Hydrophobic Coating on Woven Material for Personal Protective Equipment

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Abstract. The performance of personal protective equipment fabrics for COVID-19 health care practitioners was improved by polyvinyl alcohol (PVA) coating. The PVA enhances fabric's resistance to body fluid penetration, on the other hand, also increases its hydrophilic properties. However, hydrophobic is required to prevent microdroplets and body fluid wetting on the fabrics. The hydrophobic effect was increased by immersed the fabrics in silica nanoparticles that resulted in a water contact angle of 133.41° ± 10.8°.

1. Introduction
An increasing number of people infected by the viral spread of Covid-19 has proportionally increased the demand for personal protective equipment (PPE). Especially, PPE is necessary for health workers who deal with a higher risk of infection. For spread prevention of Covid-19 infection, people need at least a mask protection [1]. Therefore, wearing PPE is feasible to control and prevent disease transmission [2].

The complete PPE kit includes a face shield, goggles, mask, gloves, head cap, shoe covers, combined with a gown or coveralls [3]. The Covid-19 coveralls for viral protection materials typically used are polypropylene, polyester, polyethylene, and cellulose in forms of nonwoven or woven fibers [4], because these materials potentially fulfill the required properties for coveralls like durability, hydrophobicity, and permeability [5].

Initial fabrics pore condition was permitted water penetration and microorganism. On the other hand, Polyvinyl alcohol (PVA) coating is a hydrophilic polymer with excellent film-forming properties that cover fabric pores [3]. The presence of hydroxyl groups on PVA treated fabric might increase the wetting behavior [6]. Because of improved hydrophilicity of PVA coated fabric, PPE hydrophobicity is desirable to prevent microdroplet and body fluid attachment on fabrics surface [7].

Hydrophobicity of PPE materials was measured by a contact angle between a water droplet and fabric surface that defined as a water contact angle (WCA). The WCA of hydrophilic and hydrophobic effect on the surface of the fabric are indicated with values lower than 90° and higher than 90°, respectively [8]. The maximum 156.84° ± 1.5° WCA of the fabric with superhydrophobic properties was achieved on a cotton surface coated using SiO2 nanoparticles and PVA with boric acid as the
crosslinker [9]. In this study, adsorption of nano-silica after PVA coating was conducted to observe the hydrophobic effect of the treated fabric.

2. Materials and Methods

2.1. Materials

Micro taffeta woven fabric was used as raw materials for PPE. Polyvinyl alcohol (PVA) (Catalogue Number 1.14266.0100, Merck, New Jersey, United States), ethanol (Catalogue Number 1.00983.1000 Merck, New Jersey, United States) solvent-based colloidal nano-silica (SB-nano-silica) (Catalogue Number GE7631869B, MaxLab, Tangerang, Indonesia) and Teepol (Citra Sari Kimia, Jakarta, Indonesia) were used as coating treatment materials.

2.2. Preparation of PVA Solution

PVA solution was prepared by mixing PVA with 200 mL deionized water and heated to a temperature of 80°C for 1.5 hours in a 500 mL (Catalogue Number TE32, Asahi Glass, Indonesia) beaker and stirred about 300 to 400 rpm using a 6 cm magnetic stirrer bar. The solution then was conditioned at room temperature to dissolved bubbles that were obtained during stirring.

2.3. Preparation of Woven Fabrics

The woven fabric with a size of 7.5 × 7.5 cm was soaked into 15% wetting agent Teepol solution for 15 minutes followed by air-dried for 3-5 minutes. Then, the PVA solution was coated on the fabrics by poured the solution on dried fabrics and padded with a roller pad. Next, coated fabrics are cured in a 160°C oven for 50 minutes. The cured coated fabric then was soaked in 10% SB-nano-silica for 15 minutes and dried again in a 120°C oven for 20 minutes.

2.4. Characterization

Hydrophobicity of the coated fabric as indicated by water contact angle (WCA) value, was measured by taking images of 5µL water droplets with a DSLR camera (Nikon D700, Minato-ku, Tokyo, Japan). The formed droplets angle image was measured with FIJI ImageJ Software [10]. Formation of functional groups between PVA, SB-nano-silica, and the fabric was measured by Fourier transform infrared (FTIR) spectroscopy on (Perkin Elmer, Spectrum 2 FTIR).

