Designing flexible, smooth, highly transparent and hazy CNF films

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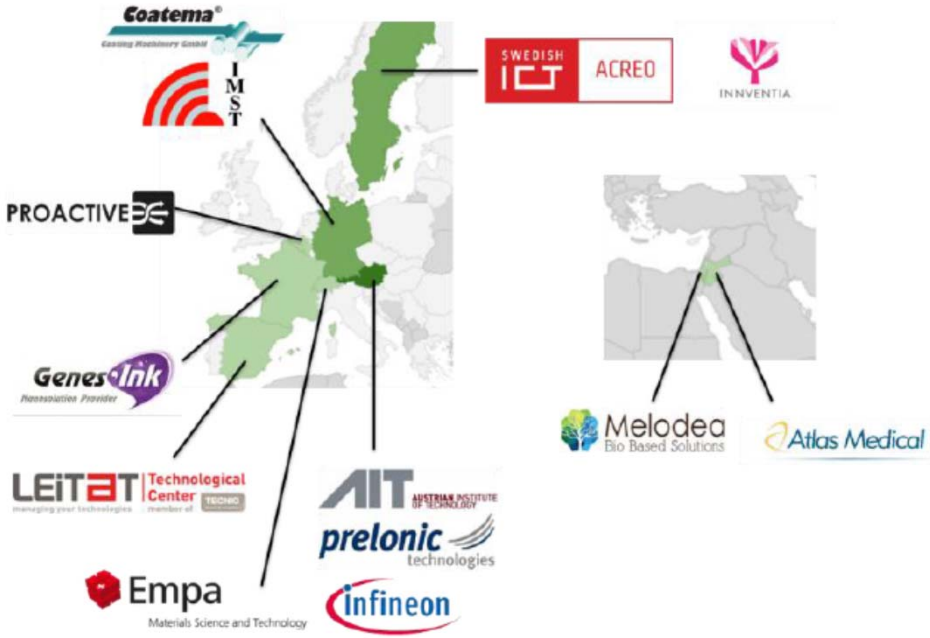
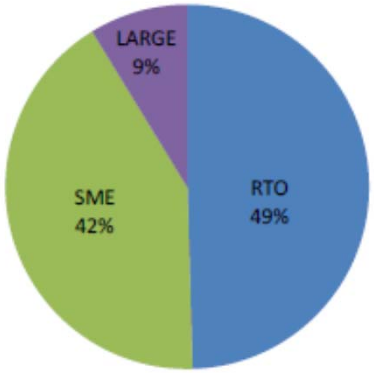
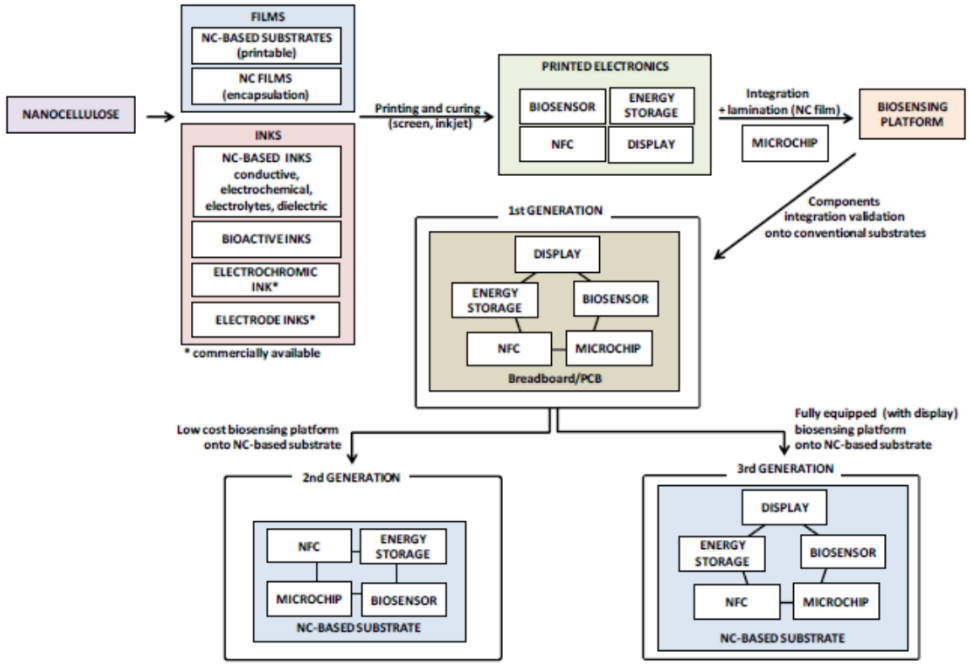
Greensense

