

Flexible cellulose nanopaper with high wet tensile strength, high toughness and tunable ultraviolet blocking ability fabricated from tobacco stalk via a sustainable method †

Qingbo Wang^{‡ab}, Haishun Du^{‡ad}, Fang Zhang^c, Yuedong Zhang^a, Meiyang Wu^a, Guang Yu^a, Chao Liu^{*a}, Bin Li^{*a} and Hui Peng^a

^a CAS Key Laboratory of Bio-based Material, CAS Key Laboratory of Biofuels, Qingdao Institute of Bioenergy and Bioprocess Technology, Chinese Academy of Sciences, Qingdao, Shandong, 266101, China. Email: liuchao@qibebt.ac.cn; libin@qibebt.ac.cn.

^b Faculty of Modern Agricultural Engineering, Kunming University of science and technology, Kunming, 650504, China.

^c National Engineering Research Center for Nanotechnology, Shanghai, 200241, China

^d Department of Chemical Engineering, Auburn University, Auburn, AL 36849, USA

[‡] Both authors contributed equally.

Table S1 – Chemical composition of the samples

Sample	Cellulose (%)	Hemicellulose (%)	Lignin (%)
TS ^a	40.5±0.6	16.5±0.1	24.3±0.2
10AT ^b	56.5±0.5	14.8±0.3	21.7±0.2
15AT ^c	57.9±0.5	14.2±0.1	15.6±0.4
20AT ^d	60.4±0.3	13.5±0.7	14.0±0.6
BT ^e	73.1±0.2	17.4±0.4	0.1±0.1
14F ^f	76.2±0.7	2.4±0.2	13.7±0.1
12F ^g	78.4±0.9	2.2±0.1	12.3±0.4
10F ^h	83.7±0.4	1.4±0.3	10.3±0.5
6F ⁱ	87.4±0.2	1.3±0.2	5.8±0.4
3F ^j	89.7±0.1	0.9±0.7	3.4±0.2
OF ^k	95.3±0.4	0.2±0.1	0.1±0

^a Tobacco stalk. ^{b-d} The cooked TS samples by the ammonium sulfite with the dose of 10, 15 and 20 wt% (based on the oven dried mass of TS). ^e Bleached TS samples. ^{f-g} The hydrolyzed TS samples by FA with the lignin contents of 13.7 and 12.3%, respectively. ^{h-k} The hydrolyzed 10AT, 15AT, 20 AT and BT samples by FA with the lignin contents of 10.3, 5.8, 3.4 and 0%, respectively.

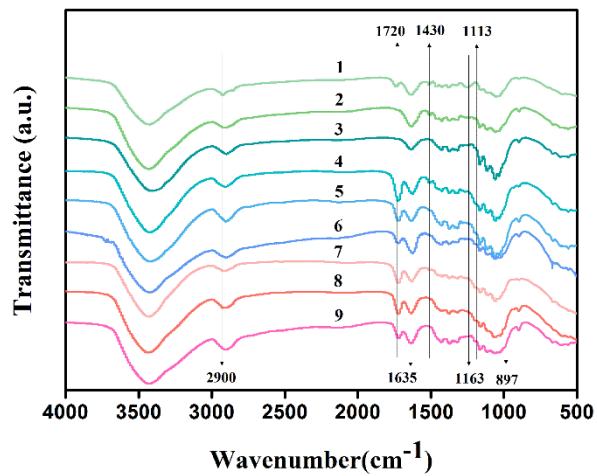


Figure S1 - FTIR spectra of (1-9) TS, 20AT, BT, 14F, 3F, OF, 14-CNFs, 3-CNFs and 0-CNFs samples.

