Analysis of softwood nanopapers for printed electronics

Marc Delgado-Aguilar[1], Quim tarrés[1], Israel González[1], M. Àngels Pèlach[1], Eloi Ramon[2], Pere Mutjé[1]

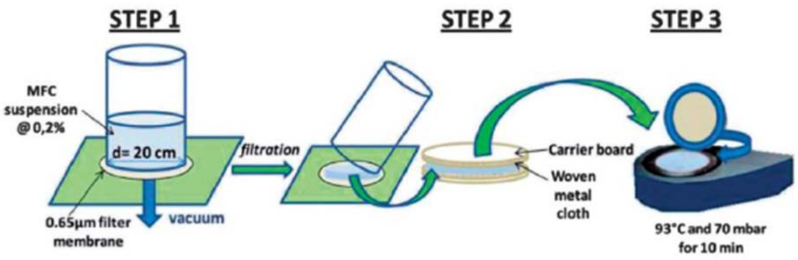
Objectives

- To develop a highly transparent substrate made of 100% cellulose nanofibers (CNF) able to be printed with conductive inks.

- To assess the mechanical properties, its surface and its capability to be printed.

- To print an electronic circuit on the nanopaper.

Methodology



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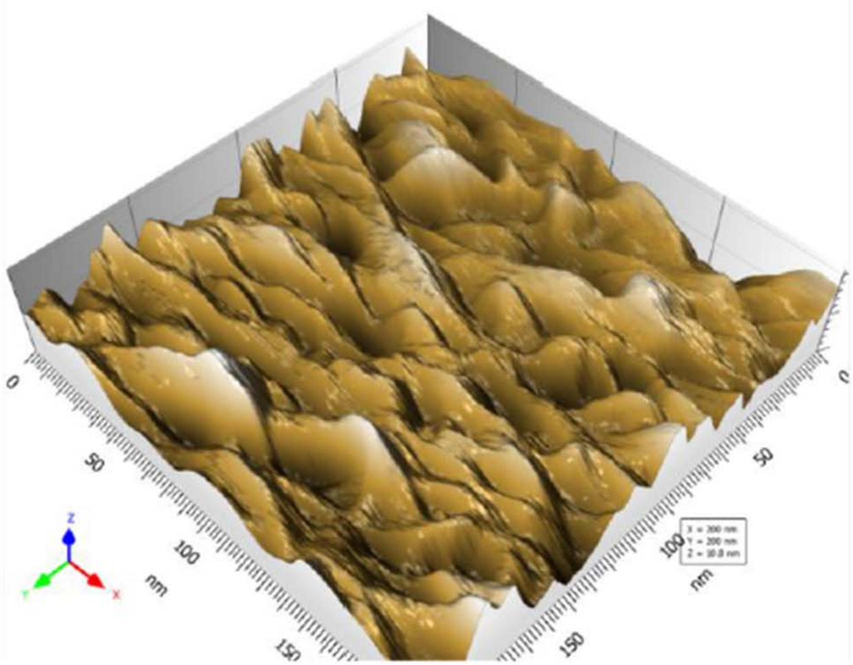
Results

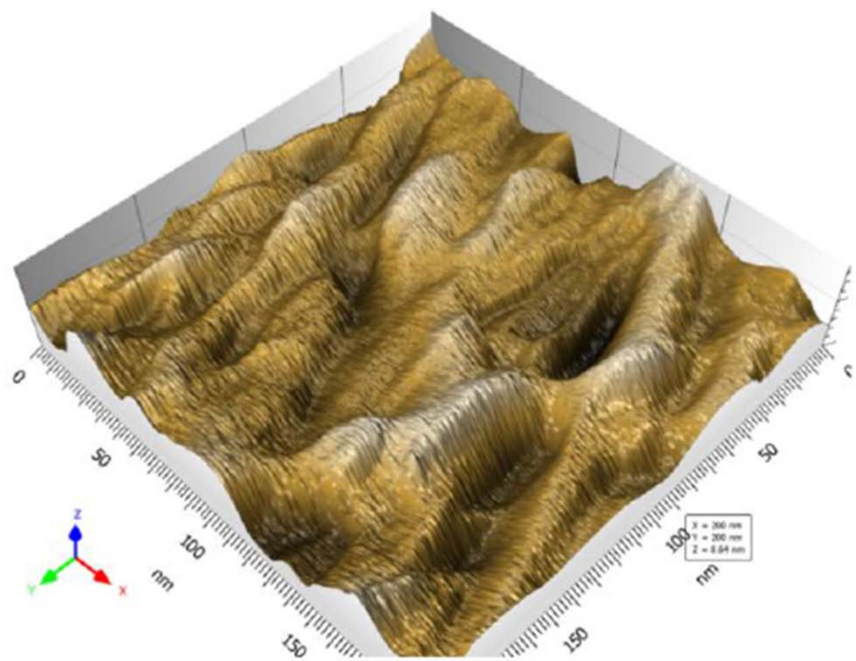
Oxidation degree (mmols)	Pine				Eucalyptus			
	T.S. (MPa)	B.L. (m)	Y.M. (GPa)	ε (%)	T.S. (MPa)	B.L. (m)	Y.M. (GPa)	ε (%)
5	91,83	9020	8,53	2,38	96,83	10688	11,59	1,27
10	187,26	12569	16,15	2,91	154,00	10482	11,63	1,97
15	165,95	11268	15,65	2,02	109,95	8663	11,81	2,22

