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Research Article

DEVELOPMENT OF HYDROPHOBIC NONWOVEN FABRIC FOR OIL SPILL AND MEDICAL APPLICATIONS

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ABSTRACT

The objective of this study to develop needle punched cotton nonwoven fabric followed with modifying super hydrophobic and oleophilic property using Toluene -2,4 diisocynate (TDI) agent by pad-dry-cure method. Both the hydrophobicity and oleophilicity of treated bamboo fabric was controlled by adjusting the concentration of TDI. It was found that with an increase in the TDI content, the hydrophobicity and oleophilicity of bamboo fibre surface increased; there by exhibiting oil sorption ability. The effect of surface wetting behavior on oil and water sorption efficiency of the fabric and antimicrobial property was studied. The results show that the developed hydrophobic and oleophilic property of fabric exhibit oil absorption capacity of approximately 10.5 g/g and 96.28 weight % of oil-water separation efficiency with strong durability and mechanical strength. The bacteriostatic rates of natural bamboo fiber based fabric against the bacteria were 40.2%; that of treated fabric were 95.0%.

Key words: Bamboo fabric, Toluene -2,4 diisocynate, Oil sorption, Antimicrobial property, Super hydrophobic, Medical textile

INTRODUCTION

Super hydrophobic fibrous materials are those having surfaces that are really difficult to wet, with water contact angle of > 150° have found numerous potential practical applications such as self-cleaning surface, prevention of the adhesion of snow and others. Self-cleaning surfaces, for their suitability in less soiling and washing requirement, have drawn much attention. Especially, medical textiles need super hydrophobicity to protect infection by pathogenic fungus[1-2]. Among the methods to develop the self-cleaning textiles, fabrication of textiles surface having the binary structure like lotus leaf surface for a separating oil from water, cleaning water from oil contaminants has recently been of particular interest[3].

Since the hydrophobicity of surface is determined by its chemical composition surface roughness, the super hydrophobicity can be obtained by lowering the surface tension and by enhancing the surface roughness[4-5]. Various approaches have been used to obtain super hydrophobicity on cellulosic material treating with acrylic, silicone[6], and diisocyanate[7] based chemical agents and others[8]. A cellulosic based fibrous material is greatly hydrophilic, is more benefited to modify hydrophobic. Modification of bamboo to make it super hydrophobic extends the use of bamboo even further to various other end uses, like water repellent, self-cleaning fabric, oil spill clean-up where would repel the water and absorb the oil.

Especially, textile products contaminated by pathogenic microorganism play the main part of medium causing transmitted virus. Surgical gown, nurse uniform, bed sheet in a hospital room deliver virus of patient to other place and they are attracting the cause of nosocomial infection[9-10]. Therefore, utilizing super hydrophobic textile is recommended to minimize virus transmission by patient's blood and physical secretion. Other advantages of super hydrophobic material are adsorption and purification of water from oil products. We consider sorbents are used for oil leakage elimination and for purification of oil-containing waste water from oil-processing and oil-mining plants.

In this work, we develop a novel method of imparting hydrophobic and oleophilic properties to cellulosic materials by pad-dry-cure method. Bamboo fibre is a cellulosic fibre with slight antimicrobial, hydrophilicity and oleophilicity. As part of our efforts to develop expanded uses of bamboo by products, we are conducting a series of reactions on bamboo with Tolylene -2,4-diisocyanate to produce chemically modified polymeric materials. In consequence of such treatment the surface of bamboo fibre is modified with replacing the OH groups into NCO groups of the diisocyanate to form covalent bond. We consider modified fibrous materials that can be used both for medical and oil separation applications.

MATERIALS AND METHODS
Materials

Needle punched nonwoven fibrous materials were prepared with 100% Bamboo fibre had a staple length of 30 mm and a micronaire value of 5.1. The parallel laid webs were produced using a laboratory carding machine. Then the webs were punched on DILO needle loom, od-11 /6, cbf/6 lab model using 15*18*32*3.5 cb needle board. The fabrics were processed at a linear speed of 1.5 meters/min using 150 strokes /minute. Fabric thickness was controlled in the range of 4mm. Tolylene -2,4-diisocyanate (2,4 -TDI) purchased from Sigma – Aldrich. Engine oil from Hindustan petroleum products. These chemicals are of laboratory grade and there is no need of further purification.

Methods

The nonwoven fabric was impregnated in various concentration of aqueous solution of tolylene -2,4-diisocyanate (5%, 10%, 15%, 20%, 25%) in an organic solvent, then squeezed with a wet pick of 80% and dried in oven to constant temperature. After drying the fabric is passed into curing chamber for fixing the NCO group of TDI into OH group of bamboo.