3. Results and Discussion

3.1. Water Contact Angle (WCA)

The initial average WCA value prior fabric/PVA coated is 55.65° ± 5.3°. The average WCA value post fabric/PVA soaked in SB-nano-silica solution is 133.41° ± 10.8°. Results indicated that post-treatment improved the hydrophobicity of the fabric (Figure 1). With visual illustration between initial and treated fabric condition is shown in Figure 2.

![Figure 1. WCA value of fabric/PVA and fabric/PVA/SiO2 p = 0.0003.](image-url)
Figure 2. Water droplet of fabric/PVA (a) and fabric/PVA/SiO₂ (b).

3.2. FTIR Analysis
FTIR spectra of control and treated fabric are shown in Figure 3. Strong C=O symmetric stretching of the carbonyl groups at 1712 cm⁻¹ showing ester bonds of polyester fabric (black plot). The carboxylate anion gave rise to an asymmetric stretching small band at 1575 cm⁻¹. The weak C−H bending and intense C−C bending vibrations at 723 and 871 cm⁻¹ showing benzene rings in the polyester fabric [11].

Figure 3. FTIR spectra of fabric, Fabric/PVA, and Fabric/PVA/SiO₂.
For PVA treated fabric, C=O stretching vibration band at 1709 cm⁻¹, C−O−C stretching vibration band at 1087 and 1246 cm⁻¹ show the presence of ester linkage (red plot). The strong peak at 3310 cm⁻¹ indicates PVA contributes to the hydroxyl groups and shows the existence of an intermolecular O−H bond [6].
The peak at 1086 cm⁻¹, 844 cm⁻¹, and 472 cm⁻¹ for PVA and SB-nano-silica treated fabric shows Si−O−Si asymmetrical stretching band, symmetric stretching, and bending vibrations bands, respectively (blue plot) [12]. The peak at 3298 cm⁻¹ not as strong as the fabric/PVA, indicates hydroxyl groups have condensation to form silanol bridges.

4. Conclusion
Hydrophobic coating on woven fabric has increased the water contact angle of treated fabric and functional groups confirmed by FTIR analysis. This treated fabric could be potential as the raw material for personal protective equipment. Further research and development are required to improve prototyping and industrial scale-up process.
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5. References
[1] Covid- W H O 2020 Advice on the use of masks in the context of COVID-19 Who 1–5
[2] Hick J L and Thorne C D 2006 Personal Protective Equipment Disaster Med. 246–54
[3] Pingan H, Mengjun J, Yanyan Z and Ling H 2017 A silica/PVA adhesive hybrid material with high transparency, thermostability and mechanical strength RSC Adv. 7 2450–9
[4] Kilinc F S 2015 A Review of Isolation Gowns in Healthcare: Fabric and Gown Properties Physiol. Behav. 10 180–90
[5] Dolez P I and Mlynarek J 2016 Smart materials for personal protective equipment: Tendencies and recent developments (Elsevier Ltd)
[6] Natarajan S and Jeyakodi Moses J 2012 Surface modification of polyester fabric using polyvinyl alcohol in alkaline medium Indian J. Fibre Text. Res. 37 287–91
[7] Mahapatra P S, Chatterjee S, Tiwari M K, Ganguly R and Megaridis C M 2020 Surface Treatments to Enhance the Functionality of PPEs Trans. Indian Natl. Acad. Eng. 5 333–6
[8] Song J and Rojas O J 2013 Approaching super-hydrophobicity from cellullosic materials: A Review Nord. Pulp Pap. Res. 28
[9] Jannatun N, Taraqqi-A-Kamal A, Rehman R, Kuker J and Lahiri S K 2020 A facile cross-linking approach to fabricate durable and self-healing superhydrophobic coatings of SiO2-PVA@PDMS on cotton textile Eur. Polym. J. 134 109836
[10] Schindelin J, Arganda-Carreras I, Frise E, Kaynig V, Longair M, Pietzsch T, Preibisch S, Rueden C, Saalfeld S, Schmid B, Tinevez J-Y, White D J, Hartenstein V, Eliceiri K, Tomancak P, and Cardona A 2012 Fiji: an open-source platform for biological-image analysis Nat. Methods 9 676–82
[11] Gashti M P and Ebrahimi I 2011 Radiation Effects and Defects in Solids: Incorporating Plasma Science and Plasma Technology Influence of atmospheric-air plasma on the coating of a nonionic lubricating agent on polyester fiber Radiat. Eff. Defects Solids 166 37–41
[12] Pirzada T, Arvidson S A, Saquing C D, Shah S S and Khan S A 2012 Hybrid silica-PVA nanofibers via sol-gel electrospinning Langmuir 28 5834–44