigation of the perdurable antimicrobial activity, anti-mite activity and other wearability properties of the treated textiles had been reported. Herein, we developed a one-step eco-friendly photochemical finishing method to fabricate polyester fabrics with excellent hydrophilicity, antistatic property, perdurable antimicrobial, and anti-mite activities by using a benzophenone group terminated quaternary ammonium salt (BP-QAS, **1**) as an antimicrobial and anti-mite finishing agent *via* mild UV light irradiation (λ = 365 nm, 1.71 mW/cm^2) activated rapid photochemical hydrogen abstraction reaction [46]. Moreover, we found that the BP-QAS finished PET fabrics (**2**) are significantly improved in properties (Scheme 1): (i) greatly enhanced hydrophilic and antistatic properties; (ii) broad-spectrum antimicrobial activities even including the killing of drug-resistant bacteria and fungi; (iii) excellent acaricidal activity; (iv) improved cohesive force between the fibers leading to the improved tear strength; (v) no skin irritation and no toxicity, which are significant improvements that have not been studied or shown in other studies.

2. Results

The BP-QAS was synthesized by the bromination reaction of methyl group in 4-methylbenzophenone, followed by a nucleophilic substitution of 4-bromomethyl benzophenone with *N*,*N*-dimethyldodecylamine (Scheme S1). And the BP-QAS was bonded onto the surface of raw PET fabrics *via* the photochemical hydrogen abstraction reaction between



Scheme 1. Photochemical finishing of PET fabrics by using quaternary ammonium salt terminated with benzophenone group (BP-QAS) with an excellent hydrophilic property, antistatic property, durable broad-spectrum antimicrobial, and acaricidal activities.