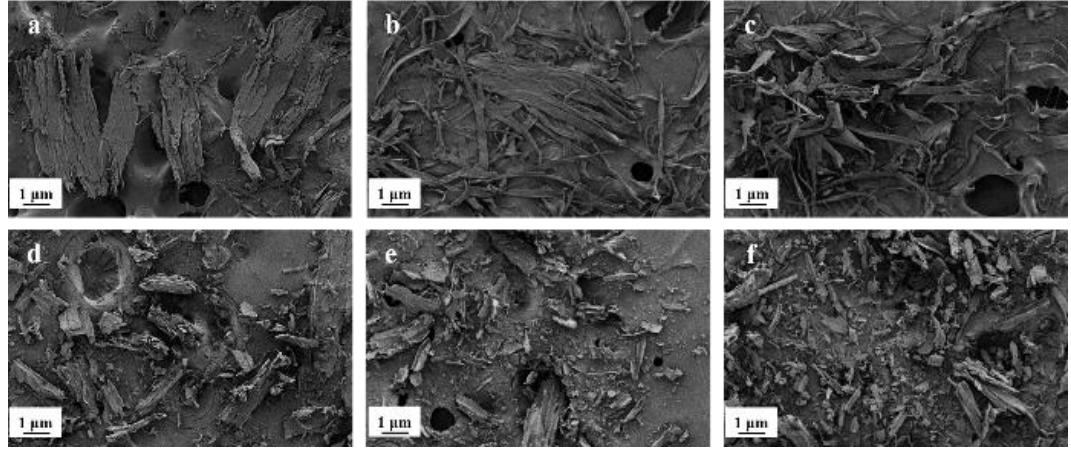


Figure S2 - SEM images of (a) TS, (b) 20AT, (c) BT, (d) 14F, (e) 3F and (f) OF samples.

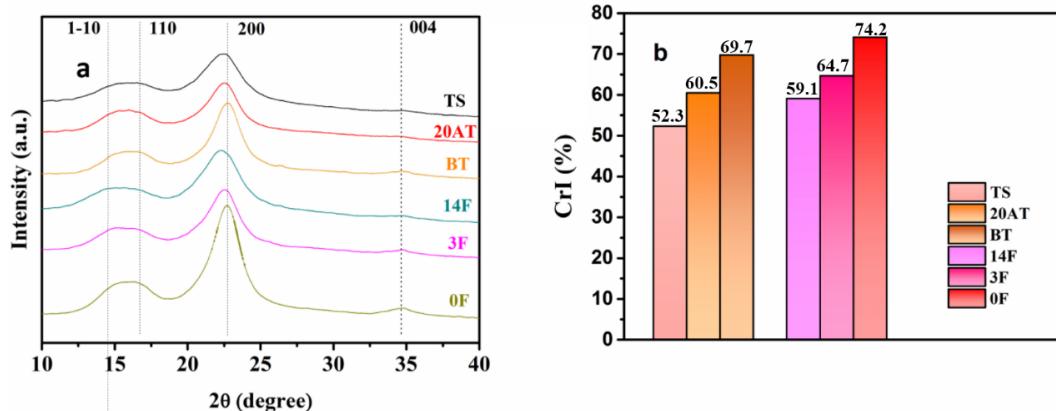


Figure S3 - XRD pattern (a) and CrI (b) of TS, 20AT, BT, 14F, 3F and OF samples.

Table S2 – T_{on} and T_{max} of TS, 20AT, BT, 14F, 3F, OF 14-CNFs, 3-CNFs 0-CNFs, 14-CNP, 3-CNP and 0-CNP samples

Sample	T_{on}^a	T_{max}^b
TS ^c	290	344
20AT ^d	319	362
BT ^e	320	357
14F ^f	345	366
3F ^g	342	365
OF ^h	338	364
14-CNF ⁱ	308	339
3-CNF ^j	304	339
0-CNF ^k	299	339
14-CNP ^l	332	360
3-CNP ^m	327	359
0-CNP ⁿ	318	361

^a The onset temperature of thermal decomposition (°C). ^b The temperature of maximum decomposition (°C). ^c Tobacco stalk. ^dThe cooked TS sample by ammonium sulfite with the dose of 20 wt% (based on the oven dried mass of TS). ^e Bleached sample. ^{f-h} The samples obtained by FA hydrolysis of TS, 20AT and BT. ^{h-k}CNF samples obtained after homogenization of 14F, 3F and OF. ^{l-n}CNP fabricated by 14-CNF, 3-CNF and 0-CNF, respectively.