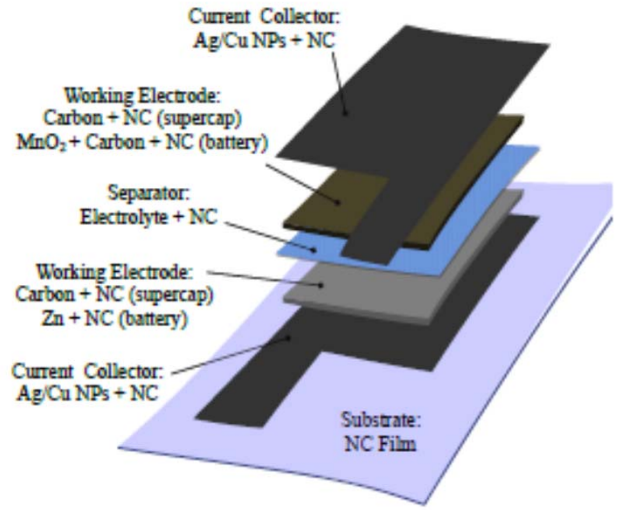
- EU project within HORIZON 2020 - PILOTS-05-2017: Paper-based electronics , 2018-2021
- 13 partners
- Greensense total EU contribution: 10 M Euro



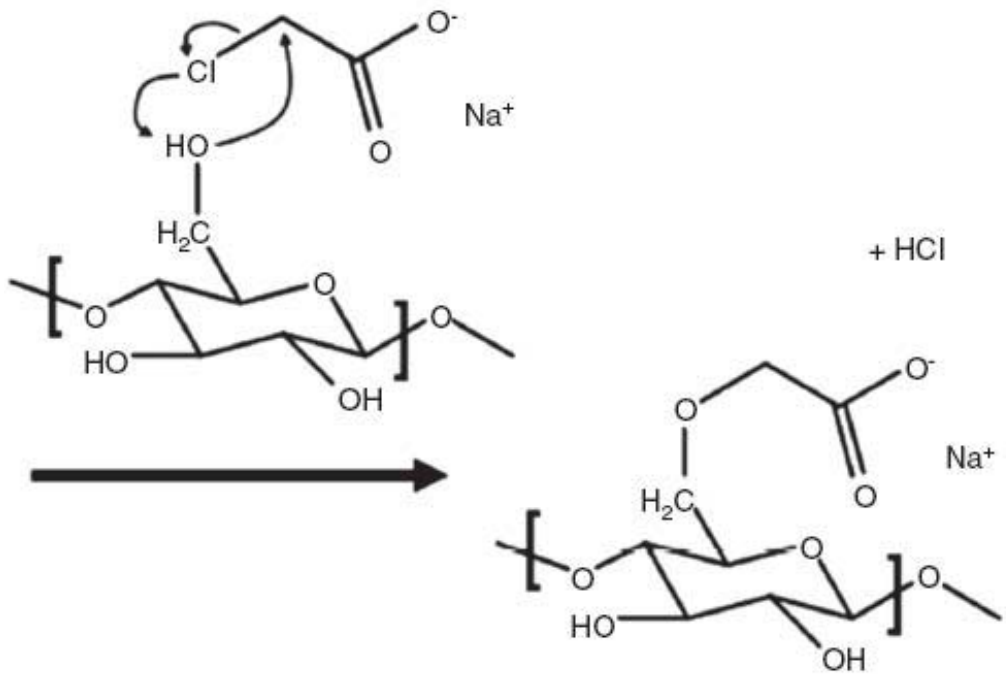


Biosensing platform for drug-of-abuse analysis





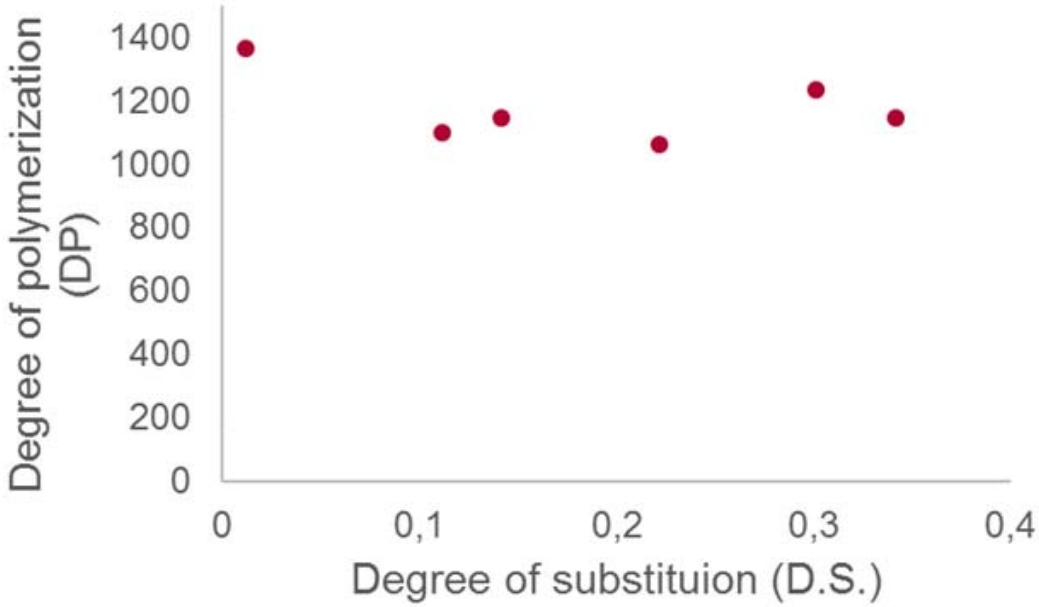
Basic principle of carboxymethylation of cellulose



