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Nanotitania/mulberry fibers as novel textile with anti-yellowing and intrinsic antimicrobial properties

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Abstract

The present work for the first time introduces a new class of textile consisting of mulberry fibers uniformly laden with titania nanorods. This unique natural-synthetic composite textile is self-cleaning and environmental friendly. The utilized composite was characterized by scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDX), X-ray diffraction pattern (XRD), electron probe microanalysis (EPMA), transmission electron microscopy (TEM), thermogravimetric analysis (TGA) and UV–vis diffused reflectance spectrum (UV-DRS). The SEM images clearly show homogeneous distribution of titania nanorods on the surface of mulberry fibers (MF). XRD and FTIR results confirm the presence of titania in the composite materials. Antimicrobial potential and UV protection due to presence of titania nanorods on MFs was investigated in this study. Results of this investigation indicated that MFs-TiO_2 composite exhibit admirable antibacterial activity. From the antimicrobial kinetic test on *E. coli*, it was established that the composite textile possess improved bactericidal activity than pure mulberry textile. Moreover, titania present on the mulberry fibers impart anti-yellowing, self-cleaning properties, which were endorsed due to the scattering effect of UV radiation by titania nanorods. Thus our study provides the clue/grounds to select mulberry fibers/titania composite as a material of choice for fabrication of promising antimicrobial future textile.

Keywords: Mulberry fibers; Titania nanorods; Future textile; Anti-yellowing; Antimicrobial activity

1. Introduction

The natural fiber composites have recently attracted huge interest and have become highly valuable materials [1]. Natural fibers, for instance, hemp, sisal, jute, kenaf, flax, etc. are nowadays frequently used as reinforcing material for polymer-based matrices [2]. The optimal utilization of natural resources has been increased. Particularly, utilization of natural products has significantly contributed to reduce the environmental pollution as well as the burden of waste disposal.

To this end the natural cellulosic fibers have always received much attention due to their versatile characteristics. Besides, these fibers are frequently used to fulfill various daily life needs. They have been highly preferred in textile industry especially for fabrication of organic fabrics. Among the natural fibers, mulberry bast fibers have many advantages, such as antibacterial function, health protection and good mechanical properties. The fibrous bark of the mulberry trees is used for paper-making, food, additives in optical and pharmaceutical industries, and textile industries. Mulberry (*Broussonetia kazinoki* Siebold), belongs to family *Moraceae*, has frequently been used in various medical applications. Mulberry has been used for reduction of glucose

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level in the blood [3], to decrease the blood cholesterol and lipid level [4,5], as food packaging material [6], for agriculture and horticulture applications [7]. The root bark of white mulberry species has anthelmintic, purgative and vermifuge [8] applications. Its leaf extract also act as antimicrobial agent [9]. Recently mulberry paper has attracted great attention due to its multiple benefits. Hanji, a product of mulberry paper, mainly found in Asian countries such as Korea, Japan, China, Thailand, Philippines etc. It is environmental-friendly natural fiber traditionally used as paper in various applications. Hanji products, (especially made up of Hanji yarns) have several distinguished functions such as antimicrobial, deodorization, fast drying ability of water and sweat, facile dyeing ability and so on. Additionally, Hanji yarn is light-weight and biodegradable, possess good durability, and retains its shape even after repeated washings. In this study we have selected the mulberry fibers (Hanji yarn product) for the synthesis of MFs/TiO_2 nanocomposite with the aim to propose novel textile for organic fabrics.

In spite of numerous fruitful applications of mulberry fibers, the Hanji product has a major disadvantage. It has been observed that Hanji absorbs solar radiations (ultraviolet/and visible light) from sun, which changes physicochemical characters. Due to the light oxidation process, chain scission of polymer through rearrangement of chemical structure occurs [10], which eventually cause yellowing of Hanji. To overcome the aforementioned drawbacks of mulberry fibers we have introduced TiO_2 nanorods as dopant material. Nowadays the light scattering property of titanium dioxide particles has been the subject of substantial research as TiO_2 possesses huge technological applications which often depend on its high light scattering efficiency. Moreover, TiO_2 is being used to impart opacity to a wide variety of products including coatings, paints, plastics, paper, rubber printing inks, synthetic fibers, ceramics, cosmetics, and even toothpaste [11] because of its exceptionally high refractive index and whiteness. Additionally TiO_2 is well known for its UV protection performance [12,13]. Nevertheless, it is well established now, when the morphology is nanosized, the performance can be improved manifolds [14].

