Original Research Article

Bentonite nanoclay assisted hydrophilic nylon fabrics

ABSTRACT

Aims: Biomimetic surface modifications have gained significant attention in fabric innovations. In this study, elephants mud bathing was mimicked to create a superior hydrophilic nylon fabric.
Place and Duration of Study: Sri Lanka institute of nanotechnology and University of Moratuwa, Sri Lanka, between June 2017 and March 2018.
Methodology: Bentonite nanoclay was grafted on nylon using silane as a coupling agent. Fourier transform infrared spectrophotometry, Scanning electron microscopy, Energy dispersive X-ray spectroscopy and thermogravimetric analysis confirmed the successful grafting of nanoclay on nylon while the wettability was proved using textiles protocols.
Results: Infrared spectroscopy and elemental analysis confirmed the presence of organic chains and Si groups in bentonite nanoclay modified nylon fabrics. The accomplishment of the surface modification was quantitatively proved by thermogravimetric analysis. SEM images clearly show a thin layer of clay on nylon fibres after being treated with bentonite nanoclay. BNC coated nylon show superior wettability and dryability results. **Conclusion:** It is expected that this bio-inspired wettable nylon fabric may break the barrier of using nylon in various hydrophilic textile applications.

Keywords: Bentonite nanoclay; Biomimetic; Surface modifications; Nylon

1. INTRODUCTION

Moisture management is one of the key performance criteria in today's apparel industry [1]. However, high demanded synthetic fabrics such as nylon are lack in moisture management property due to their hydrophobic nature. Nylon fabrics are excellent in mechanical, thermal, and chemical properties. Yet, Nylon fabric is weak in particular properties such as anti-electrostatic property, lack of comfortable touch with human skin, and low moisture regain [2]. Hence, new chemistries for surface modifications in creating hydrophilic nylon fabrics to meet market needs have received much attention [3, 4]. Nature always provides sustainable, cost-effective, and flexible alternatives for various problems of the eco system [5, 6]. By mimicking the nature's way of cooling elephant's body temperature using mud, nanoclay was identified as an ideal sustainable solution to develop a wettable nylon fabric. The nano size space between adjacent platelets of bentonite nanoclay (BNC) comprises of exchangeable cations, which draw water and form a rigid network made up of water layers [7, 8]. Hence, this nanospace is vital for BNC's incomparable hydrophilicity. In this study, a silane coupling agent couples BNC and nylon with the intention of increasing hydrophilic properties of nylon.

2. METHODOLOGY

Purified nylon was stirred in 2 mmoldm-3 of (3-Glycidyloxypropyl)trimethoxysilane solution for 1 hour. APTES modified fabric was padded and cured at 110 °C and washed thoroughly. A dispersion of clay was obtained by dissolving 4 g of bentonite clay (Aldrich), in 100 ml of deionized water. BNC of 100 nm size was obtained by ball milling (FRITSCH PULVERISETTE 7-grinder). Then, the fabric was dipped in a dispersion of BNC for 1 hour. Dipped fabric was padded and cured at 110 °C and washed thoroughly. BNC grafted and pristine nylon fabric samples were characterized by Fourier transform infrared spectrophotometry (FTIR), Scanning electron microscopy (SEM) and Energy dispersive X-ray spectroscopy (EDX). Thermogravimetric analysis (TGA) was carried out on an SDT Q600

thermoanalyser (TA Instrument, sample mass ~10 mg; heating rate 10 °C/min; nitrogen flow). Wettability of fabric samples was measured using ASTM TS-018 protocol. A drop of distilled water was allowed to fall onto fabric sample, and the time taken for water to get fully absorbed into the fabric was recorded. The absorptive capacity of fabrics was tested using ASTM D1117-80 protocol. Five samples (76 mm^2) of treated and pristine nylon were weighed and dipped in distilled water for 5 min and hung vertically for another 5 min to allow extra water to drip down. Finally, fabrics were weighed again. The drying rate of fabric was measured by exposing to 10 µL of water, while in contact with a heated plate set to 37 °C (human body perspiring temperature). To check the stability of BNC coating on nylon, 20 washing cycles were performed at 50 °C with non-ionic detergent Ultravon CN Ciba for 45 min (AATCC 61 (2A)).