Wågberg, L., Decher, G., Norgren, M., Lindström, T., Ankerfors, M. Axnäs, K. *Langmuir* 2008, 24, 784-795.
Wågberg, L.; Winter, L.; Lindström, T. *Colloids Surf.* **1987**, *27*, 163

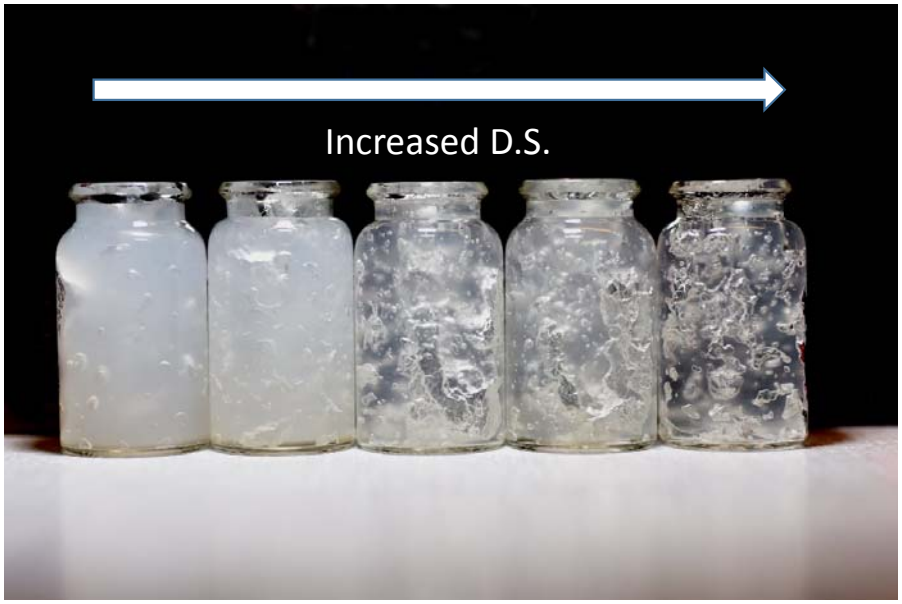
Total charge density (μekv./g), surface charge density (μekv./g), surface/total charge ratio and corresponding degree of substitution (D.S.) of carboxymethylated pulp.

Monochloroacetic acid(g)	Total charge density (μekv./g)	degree of substitution (D.S.)	surface charge density (μekv./g)	surface/total charge ratio
N/A	38	N/A	2	0,05
8,2	647	0,11	81	0,13
12,3	789	0,14	123	0,16
24,6	1203	0,22	301	0,25
30,4	1618	0,30	944	0,58
36,1	1780	0,34	1316	0,74

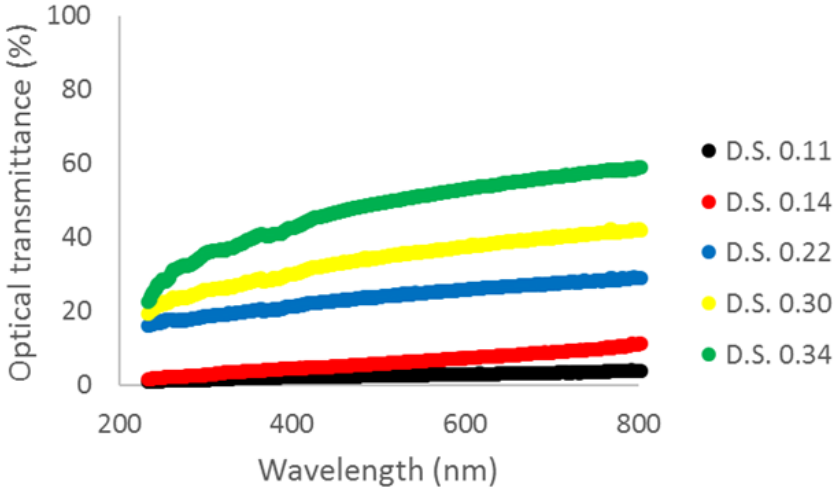


DP determined by viscosity measurement of carboxymethylated pulp with different D.S.

Marx-Figini, M., *Angewandte Makromolekulare Chemie*, 72, 1, 1978, 161-171.



