Studying the Adhesion of thin CNF Layers on Fabric and their Effectiveness as UV-light Filters

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Abstract

We investigate the possibility of creating UV resistant clothing material using Cellulose NanoFibrils (CNF) films deposited on fabric material. For this purpose we have to choose an ideal fabric and CNF deposition methodology. We also look into optimal options of adding layers of Lignin and their effects on the CNF layer.

Contents

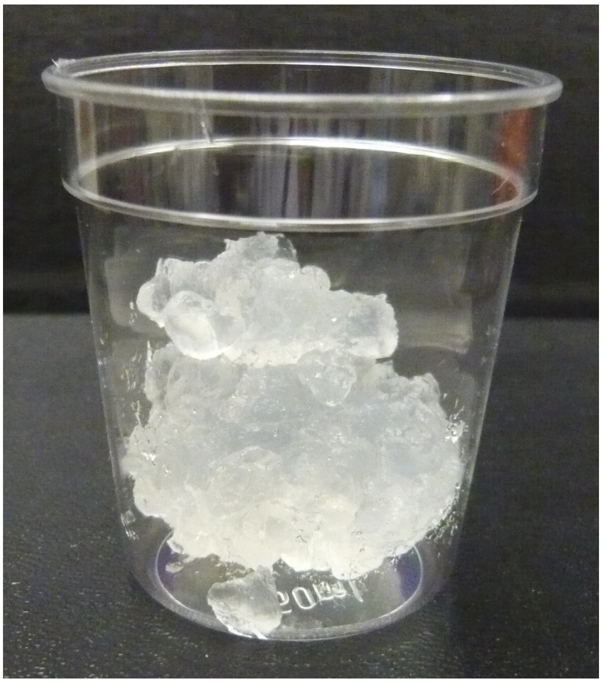


Figure 1: CNF before dilution

1 Motivation

The purpose of this project was the development of a see through clothing material that can have the same efficiency as an SPF50 cream at blocking harmful UV rays. We investigate that possibility by coating the fabrics with a thin CNF layer.

2 Cellulose NanoFibrils (CNF)

Carbon NanoFirbrils are long thin threads of cellulose that are mainly manufactured from wood pulp [1], making them an interesting subject of study for sustainable inventions.

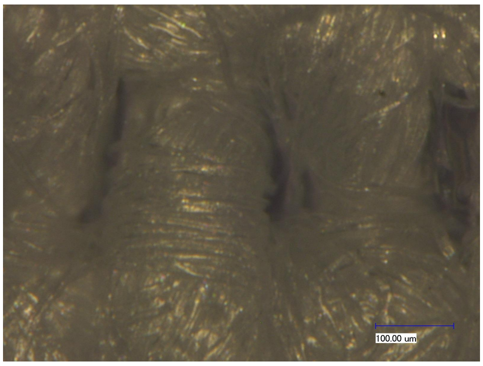
The CNF we use in the lab is a viscous translucent gel-like substance that is diluted in distilled water in whatever ratio is required. It has to remain chilled and away from any organic solvents.

3 Investigations

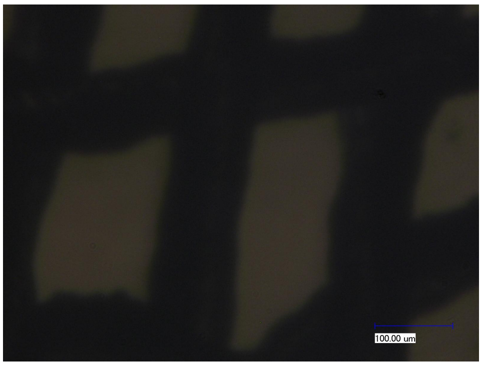
3.1 Ideal Fabric type for CNF layers

We start with a collection of fabrics of which we should choose the most viable for the CNF layers to sit on it. The goal here is to have an end product that is layered with CNF but still as translucent as possible in the visible spectrum. For this we need to choose a fabric who's threading is wide enough to let light pass through (there wont be a point in doing this for a material that blocks all of the visible spectrum since it would have already achieved our goals for the UV-resistance) but narrow enough for the CNF to be stable.