3. RESULTS AND DISCUSSION

(3-Glycidyloxypropyl)trimethoxysilane was employed as a coupling agent and the methoxy groups first hydrolysed into hydroxyl, and react with hydroxyl groups on the surface of BNC, forming a stable Si–O–Si bond on drying. **react with hydroxyl groups on the surface of BNC, forming a stable Si–O–Si bond on drying**. Epoxy silane contains a reactive epoxy group could react with secondary amines in nylon fabric [9]. The reaction process is shown in Fig. 1. The presence of characteristic absorption bands in FTIR spectra of BNC grafted nylon proves a new bond formation between silane modified BNC and nylon fabric. Successfully grafted epoxy silane on BNC can be confirmed by a group of absorption bands in 3000–2800 cm^{-1} in spectrum E (Fig. 2). This absorption is attributed to the valence vibration (CH) of propyl chain in epoxy silane. Absorption band in 1095-1075 cm^{-1} in spectrum B (Fig. 2.) shows the strong broad band which is attributed to valence vibration of Si–O–Si. Blue colour region in spectrum D (Fig. 2.) shows a broad intense absorption band (above 3420 cm^{-1}) due to vibrations of OH^- groups in water molecules of clay, participating in the formation of hydrogen bonds. In spectrum D (Fig. 2.), intensive bands in approximately 1095-1075 cm^{-1} represent the asymmetric stretching of siloxane groups (Si–O–Si) [10]. Hence, FTIR spectra show that nylon has been modified by clay successfully.

Comment [P1]: Repetition?

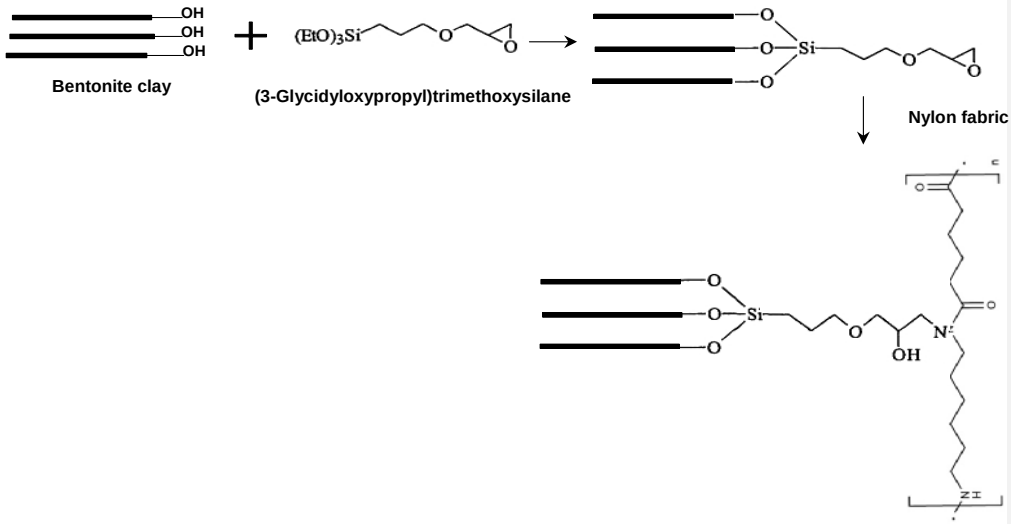

Fig. 1. The reaction process of silane functionalized BNC reacting with nylon fabrics