The changes in surface morphology of the coated and washed samples were analyzed by scanning electron microscopy (SEM) using JSM 6360, Jeol, Japan with an accelerating voltage of 4.0 kV and 100 x magnification.

FTIR Spectroscopy offers a very convenient way to identify finish from textiles. The basis for FTIR Spectroscopy is the structural information about a compound that can be found from its infrared spectrum. The FTIR Spectra was recorded in the range of 4000-400 cm^{-1} on FTIR 8000 S Spectrometer.

The physical property related to comfort of processed sample was measured with water vapor transmission rate (ASTM E 96) and air permeability (ASTM D 737). Water repellent property was measured using spry test and water contact angle.

Escherichia coli (E. coli, 8099), gram-positive and negative bacteria, staphylococcus aureus (S. aureus, ATCC 6538) and fungi Candida albicans (C. albicans, ATCC10231) were used as test organism. Nutrient Agar and Nutrition Broth culture medium were prepared for the bacteria growing and Sabouraud's Agar culture medium was used for the fungi culture. Buffer solution used for diluting was phosphate buffer solution. The antibacterial activity was tested with the shake flask test referring to GB/T 20944. 3-2008 Textiles-Evaluation for antibacterial activity-Part 3: Shake flask method.

The fabric sample (1 g) was place into a stainless-steel mesh weighed before and immersed in different oils at room temperature. At given time period, the sample and the mesh were separated from the oil, drained for 20 seconds and wiped with filter paper to remove excess oil from the bottom of the mesh. The oil absorbency of the fabric was determined by weighing the samples before and after the absorption, by the following equation (1). All oil absorbency was measured five times and an average value was used.

$$Q = \frac{m_2 - m_1}{m_1} \text{............Equ.,(1)}$$

Where, Q is oil absorbency calculated as grams of oil per gram of sample (g/g of fibre material), m_1 and m_2 are the weights of sample before and after oil absorption, respectively.

RESULT AND DISCUSSION

Surface Morphology of Fabric

Scanning electron micrograph of the treated fabrics is shown in Figure 1. The figure 1 shows that the surface of the treated fabric seems to be clear that the TDI solution coated the surface of the fibre without damaging the porous structure. However, the wettability of the fabric was transformed from hydrophilic to highly oleophilic and hydrophobic. Diesel oil can easily wet the treated nonwoven fabric and therefore penetrate through the porous media.

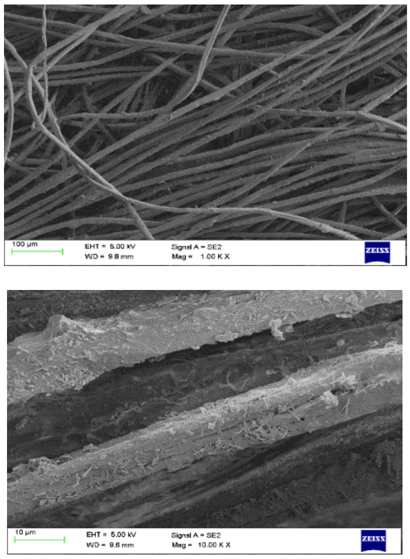

Figure 1: SEM image of treated nonwoven fabric

Chemical Structure Analysis of Fabric

The IR spectra obtained for HPMC polymer treated fabric is presented in Figure 2. The IR absorption bands and their tentative assignments are given in Table 3. In TDI treated fabric, the C-H stretching vibration exhibited in the region at 2975-2815 cm^{-1}. Incorporation of TDI in fabric shows in Figure 2 followed by drying and curing resulted in strong additional band due to NCO group 2, 4 TDI at 2272 cm^{-1} . The characteristic absorption for O-H stretching was observed at 3298cm^{-1}. The area of absorption in 3250 – 3300 cm^{-1} corresponds to the -NH related bond, another band at 2922 cm^{-1} indicated the presence of OH stretching vibrations corresponding to bonded OH and NCO groups. Absorption due to aromatic compound of TDI was observed at 2900-3100 cm^{-1}, which confirms the reaction between OH groups of cellulosic and NCO groups of TDI.