T.S. – Tensile Strength; B.L. – Breaking length; Y.M. – Young Modulus; ε – Elongation at break

Results

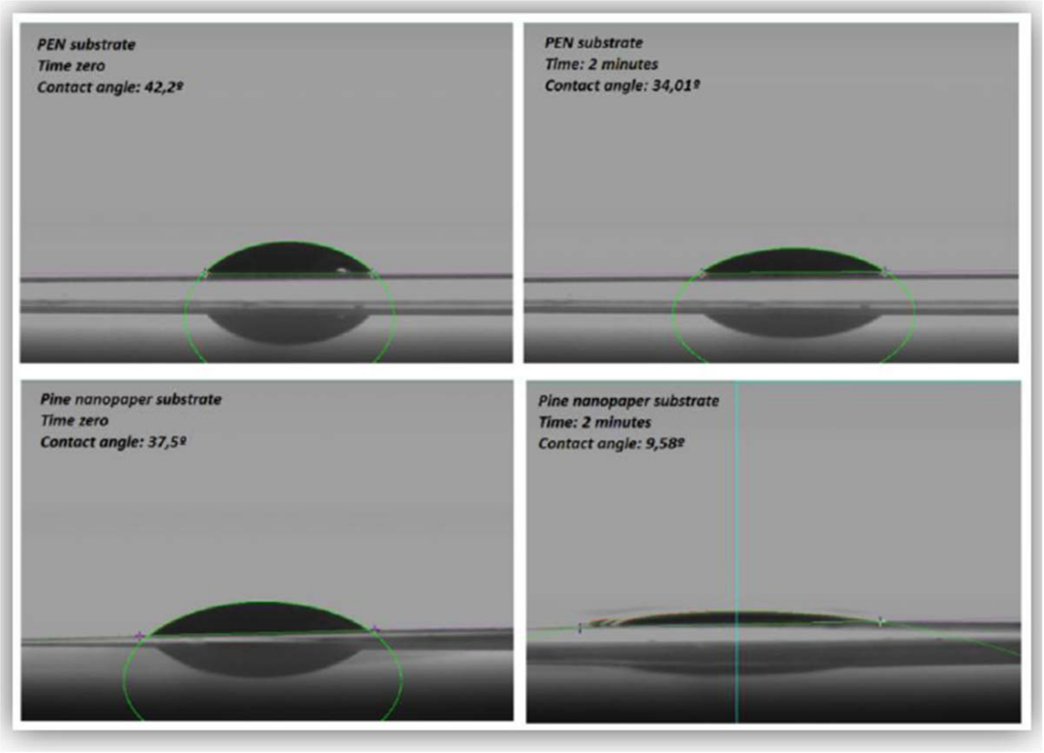


Eucalyptus nanopaper
10 mmols



Pine nanopaper
10 mmols

Results

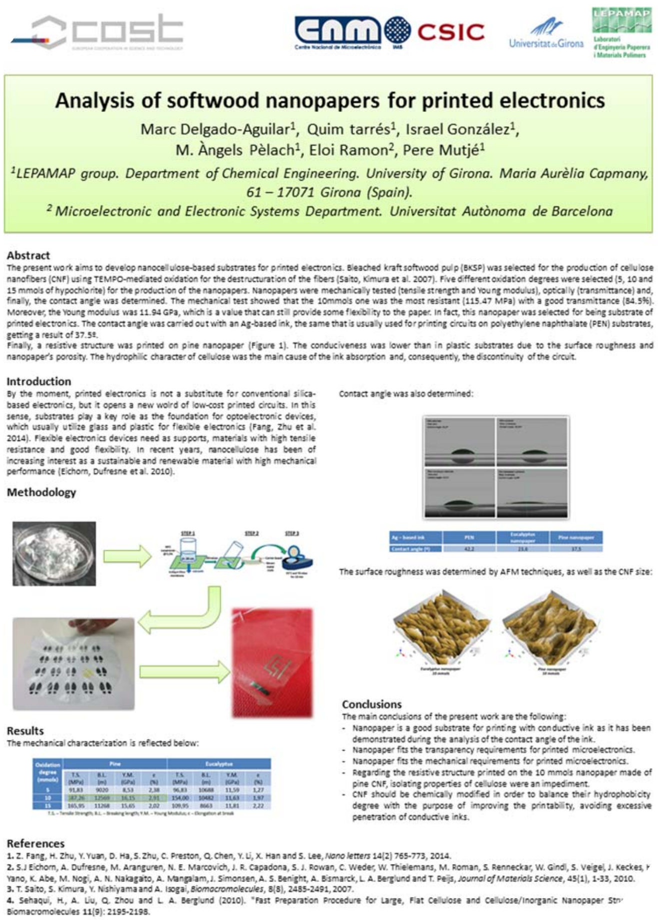


Ag – based ink	PEN	Eucalyptus nanopaper	Pine nanopaper
Contact angle (º)	42,2	23,6	37,5

Conclusions

The main conclusions of the present work are the following:

- Nanopaper is a good substrate for printing with conductive ink as it has been demonstrated during the analysis of the contact angle of the ink.
- Nanopaper fits the transparency requirements for printed microelectronics.
- Nanopaper fits the mechanical requirements for printed microelectronics.
- Regarding the resistive structure printed on the 10 mmols nanopaper made of pine CNF, isolating properties of cellulose were an impediment.
- CNF should be chemically modified in order to balance their hydrophobicity degree with the purpose of improving the printability, avoiding excessive penetration of conductive inks.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Abstract

The present work aims to develop nanocellulose-based substrates for printed electronics. Bleached kraft softwood pulp (BKSP) was selected for the production of cellulose nanofibers (CNF) using TEMPO-mediated oxidation for the destructuration of the fibers (Saito, Kimura et al. 2007). Five different oxidation degrees were selected (5, 10 and 15 mmols of hypochlorite) for the production of the nanopapers. Nanopapers were mechanically tested (tensile strength and Young modulus), optically (transmittance) and, finally, the contact angle was determined. The mechanical test showed that the 10mmols one was the most resistant (115.47 MPa) with a good transmittance (84.5%). Moreover, the Young modulus was 11.94 GPa, which is a value that can still