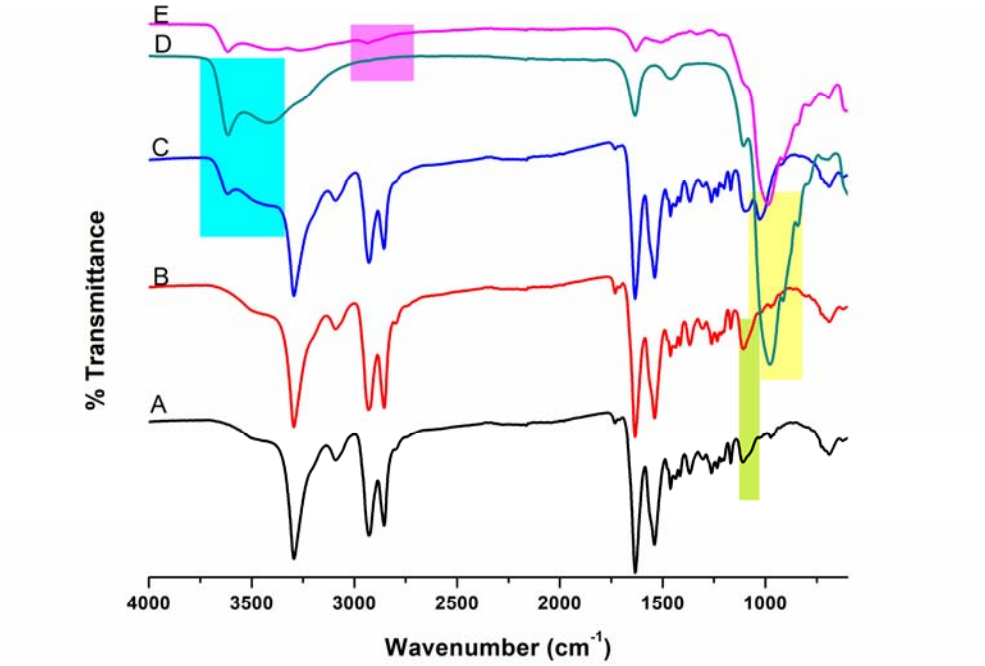

Fig. 2. FTIR spectra of (A) pristine nylon, (B) silane modified nylon, (C) BNC functionalized nylon (D) BNC and (E) Epoxy modified BNC.

SEM image of pristine nylon fabric (Fig. 3. A) indicates a smooth fibre surface after the purification. SEM images in Fig. 3. B and C clearly show a thin layer of BNC on nylon fibres after being treated with BNC. After the tenth washing cycle, the surface morphology (Fig. 3. D) is same as the unwashed sample. BNC grafted nylon was further proved by EDX analysis (Fig. 4.) showing presence of significant amounts of silicon, aluminum, calcium, sodium, and magnesium elements.