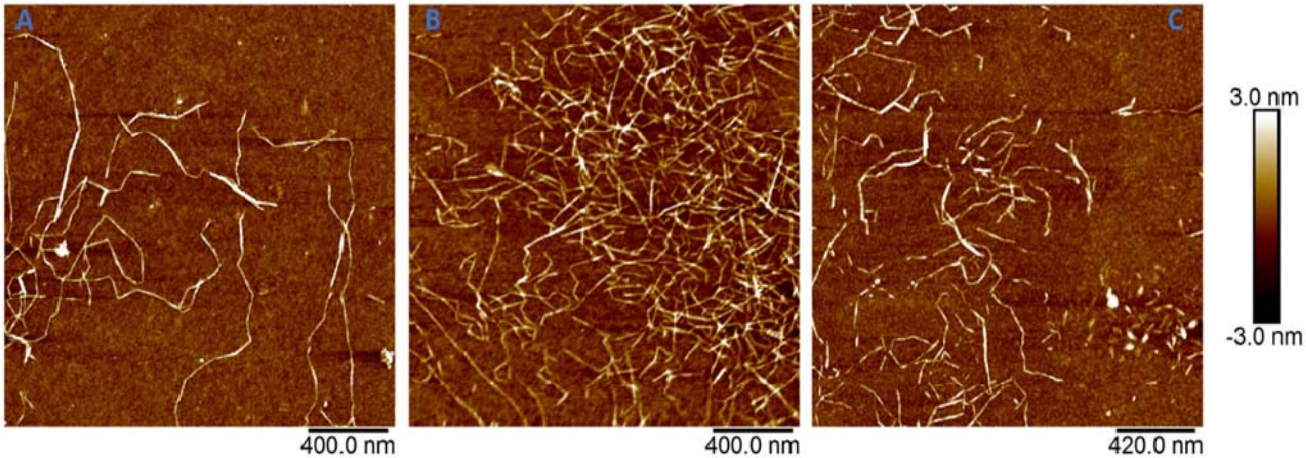
Carboxymethylated CNF with different D.S. (charge density)



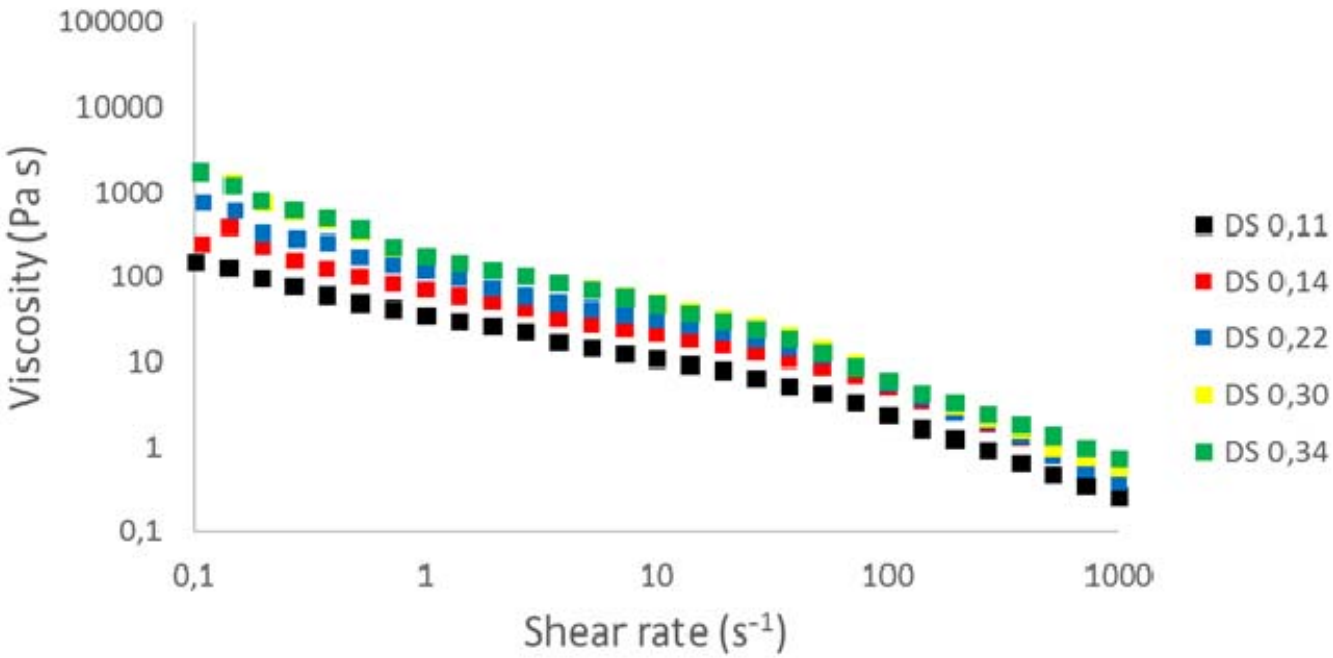
Optical transmittance of the CNF dispersions at 0.3 wt.% consistency.

Surface charge density (μekv./g), surface/total charge ratio and fine fraction of CNF.

surface charge density (μekv./g)	surface/total charge ratio	Fine fraction (%)
321	0,50	31
456	0,58	26
884	0,73	31
1206	0,75	57
1379	0,77	67