provide some flexibility to the paper. In fact, this nanopaper was selected for being substrate of printed electronics. The contact angle was carried out with an Ag-based ink, the same that is usually used for printing circuits on polyethylene naphthalate (PEN) substrates, getting a result of 37.5º.

Finally, a resistive structure was printed on pine nanopaper (Figure 1). The conduciveness was lower than in plastic substrates due to the surface roughness and nanopaper's porosity. The hydrophilic character of cellulose was the main cause of the ink absorption and, consequently, the discontinuity of the circuit.

Introduction

By the moment, printed electronics is not a substitute for conventional silica-based electronics, but it opens a new woird of low-cost printed circuits. In this sense, substrates play a key role as the foundation for optoelectronic devices, which usually utilize glass and plastic for flexible electronics (Fang, Zhu et al. 2014). Flexible electronics devices need as supports, materials with high tensile resistance and good flexibility. In recent years, nanocellulose has been of increasing interest as a sustainable and renewable material with high mechanical performance (Eichorn, Dufresne et al. 2010).

Methodology

Contact angle was also determined:

Ag – based ink	PEN	Eucalyptus nanopaper	Pine nanopaper
Contact angle (º)	42,2	23,6	37,5

The surface roughness was determined by AFM techniques, as well as the CNF size:

Results

The mechanical characterization is reflected below:

Oxidation degree (mmols)	Pine				Eucalyptus			
	T.S. (MPa)	B.L. (m)	Y.M. (GPa)	ε (%)	T.S. (MPa)	B.L. (m)	Y.M. (GPa)	ε (%)
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hanks for your attention!

Have a look to the poster and do not hesitate to contact me for any inquiry!

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