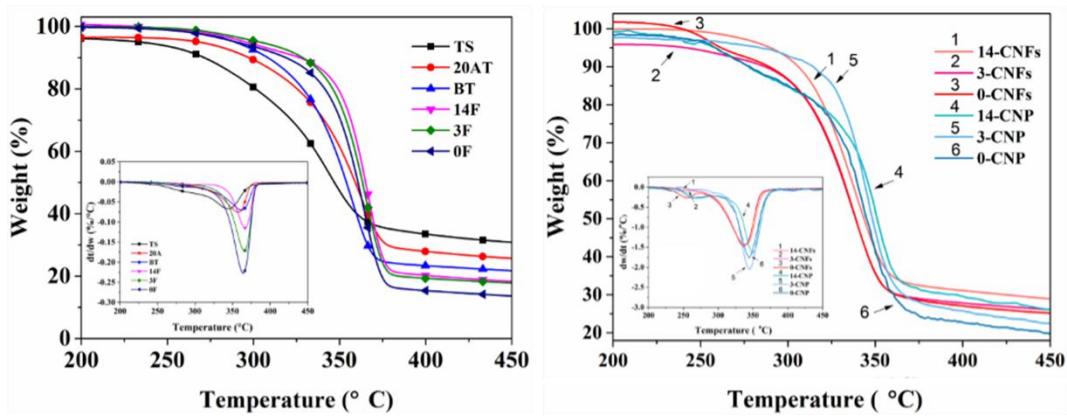


Figure S4 - TG and DTG of TS, 20AT, BT, 14F, 3F, OF 14-CNFs, 3-CNFs 0-CNFs, 14-CNP, 3-CNP and 0-CNP samples.

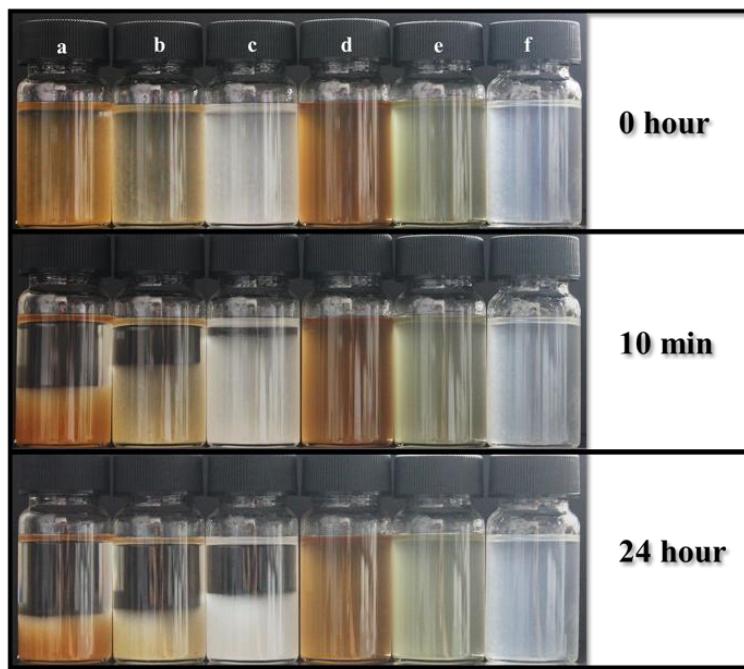


Figure S5 - Dispersibility of (a) 14F, (b) 3F, (c) 0F, (d) 14-CNFs, (e) 3-CNFs and (F) 0-CNFs samples at 0 h, 10 min and 24 h.