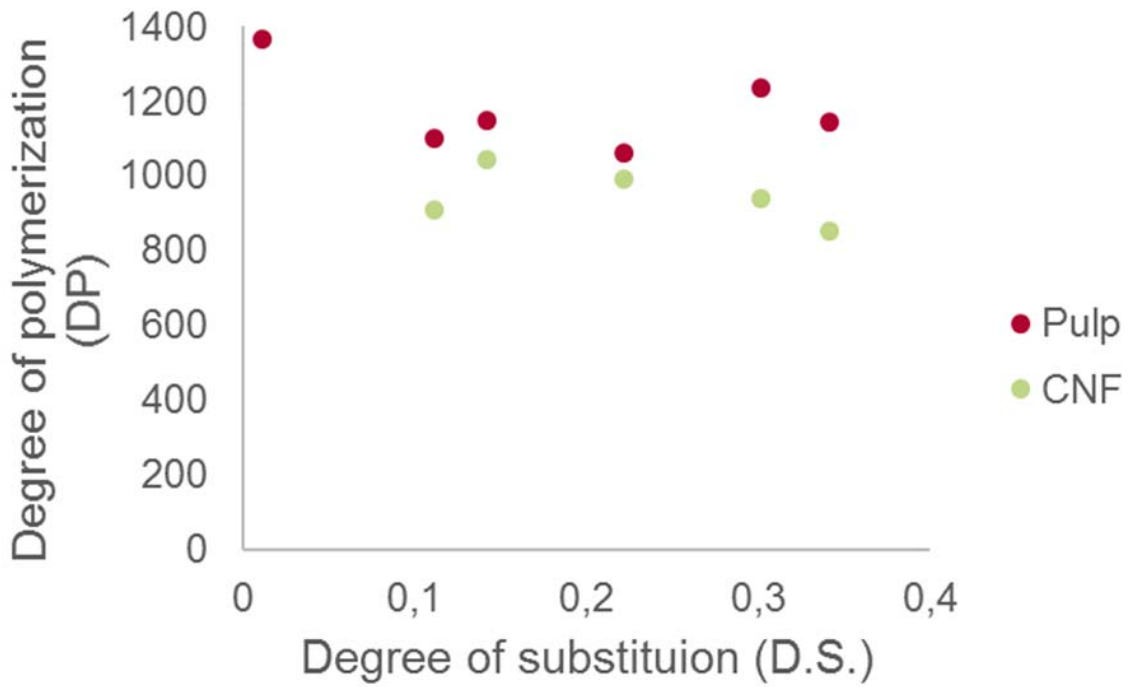


AFM images of CNF absorbed to PAH-treated silica wafers. A) D.S. 0.11. B) D.S. 0.22 C) D.S. 0.34



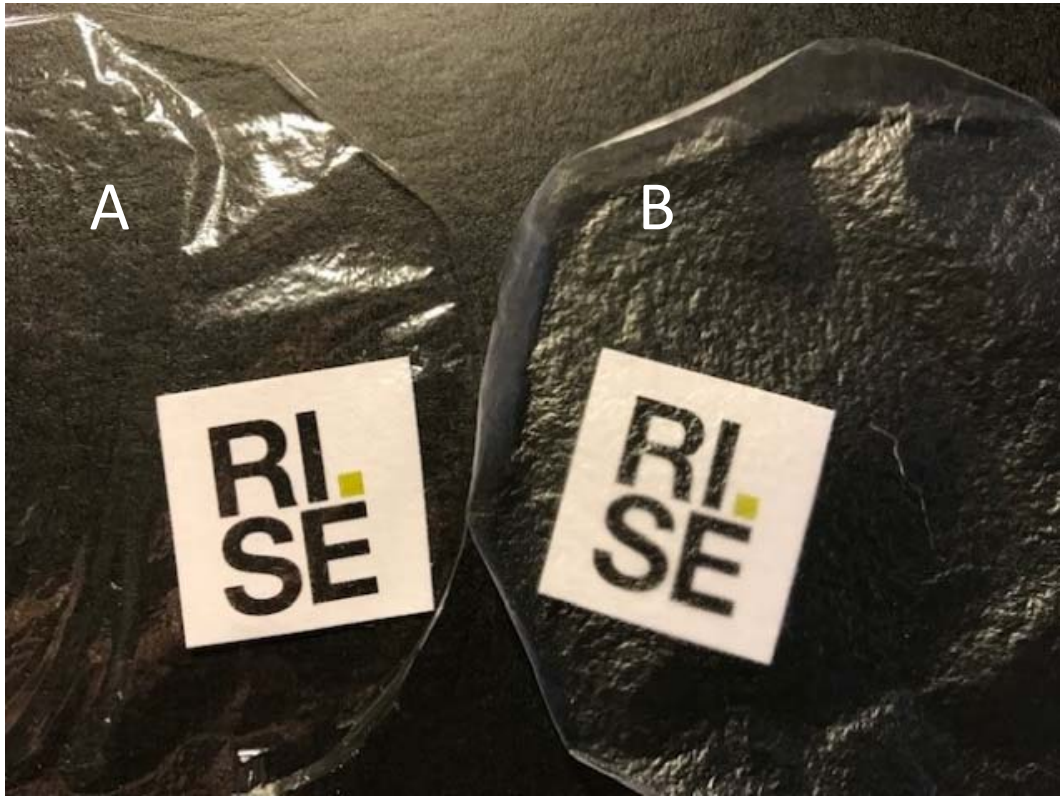
Viscosity versus shear rate for carboxymethylated CNF dispersions.

