Chemical Engineering Journal 336 (2018) 123–132

Contents lists available at ScienceDirect

Chemical Engineering Journal

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

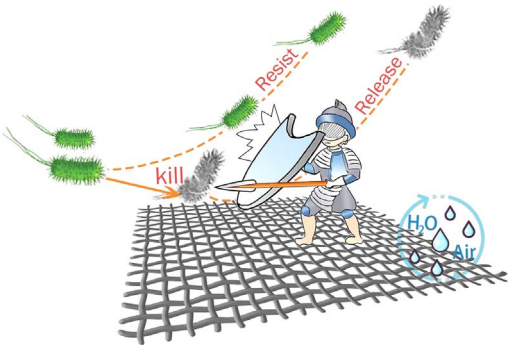
New insights into synergistic antimicrobial and antifouling cotton fabrics via dually finished with quaternary ammonium salt and zwitterionic sulfobetaine

Shaobo Zhang[a,1], Xinghui Yang[b,1], Bin Tang[c,1], Lingjun Yuan[a], Kui Wang[c], Xiangyu Liu[a], Xingli Zhu[a], Jianna Li[d], Zaochuan Ge[a], Shiguo Chen[a,*]

[a] Nanshan District Key Lab for Biopolymers and Safety Evaluation, Shenzhen Key Laboratory of Polymer Science and Technology, Guangdong Research Center for Interfacial Engineering of Functional Materials, College of Materials Science and Engineering, Shenzhen University, Shenzhen 518060, PR China
[b] Guangzhou Fibre Product Testing and Research Institute, Guangzhou 511447, PR China
[c] Department of Biomedical Engineering, Southern University of Science and Technology, Shenzhen 518055, PR China
[d] Shenzhen Key Laboratory of Translational Medicine of Tumor, Shenzhen University Health Science Center, Shenzhen 518060, PR China

GRAPHICAL ABSTRACT

Novel cotton fabrics with antifouling and bactericidal activities based on synergic “repel-and-kill” approaches.



ARTICLE INFO

Keywords:
Fabrics
Finishing
Zwitterion
Quaternary ammonium salt
Aantimicrobial
Antifouling

ABSTRACT

We report a facile and environment-friendly finishing method for cotton fabrics using zwitterionic sulfopropylbetaine (ISB) and quaternary ammonium salt (IQAS) with reactive isocyanate group (NCO) as antimicrobial finishing agents via dipping–padding–drying process. The results showed that ISB and IQAS can be covalently bound onto the cotton fabric surface, imparting exellent antifouling activity and bactericidal activity, respectively. The dually finished cotton fabrics exhibited excellent bactericidal and antifouling performance without significantly affect their water vapor permeability and air permeability. All the finished cotton fabrics exhibited improved breaking strength, tearing strength, bursting strength and hydrophilicity compared to raw cotton fabrics. Atomic force microscope research results indicated that the adhesion force between bacterial and finished cotton fabric surfaces increased with the QAS content, and they can be tailored by changing the ISB/IQAS ratio. Most importantly, non-leaching antimicrobial and antifouling cotton fabrics did not induce skin stimulation and toxic effects to animals because ISB and IQAS were chemically bound to cotton fabrics, ensuring that

* Corresponding author.
E-mail address: csg@szu.edu.cn (S. Chen).
[1] These authors contributed equally to this work and should be considered co-first authors.

https://doi.org/10.1016/j.cej.2017.10.168
Received 14 August 2017; Received in revised form 19 October 2017; Accepted 30 October 2017
Available online 02 November 2017
1385-8947/

our finishing method have great potential for industrial and healthcare applications, including but not limited to fabrics, surgical equipment water purification systems, packaging and public health settings.

1. Introduction

Breathable and comfortable cotton fabrics remain the most popular clothing fabrics due to their excellent moisture management properties owing to large number of hydrophilic functional groups present in their molecules [1]; however, porous and good hydrophilic cotton fabrics provide an appropriate environment for the survival and reproduction of microorganisms [2]; and pathogenic bacteria can proliferate rapidly on the fabric to form bacterial plaques/biofilms under certain conditions, leading to unpleasant odor, stains, or discoloration, reduced fabric wearability and increased cross contamination probability [3]. Especially fabrics used in hospitals are highly susceptible to pathogenic organisms and they serve as vehicles to transmit infectious diseases among patients and medical personnel [4].