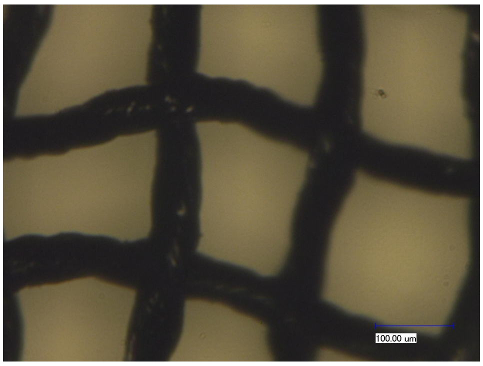
We investigate the collection of fabrics under a standard microscope, and extract the following figures



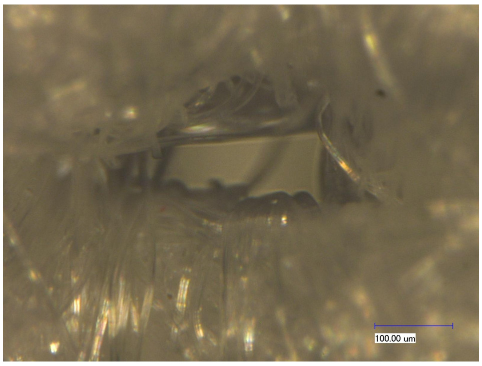
(a) Cotton



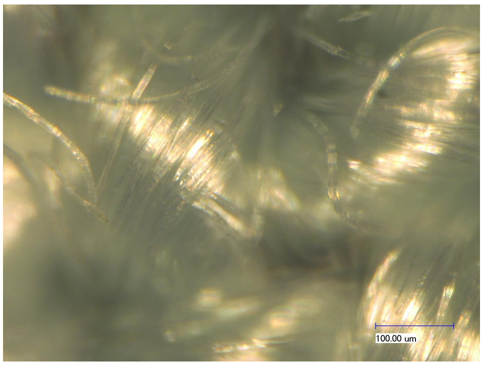
(b) Polyester



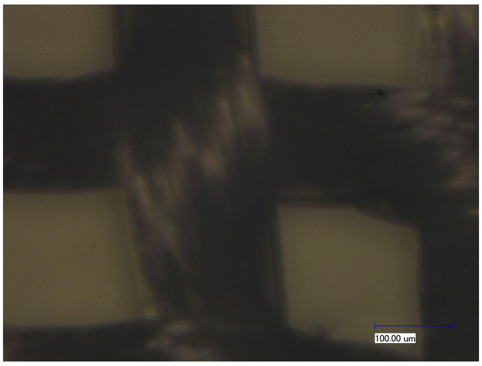
(c) Silk



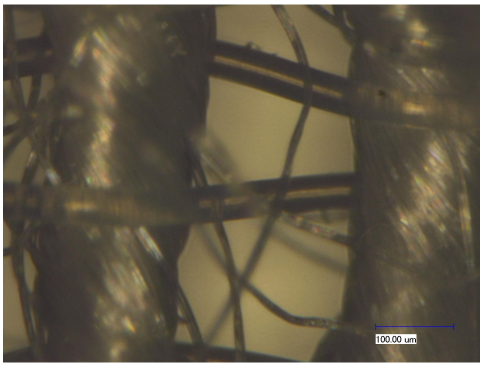
(d) Linen and Viscase (55:45)



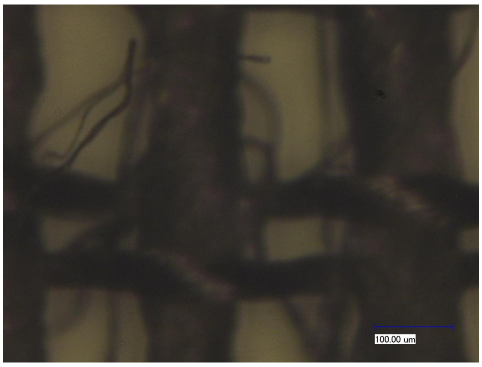
(e) Viscase and Linen (85:15)



(f) Polyester and Modecryl (40:60)



(g) Nylon and Cotton (65:35)



(h) Cotton and Silk (70:30)

Figure 2: Collection of Fabric under Microscope.