Im, W., Rajabi Abhari, A., Jung Youn, H., Lae Lee, H., *Cellulose* (2018) 25:5781–5789

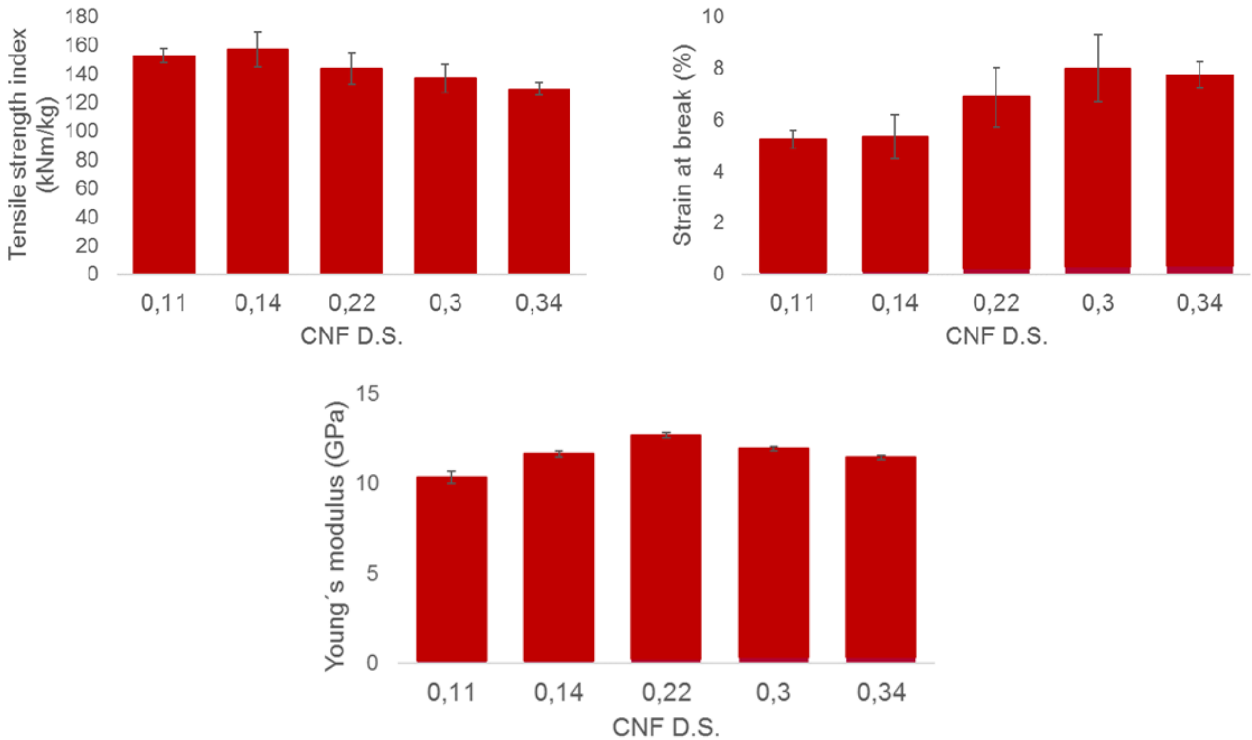


Degree of polymerization determined by viscosity measurement of carboxymethylated pulp and corresponding CNF with different D.S.

Marx-Figini, M., *Angewandte Makromolekulare Chemie*, 72, 1, 1978, 161-171.