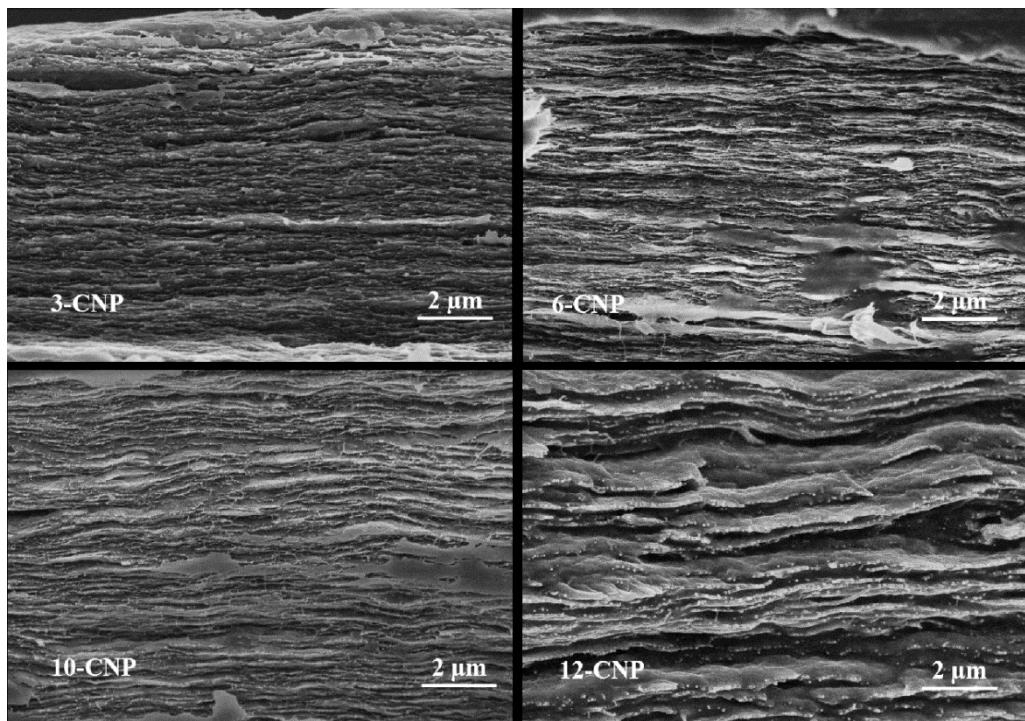


Figure S6 - SEM cross-section images of 3-CNP, 6-CNP, 10-CNP and 12-CNP samples.

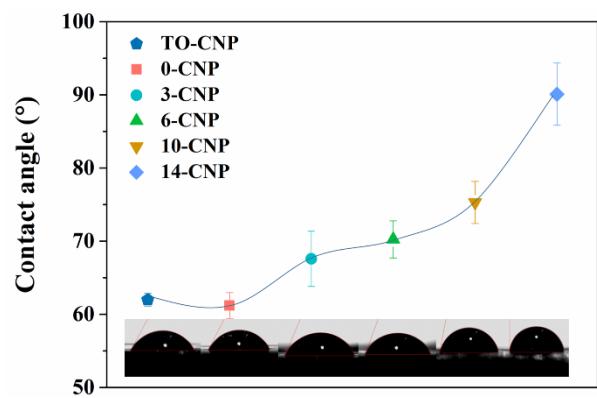


Figure S7 - Contact angle of CNP samples.