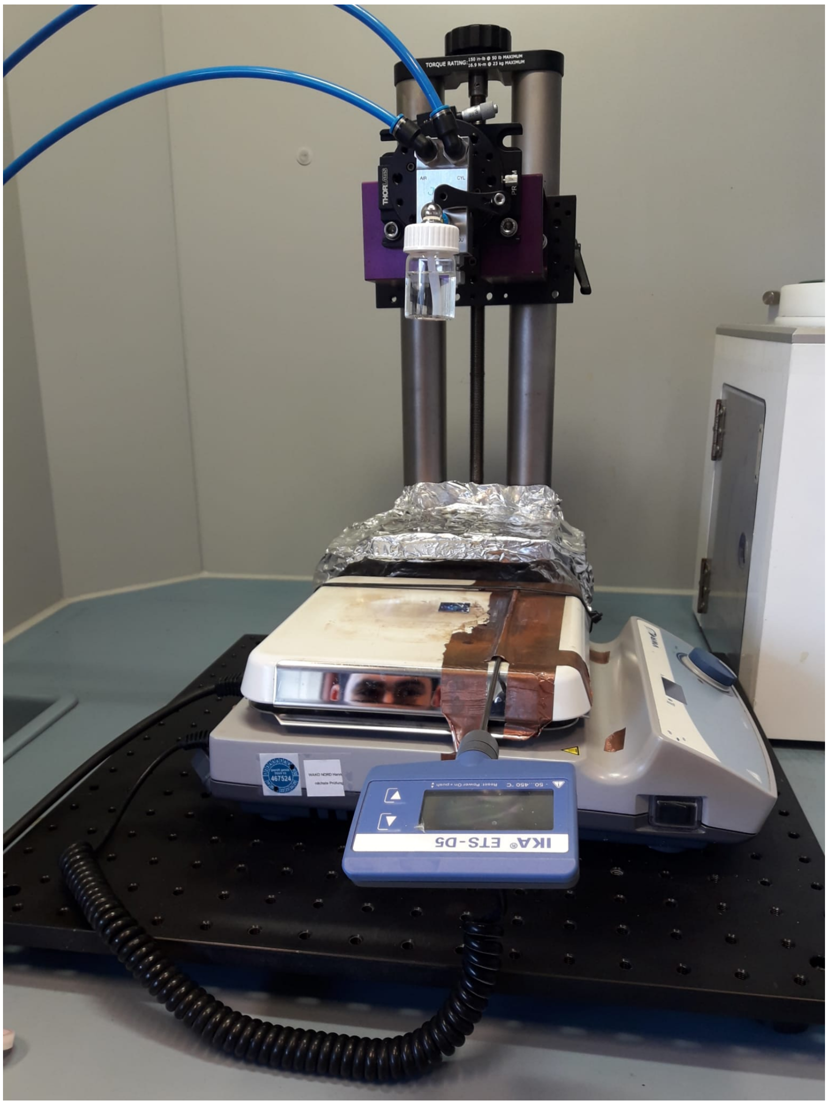


Figure 3: Spray Setup

As a compromise we decided to go with the the last one, the Cotton and Silk fabric with ratio 70:30. It offered good visibility and had small loose threads in its holes that would give the CNF layers there more stability.

3.2 Coating the Fabric with CNF

In order to place this CNF layer on the fabric, multiple methods can be used. Our strategy will be spray deposition as it offers a lot of control over the deposited quantity and offers the option of fast evaporation using a hot plate.
Our setup here consists of a spray deposition nozzle where the fluid will be blasted unto the sample which is placed on a hot bed. This allows fast successive sprays of layers that evaporate fast enough to be able to form a buildup of multiple layers.

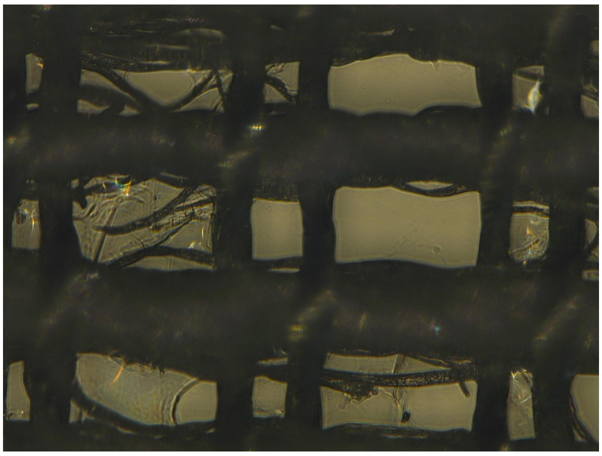


Figure 4: First Spray Deposition trial. Some hints of a CNF (20:1) layer exist in the corners of the fibers but not nearly enough to cover the gap completely.