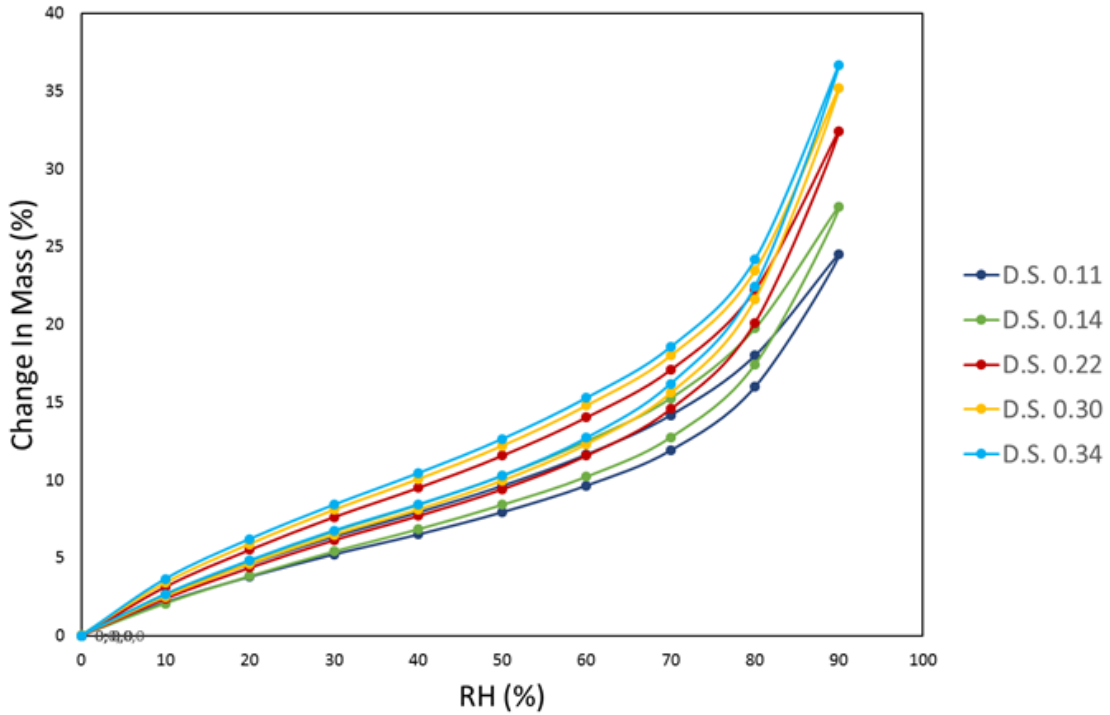


Transparent films produced from carboxymethylated CNF at a D.S. of a) 0.34 and b) 0.11



The impact of D.S. on the mechanical properties of CNF films

Im, W., Rajabi Abhari, A., Jung Youn, H., Lae Lee, H., *Cellulose* (2018) 25:5781–5789

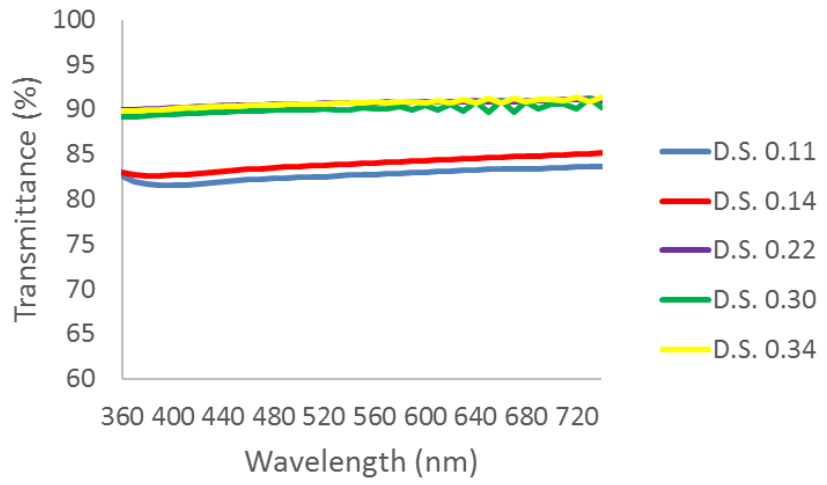


Water sorption isotherms for CNF films based on different D.S. during the adsorption and desorption processes.

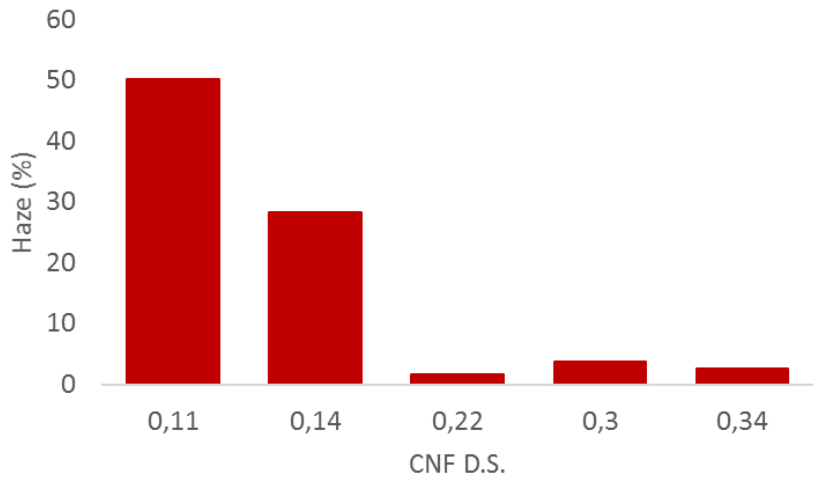
CNF D.S.	Degradation Temperature (°C)	% mass loss @ 150 °C for 30 min
0.11	325	3.3
0.14	314	4.9
0.22	305	8.1
0.30	298	7.8
0.34	297	6.4

Oxygen Transmission Rate (OTR, $cm^3/m^2 \cdot day \cdot atm$) and Oxygen Permeability ($cm^3 \cdot \mu m/m^2 \cdot day \cdot kPa$) for CNF films based on different D.S. at 23 ºC and 50 % RH.		
D.S.	Oxygen transmission rate ($cm^3/m^2 \cdot day \cdot atm$)	Oxygen Permeability ($cm^3 \cdot \mu m/m^2 \cdot day \cdot kPa$)
0.11	1.2	0.32
0.14	0.8	0.20
0.22	1.1	0.27
0.30	0.9	0.20
0.34	1.5	0.31

