Green Regeneration: Converting Electrospun Cellulose Acetate Fibers to Cellulose

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ABSTRACT

This study presents a novel method for the electrospinning of aligned cellulose acetate fibers and their subsequent regeneration into native cellulose to be used as reinforcement for composite applications. The method involves the use of a 10% (w/w) cellulose acetate solution in a 1:1 binary mixture of acetone and acetic acid, and the use of potassium hydroxide (KOH) as a deacetylation agent. The resulting fibers were characterized by SEM, and the successful regeneration of cellulose fibers was confirmed by FT-IR spectra. The findings of the study indicate that further optimization of the solution content and electrospinning process could lead to the production of high-quality cellulose fibers with great potential applications in green technology.

INTRODUCTION

Electrospinning is a versatile and cost-effective method to produce micro to nano scale fibers with a large surface area to volume ratio, high porosity, and flexibility in surface characteristics. The production of aligned cellulose fibers has been of great interest in various fields due to their unique properties and potential applications [1]. However, the electrospinning of cellulose into fibers has proven to be a challenging task due to the high viscosity and poor solubility of cellulose in common solvents. The high molecular weight of cellulose also makes it difficult to dissolve in common organic solvents. Cellulose molecules are large and entangled, making it difficult to separate them and dissolve them in a solvent.

To overcome these limitations, cellulose acetate (CA) fibers are often electrospun and then deacetylated to regenerate the native cellulose fibers [1,2]. Cellulose acetate is a modified form of cellulose in which some of the hydroxyl groups are replaced by acetyl groups. This modification reduces the hydrophilicity of cellulose and makes it more soluble in common solvents, [2] such as acetone and acetic acid, which can be used in electrospinning.

The regeneration process in this study, involves the use of potassium hydroxide (KOH) as a deacetylation agent to remove the acetyl groups from the cellulose acetate fibers, ultimately reforming the native cellulose. The KOH reacts with the acetyl groups, breaking the ester bond and regenerating the hydroxyl groups, thus creating cellulose fibers. By using this approach, it is possible to benefit from the advantages of electrospinning process while obtaining aligned cellulose fibers. The alignment of fibers improves the mechanical properties, increases the surface area, and enhances the performance of the material.

RESULTS AND CONCLUSIONS

In this study, a solution of 10% (w/w) cellulose acetate in a 1:1 binary mixture of acetone and acetic acid was successfully electrospun. The fibers were characterized using a Scanning

Electron Microscope (SEM) and the micrograph (Fig 1. (a)) shows their alignment with an average diameter of 1 µm. The cellulose acetate fibers were then deacetylated using KOH, to convert it to cellulose.

A Fourier Transform Infrared (FT-IR) was performed on the sample and a change in peaks of the spectra (Fig 1. (b)) confirmed the success of the deacetylation and cellulose regeneration process. In the FT-IR spectra of the deacetylated sample, the presence of regenerated cellulose was confirmed by the decrease of peaks attributed to acetate groups at 1745 cm^{-1}, 1375 cm^{-1}, and 1235 cm^{-1}, and the appearance of peaks at 3300 cm^{-1} and 1100 cm^{-1} indicating the presence of hydroxyl and ether groups.

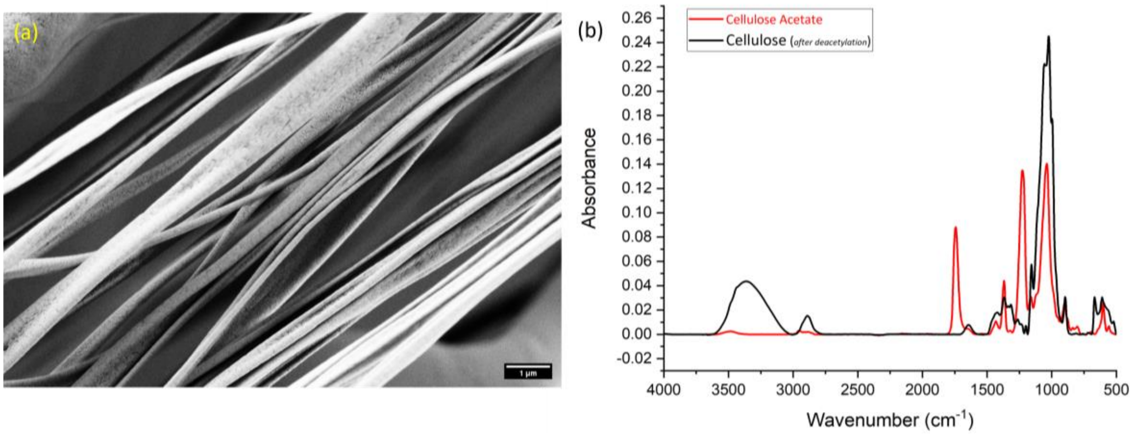

Figure 1. (a) A SEM micrograph of Cellulose acetate fibers: (b) FT-IR spectra of the electrospun cellulose acetate fibers and the regenerated cellulose after deacetylation.

The results obtained are encouraging and indicate that further optimization of the electrospinning process can lead to the development of high-quality cellulose acetate fibers. The next step forward in this research would be to electrospin cellulose acetate fibers with aligned cellulose nanocrystals (CNCs) inside them. These CNC filled aligned fibers can then be regenerated back to cellulose, which would improve its properties and open doors to many potential green applications. The ultimate goal of this work in the framework of BioCel3D project is to incorporate an aligned electrospun cellulose-based reinforcement for continuous fiber 3D printing, resulting in the creation of a technical natural fiber with improved hierarchical organization and enhanced physical properties.

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