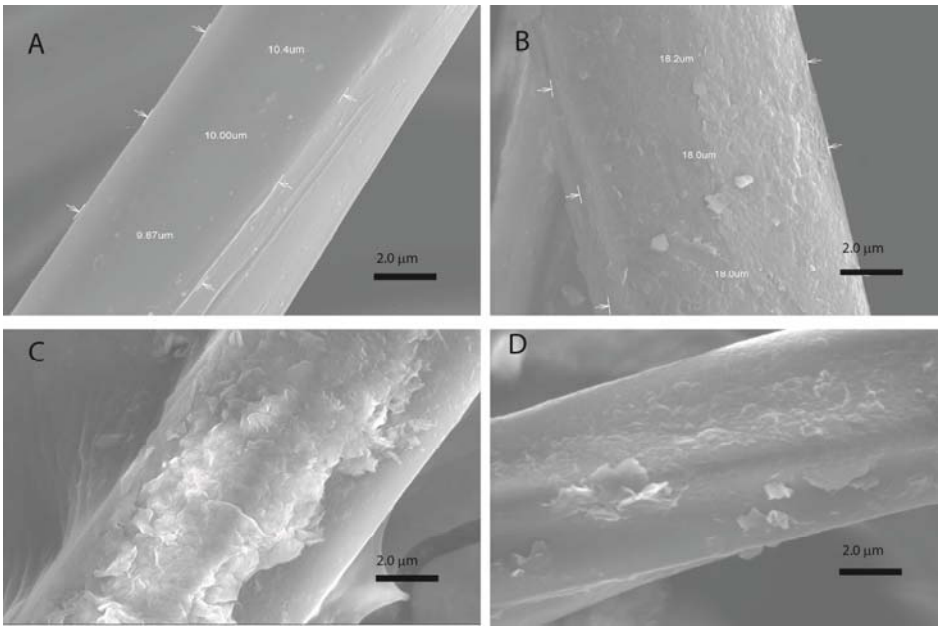

Fig. 3. SEM images of (A) pristine nylon, (B) (C) BNC modified nylon and (D) washed BNC grafted nylon.

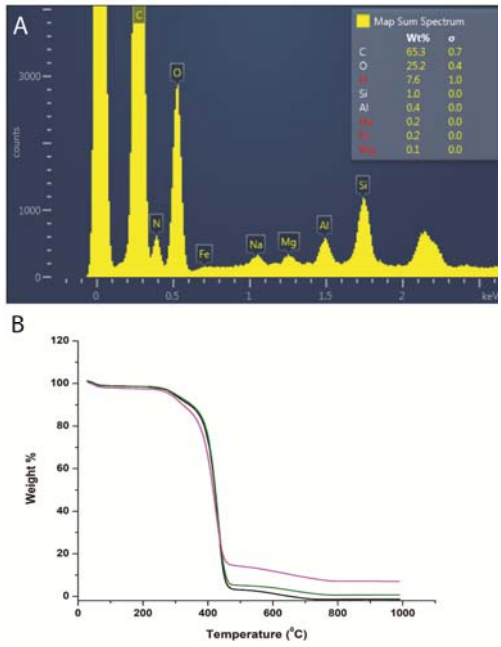

Fig. 4. (A) SEM-EDX spectrum of BNC functionalized nylon and (B) Thermograms for pristine nylon (Black), silane functionalized nylon (Green) and BNC grafted nylon (Purple).

The resulted thermograms show that pristine nylon fabric (Fig. 4. (B) Black) undergoes thermal degradation beginning at 452 ˚C and with a total mass loss of 98%. However, silane modified nylon (Fig. 4. (B) Green) undergoes the same degradation, with a lesser mass loss of 97% compared to pristine nylon. It is due to the organic and inorganic Si contents in (3-

Glycidyloxypropyl)trimethoxysilane. BNC modified nylon fabric (Fig. 4. (B) Purple) undergoes the same degradation with even a lesser mass loss of 94% compared to silane modified nylon fabric. The 6% residue remain is due to BNC bound to nylon fabric.

Table 1. Standard protocol test results for wettability.

	Pristine nylon	BNC grafted nylon	10 times washed BNC grafted nylon
Wettability test (s)	30.20	0.00	0.00
Absorptive capacity (%)*	112	280	271
Drying rate (ml/h)**	0.07	0.10	0.10

*(B-A)/A

**0.010/drying time

Excellent wettability, water absorptive capacity and drying rate of BNC grafted nylon (Table 1.) confirm the superior wettability of the nano modification due to instant diffusion of water into nanospace and clinging of water with hydroxyl groups on the surface of BNC. The surface morphology and the wettability of 20 times washed BNC grafted nylon remained same as before wash samples confirming the covalent bond between the fabric and the coating. In fact, the siloxane bond between (3-Glycidyloxypropyl)trimethoxysilane and BNC, and the amide bond between BNC and polyester fabric, have given the best adhesion and washing resistance properties to the treated nylon fabric [11].

4. CONCLUSION

FTIR spectrum confirmed the covalent bond network in (3-Glycidyloxypropyl)trimethoxysilane modified BNC coated nylon fabric. SEM images also show the occurrence of surface modification. BNC coated nylon showed superior wettability and dryability results.BNC coating on nylon appears as a convenient green modification route to produce a wettable nylon which can be used for many hydrophilic fabric applications apart from its excellent ability to substitute expensive natural fibre usage in clothing.

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