Water Vapour Transmission Rate (WVTR, $g/m^2 \cdot day \cdot atm$) and Water Vapour Permeability (WVP, $pg \cdot m/m^2 \cdot s \cdot kPa$) for CNF films based on different D.S. at 23 C and 50 % RH.		
D.S.	Water Vapour Transmission rate ($g/m^2 \cdot day \cdot atm$)	Water Vapour Permeability (g mm/m^2 d atm)
0.11	81.0	158.8
0.14	97.3	173.3
0.22	213.7	385.2
0.30	183.6	304.4
0.34	241.4	379.4

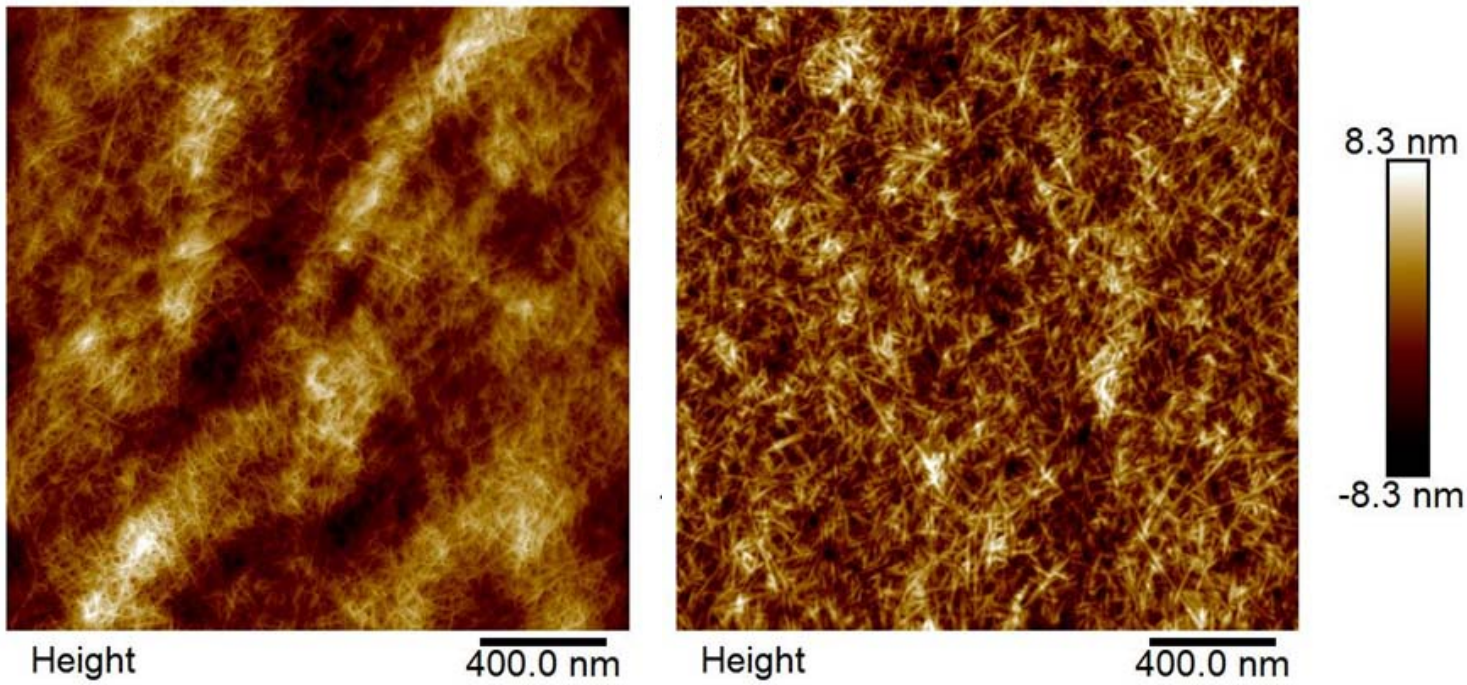


Konica Minolta CM-3610d
Aperture diameter 23 mm
diffuse:8° geometry
Observer/illuminant: C/2°



Konica Minolta CM-3610d
Aperture diameter 23 mm
diffuse:8° geometry
Observer/illuminant: C/2°
ASTM D1003-97

Yang, W., Jiao, L., Liu, W., Deng, Y., Dai, H., *Cellulose* (2018) 25:5909–5918



AFM tapping mode height images of CNF films prepared from D.S. of a) 0.11 and b) 0.34. AFM scanning area was 2 x 2 μm^2

Surface roughness, Rq (nm) ± SD, of CNF films based on different D.S. AFM scanning area was 10 x 10 μm^2 and 2 x 2 μm^2**.				
D.S.	Bottom surface roughness (nm)	Upper surface roughness (nm)	Bottom surface roughness ** (nm)	Upper surface roughness ** (nm)
0.11	35.0 ± 6.5	29.8 ± 16.3		
0.14	21.3 ± 3.8	38.3 ± 18.2		
0.22	3.9 ± 0.9	7.1 ± 5.6		
0.30	4.0 ± 1.5	9.7 ± 3.8		
0.34	8.9 ± 8.3	5.3 ± 1.3	1.6 ± 0.1	2.3 ± 0.1

Yang, W., Jiao, L., Liu, W., Deng, Y., Dai, H., *Cellulose* (2018) 25:5909–5918

Acknowledgments

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Thank you

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