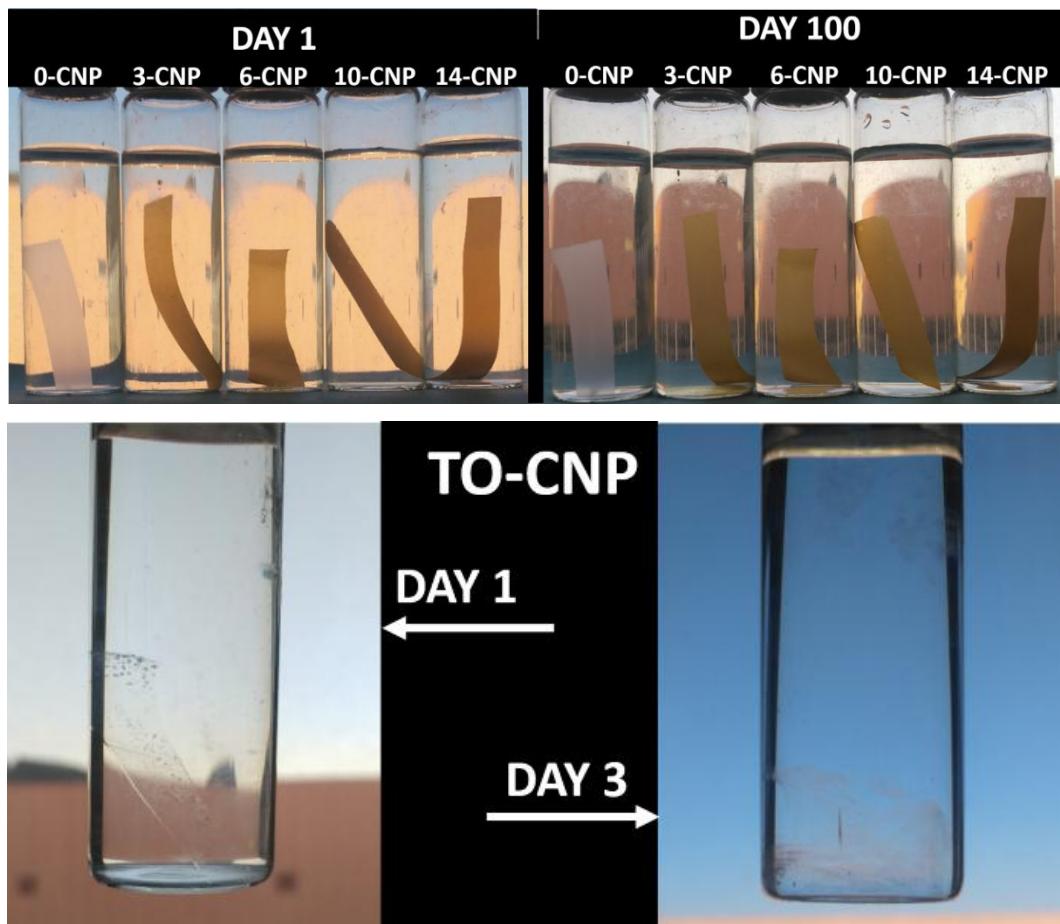


Figure S8 - Water-resisting performance of CNP samples fabricated from FA treated CNFs and TO-CNP.

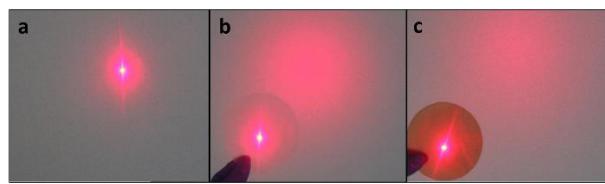


Figure S9 - Haze performance of CNP samples. (a) Laser on, (b) Through 0-CNP
(c) Through 14-CNP.

Table S3 – Optical properties of CNP samples

Sample	T(Vis) ^a	T(UVA) ^b	T(UVB) ^c	Haze ^d
0-CNP	87.27	80.68	76.34	74.21
3-CNP	69.64	24.35	4.94	83.78
6-CNP	60.68	6.15	0.08	89.78
10-CNP	55.31	3.18	0.03	91.03
12-CNP	50.60	1.91	0.03	95.27
14-CNP	48.14	1.05	0.03	95.43
TO-NP	92.29	89.10	84.37	8.16

^a Transmittance of visible light (%). ^b Transmittance of UVA (%). ^c Transmittance of UVB(%). ^d Haze of CNP (%).