To remedy this issue, considerable efforts toward the development of antimicrobial cotton textiles, and various antimicrobial finishing agents, such as quaternary ammonium compounds [5–7], *N*-halamine [8–11], poly(hexamethylene biguanide) [12,13], chitosan [14,15], metals and metal salts [6,16], metallic oxide [17,18] have been developed to finish the cotton fabrics, and many achievements have been obtained. Usually, the biofilms are notoriously resistant to disinfectants and antibiotics, and they are threatening human health [19]. Therefore, it is of great importance to obtain antimicrobial surfaces which inhibit biofilm formation. Zwitterionic betaines have received great attention due to their antimicrobial activities, biocompatibility, and excellent nonfouling properties [1,20,21]. However, small number of pathogenic bacteria passing through strong antifouling surface are still unavoidable, so nonleaching bactericidal surface is essential to render permanent bactericidal activity [5]. Therefore, to achieve the excellent antimicrobial effect, antifouling surface should be provided to prevent biofilm formation, and the bactericidal surface should be provided to rapidly kill the contacted and invasive pathogenic microbes. i.e., repelling the bacteria first and then kills the invasive bacteria.

Based on the above analysis, we report a rapid, environment-friendly, and cost-effective finishing method to prepare and cotton fabric surfaces with antifouling and bactericidal activities based on synergic “repel-and-kill” approaches using a zwitterionic sulfopropylbetaine with isocyanate group (ISB) and quaternary ammonium salt (QAS) with isocyanate group (IQAS) as antimicrobial finishing agents via dipping-padding-drying process. The bound zwitterionic sulfobetaine surface can reduce the initial bacterial attachment and delay colonization of microbes on fabric surfaces, resulting in the prevention of biofilm formation. The bound QAS can rapidly kill the invasive and contacted pathogenic microbes, rendering perdurable bactericidal activity. Additionally, finished cotton fabric with durable antifouling and bactericidal activities did not significantly affect its mechanical properties, water vapor permeability (WVP) and air permeability.

2. Results

2.1. Preparation of finished cotton fabrics and structural characterization

ISB was synthesized using the method of our previous work [1] (Scheme S1a, Supporting information). IQAS was synthesized by a

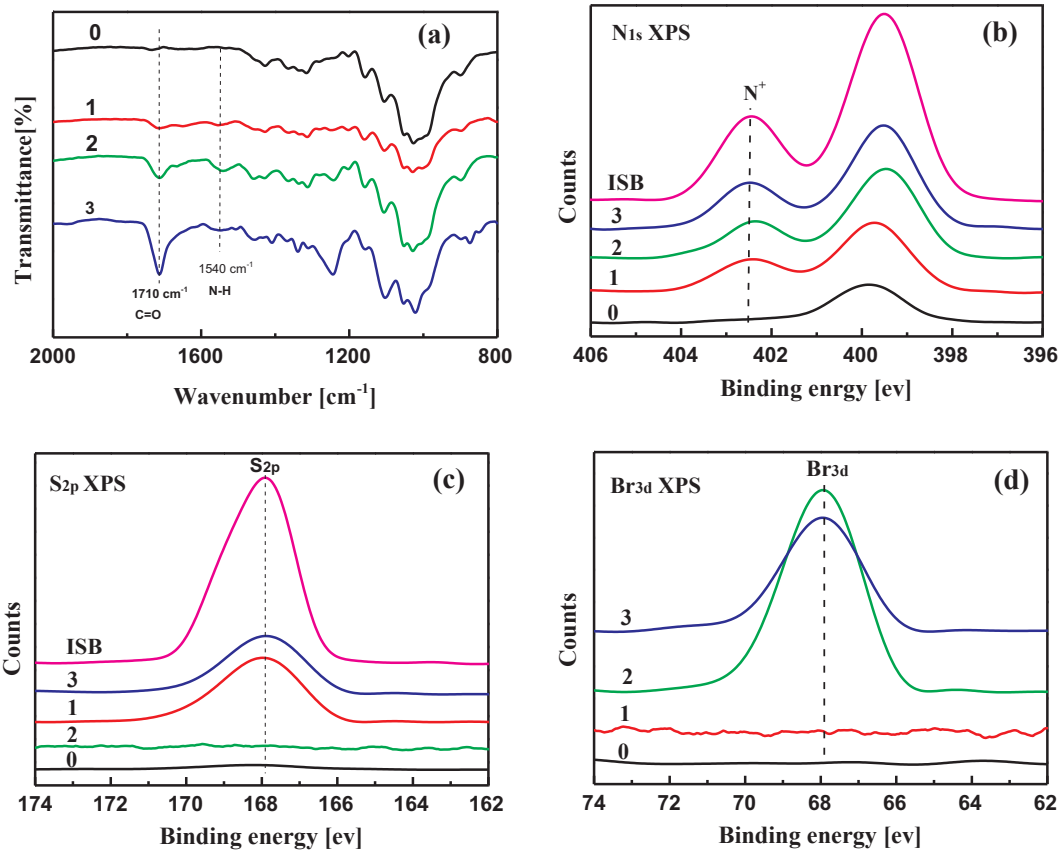


Fig. 1. Structural characterization. (a) FTIR, (b) N1s XPS, (c) S2p XPS; (d) Br3d XPS.