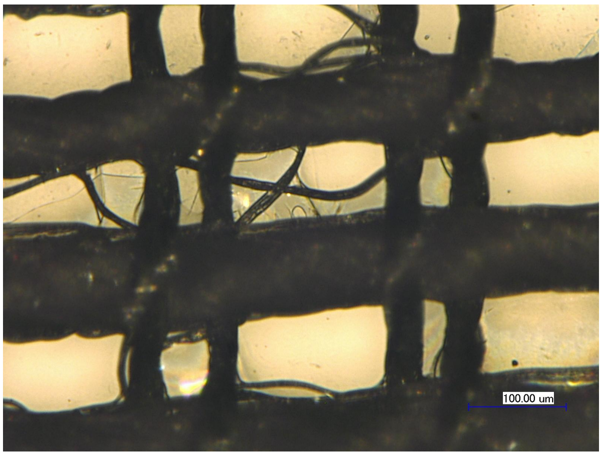


Figure 5: Spray Deposition of a CNF (5:1) layer. Coverage is still weak, even with this higher concentration.

3.2.1 Choice of CNF

First trials of spray deposition did not fare very well. The CNF fibers were not long enough to bridge the gap between the fabric threads, as can be seen in Figure 4.
In order to alleviate this problem, we started experimenting with a higher concentration of CNF solution. The solution used in Figure 4 used a 20:1 ration of CNF to water solution. Trying now with a 5:1 ration solution, we still get disappointing results, as seen in Figure 5.

Figure 6: The Centrifuge apparatus.

It started to seem that the concentration of CNF is not all that matters, but the average size of the CNF threads. This is why we proceeded to centrifuge the 5:1 CNF solution in order to extract the longer threads. We select the bottom 5 per cent of the solution in the centrifuge tube and spray it using the same setup and parameters.

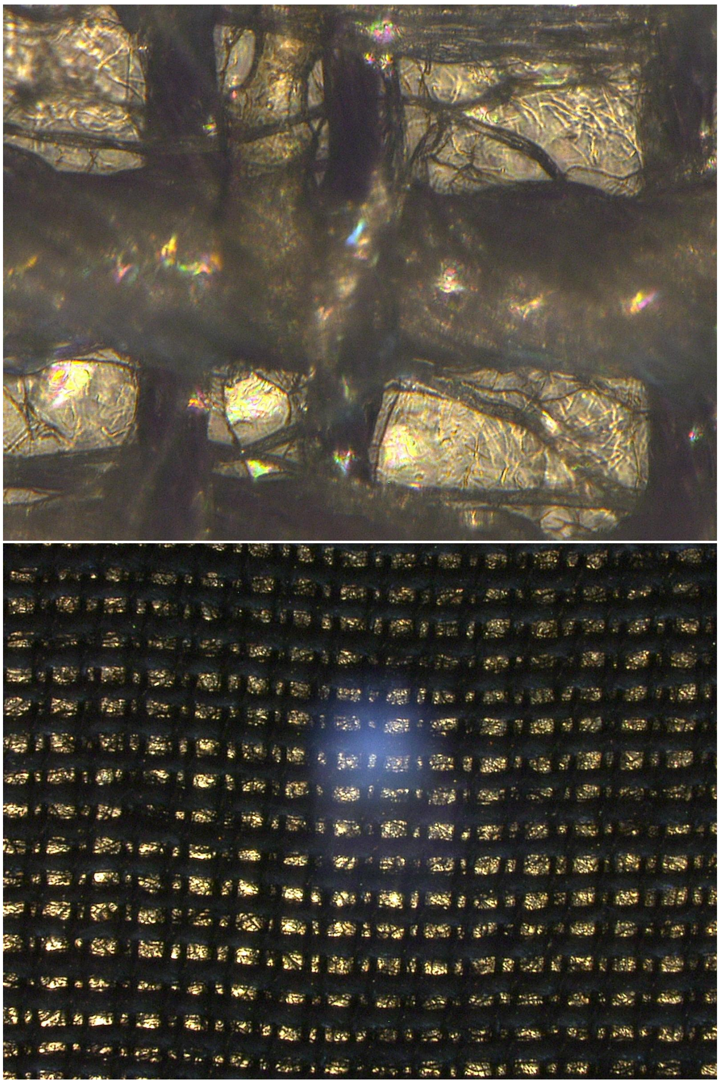


Figure 7: Spray Deposition of 5:1 centrifuged CNF onto the fabric.