Considering the distinctive properties of mulberry fibers and titania, herein we for the first time present mulberry paper composite with well dispersed titania nanorods using facile dip coating method. This introduced material revealed excellent anti-yellowing and antibacterial properties, thus our study presents a new materials in textiles.

2. Materials and methods

2.1. Materials

Natural mulberry fibers (MF, Commonly known as Hanji) were obtained from Jirisan Hanji Co. Ltd., South Korea. The precursors utilized for the synthesis of titania nanorods were polyvinyl acetate (PVAc, Mw=500000 Aldrich, USA), *N, N*-dimethylformamide (DMF, 99.5 assay, Showa Co. Japan), titanium isopropoxide (TIP, 98.0 assay, Junsei Co. Ltd., Japan). For assessing antimicrobial activity microbial *Escherichia coli* KCCM 13821 strain was purchased from Korean Culture Center of Microorganisms (KCCM). Tryptone soya broth (Torlak, Belgrade; BD Diagnostic, Becton, Dickinson & Co., USA) was used as growth medium. All other chemicals and solvents used were of analytical grade purchased from Sigma.

2.2. Titania nanorods synthesis

Titania nanorods were prepared by sol-gel electrospinning method as described elsewhere [15]. Polyvinyl acetate (PVAc, Mw=500,000 Aldrich, USA) solution was prepared by dissolving PVAc in *N, N*-dimethylformamide (DMF, 99.5 assay, Showa Co. Japan) (18 wt%) under magnetic stirring for 8 h at room temperature. 5 g of titanium isopropoxide (TIPP, 98.0 assay, Junsei Co. Ltd., Japan) was taken in a separate bottle and a few drops of acetic acid were added till the solution turns out to be transparent. Then, 6 g of PVAc solution was mixed slowly into the solution under vigorous stirring. The final resulting solution was put in a 10 ml syringe and a voltage of 20 kV was applied to this solution through two electrodes. The as-synthesized nanofibrous mat was initially dried at 80 °C for 24 h under vacuum, subsequently calcined at 600 °C for 2 h in air at a heating rate of 2 °C/min.

2.3. Mulberry paper-titania nanorods composite synthesis

Fibrous papers (1 × 1 cm) made of Mulberry tree bark were dipped in the titania aqueous solution and soaked for 5 min. The samples were then dried at 80 °C overnight under vacuum. The percent add-on on the fabric was calculated as follows: % add-on=$(w - w_0)/w_0 \times 100$. Where w is the weight of the titania treated mulberry paper and w_0 is the weight of pure mulberry paper.

2.4. Characterization

The XRD patterns of pristine MFs and MFs/TiO_2 hybrid mats were recorded on X-ray diffractometer (D/MAX 2500, Rigaku Corporation, Tokyo, Japan) with copper Kα radiation (λ=1.540 Å) over Bragg angles ranging from 10–80 degrees. The operating voltage and current were maintained at 30 kV and 40 mA respectively. The morphological features of samples were observed by a scanning electron microscope (SEM, S-7400, Hitachi High Technologies, Japan). Each specimen was uniformly distributed on carbon tape; Pt coating was applied for 10 s onto the synthesized mulberry/titania composite fibers prior to SEM observation. To get insight into topographical, compositional and morphological view of hybrid fibers, TEM was taken. The chemical composition of hybrid mats was analyzed by energy dispersive X-ray spectrometer (EDX) equipped with SEM apparatus. The light absorbance and color difference value of the samples was measured by using UV–vis diffused reflectance spectrum (UV-DRS, 525 Shimadzu) and colorimeter (X-Rite 8200) to verify anti-yellowing property.