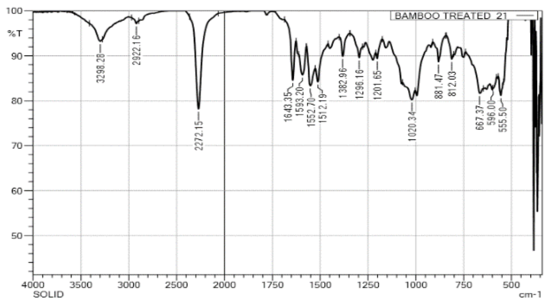

Figure 2: FTIR spectra of TDI treated nonwoven fabric

Water Repellence property

To evaluate the effect of roughness on hydrophobic nature of the surface, TDI based samples prepared by conventional finishing method were coated with various concentration of TDI. AATCC test method 193- 2005 was done on samples to evaluate the effect of roughness and low surface energy material. It can be concluded from Table 1 that 15%(v/v) TDI gave the highest rating but lowering the concentration to 5 % (v/v) had a weakening effect. This happens because the molecule attraction on drying and curing. To see the effect of roughness on hydrophobic nature, the sample with water repellence rating was tested using spray test. First the sample holders were run blank then with different samples for same duration of time. Water penetrated through sample was noted down. Less the amount of water penetrated more is the water repellent effect. However, formation of covalent bond with the help of TDI, provided appropriate roughness to the surface. Rating achieved with combined effect of roughness and 5 % TDI is 80 which is very close to rating 90 of 15 % TDI alone. Table 1 clearly shows that fabric treated with TDI using finishing liquor gave hydrophobic effect to the bamboo fabric because water penetrated is much less as compared to control fabric. The Water Contact Angle (WCA) of each fabric surface were measured, they initiate that the WCAs for CBF, TBF-5, TBF-10, TBF-15, TBF-20, and TBF-25 were 77°, 106°,136°, 154°, 156° and 156°, respectively. These results, along with the results of various other experiments, show that TDI containing OH and NCO groups are good candidates for creating hydrophobic surfaces.

Table 1: Spray rating and water contact angle of treated fabric

Fabric Code	Spray Rating (SR)	Water Contact Angle (WCA)
*CBF	60	77°
**TBF-5	80	106°
TBF-10	90	136°
TBF-15	90	154°
TBF-20	95	156°
TBF-25	95	156°

*CBF – Controlled Bamboo Fabric

**TBF – Treated Bamboo Fabric (Number represents concentration of TDI content)

Antibacterial property

The results of the antibacterial test are shown in Table 2. The untreated bamboo as the negative control sample was slight effective against bacteria, while the TDI treated fabric was very effective against all test bacteria with a bacteriostatic rate of over 95% against E. coli and 92.8% against S. aureus and C. albicans, indicating dependability of this test. The results showed that natural bamboo fiber was not effective against E. coli, S. aureus and C.albicans since the bacteriostatic rate against all of them was proportionally increasing with TDI concentration. By comparison, the bacteriostatic rate of 15% TDI treated fabric against S. aureus was over 88.4%, and that of 5% was 75.8%.

Table 2: Antibacterial property of treated fabric

Fabric Code	Bacteriostatic rate (%)		
	Escherichia coli	Staphylococcus aureus	Candida albicans
*CBF	40.2	72.8	0 (-10.7)
**TBF5	52.4	75.8	21.6
TBF10	58.2	84.3	58.2
TBF15	90.6	88.4	64.6
TBF20	92.5	90.0	75.0
TBF25	95.0	92.8	78.4

*CBF – Controlled Bamboo Fabric

**TBF – Treated Bamboo Fabric (Number represents concentration of TDI content)

Oil absorbency

Table 3 shows the engine oil absorbency of bamboo nonwoven fabric treated with 2,4-TDI solution. The OIL absorbency of the treated fabric increases with increase in the concentration of 2,4-TDI, but steadily maintain with the further increase in treatment concentration up to 20%. The steady state of the maximum oil absorbency is especially evident for TDI-treated fabric was 17.4 g/g than controlled fabric was 8 g/g oil absorbency. The result shows that developed fabric with TDI treated exhibited the highest oil-water separation efficiency and reached 94.82%.

Table 3: Oil sorption behaviour of treated fabric

Fabric Code	Oil Absorbency g/g	Oil – Water Separation Efficiency %
*CBF	8.02	56.82
**TBF5	12.48	74.06
TBF10	14.84	86.25
TBF15	16.20	90.85
TBF20	17.42	94.46
TBF25	17.87	94.82

*CBF – Controlled Bamboo Fabric

**TBF – Treated Bamboo Fabric (Number represents concentration of TDI content)

CONCLUSION

The functional textiles such as super hydrophobic textile fabrics can be used as barrier to prevent from harmful substance, blood and diverse emission. In this study, super hydrophobic textiles having bamboo fibre based nonwoven fabric were treated with TDI as water-repellent agents. The linear relationship between the nonwoven fabric moisture and the bacteriostatic rate mentions that the hygroscopic may be a manipulating factor in antibacterial performance of fabric. The TDI treated fabric increases the efficiency of oil sorption, and capacity for oil and water separation efficiency.

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