What we ended up with was way better coverage of the fabric gaps since the fibrils were now long enough. And we also achieved a highly homogeneous spread of the fibrils as seen in Figure 7

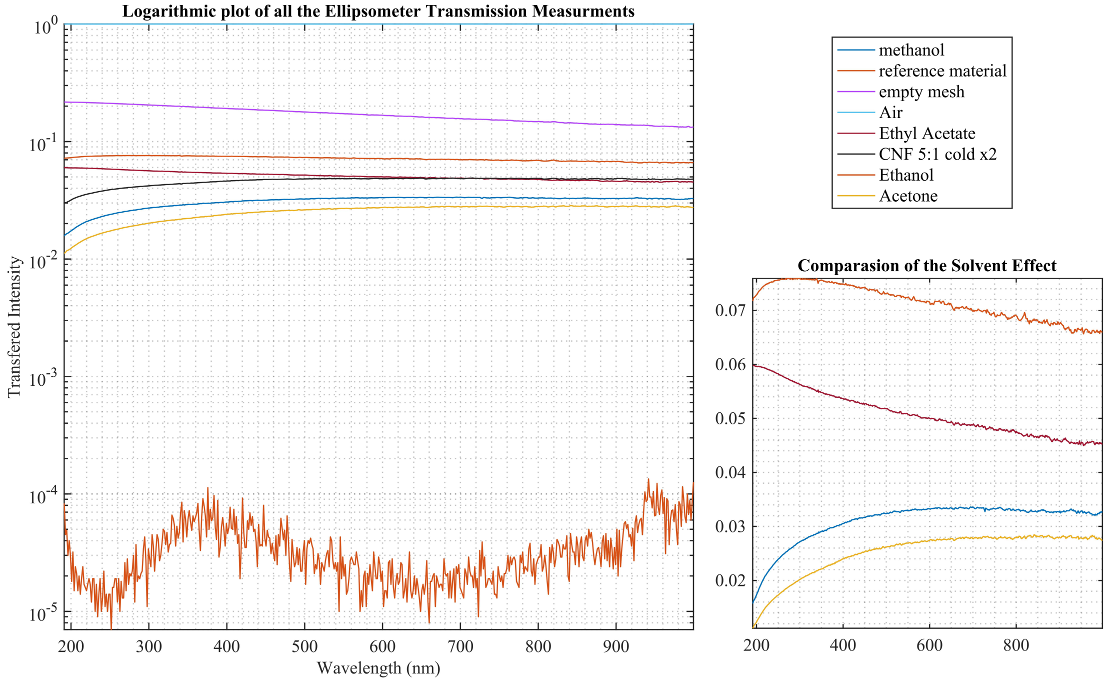


Figure 8: Transmission spectra of the various samples

Finally, we tested the transmission in the UV+visible spectrum of the sample to see how effective already the CNF coating is at blocking harmful rays. We also included a number of samples that were sprayed with organic solvents to test the stability of the CNF layer and and to find the optimal method to spray a lignin layer on top of it, which is done using an organic solvent as a carrier. We test the transmission from an ellipsometry setup that we modify to become a transmission apparatus, and register the results in Figure 8.
It can be seen that the CNF alone has already reduced the transmission, especially of high energy UV rays) by over an order of magnitude. We can also use these graphs to conclude that Acetone forms the best solvent for future applications of Lignin

References

[1] Wood-derived materials for green electronics, biological devices, and energy applications *Zhu, Hongli and Luo, Wei and Ciesielski, Peter N and Fang, Zhiqiang and Zhu, JY and Henriksson, Gunnar and Himmel, Michael E and Hu, Liangbing*