Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Precise chemical regulation of polar groups to enhance charge transfer density of cellulosic triboelectric textiles

Yuxin Ma [a, b], Chuanhui Wei [b, c], Zixun Wang [b], Tianmei Lv [b], Yingxue Tan [b, c], Jianlei He [b], Xiao Peng [b], Kai Dong [b, c, *]

[a] Center on Nanoenergy Research, Institute of Science and Technology for Carbon Peak & Neutrality; Key Laboratory of Blue Energy and Systems Integration (Guangxi University), Education Department of Guangxi Zhuang Autonomous Region; School of Physical Science & Technology, Guangxi University, Nanning 530004, P. R. China

[b] Beijing Key Laboratory of Micro-Nano Energy and Sensor, Center for High-Entropy Energy and Systems, Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences, Beijing 101400, P. R. China

[c] School of Nanoscience and Technology, University of Chinese Academy of Sciences, Beijing 100049, P. R. China

Corresponding author:

E-mail: dongkai@binn.cas.cn

1. The structure and properties of materials

The properties of cotton fabric: The weight of the cotton fabric is 230 grams, the density of the fabric is 108*58D, the yarn count is 21s*21s, the thickness is 0.3 mm, and the weaving structure is a twill woven fabric.

The properties of polytetrafluoroethylene (PTFE): PTFE is a kind of triboelectric material with strong electronegativity, and it is easy to obtain electrons. In the use of triboelectric materials, PTFE is often used as a negative triboelectric layer.

The properties of polyamide (PA): PA is a common polymer material. In the triboelectric sequence of common materials, PA belongs to the material that is easy to lose electrons. In the selection of triboelectric materials, PA is usually used as a positive friction layer material.

2. Output performance test

In the NH_2-Cellulose/PTFE output performance test experiment, a force of 10 N is applied to the fabric by controlling the starting and ending positions of the linear motor (LinMot E1100). The force of 10 N is measured by a high precision micro dynamometer (Vernier LabQuest Mini). The electrode layer of NH_2-Cellulose/PTFE is connected to the electrometer 6514 through a wire. In the process of circular contact separation of NH_2-cellulose and PTFE by linear motor control, the signals of transfer charge, open-circuit voltage and short-circuit current can be measured by electrostatic meter (Keithley 6514), and these data can be visualized by LabView program. By dividing the amount of transfer charge by the effective contact area of NH_2-Cellulose/PTFE, the transfer charge density can be obtained to be 14.1 $\mu C/m^2$.

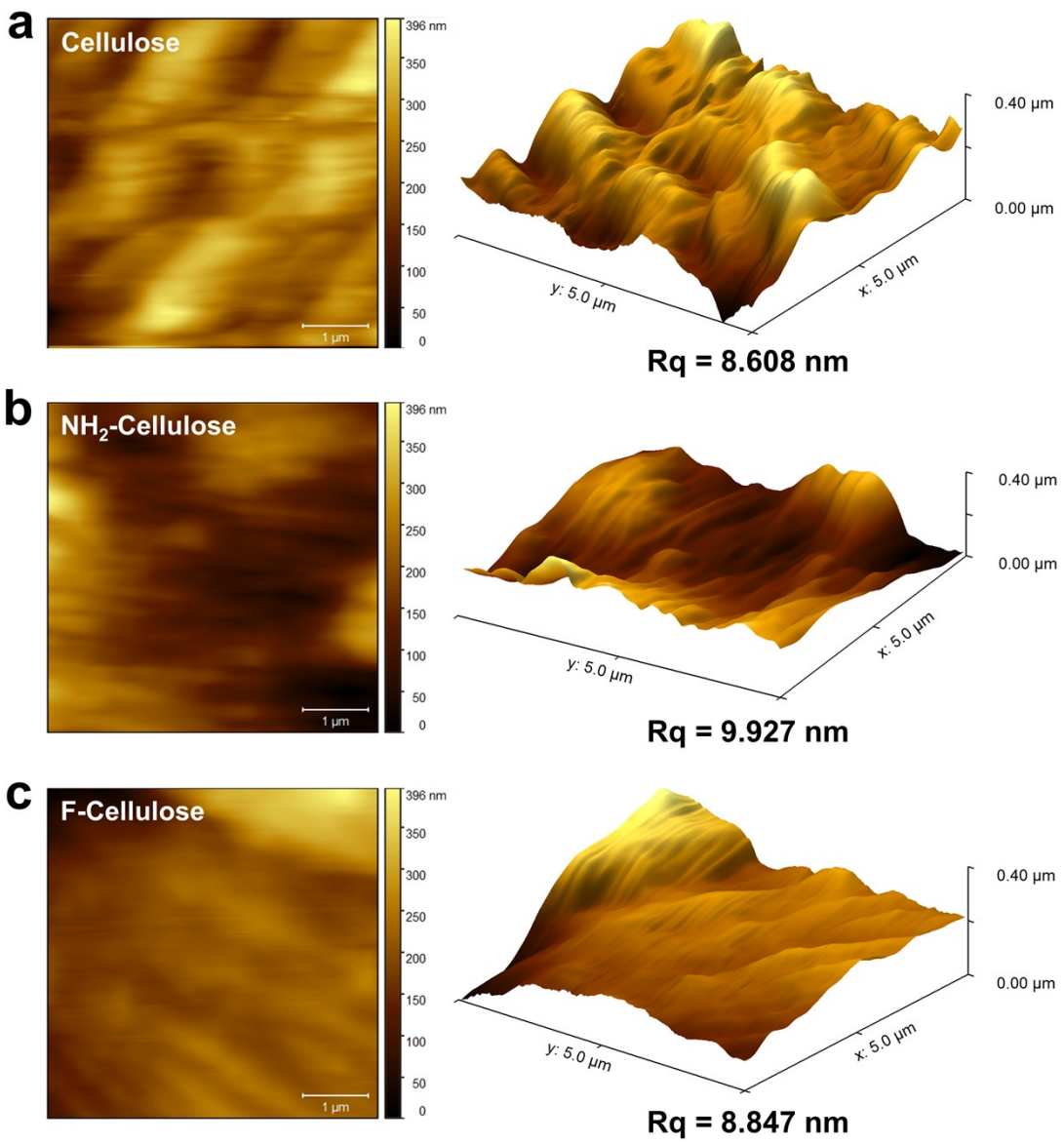

Fig. S1. AFM topology and 3D images (5×5 µm) of (a) cellulosic textiles, (b) NH_2-Cellulose and (c) F-Cellulose.

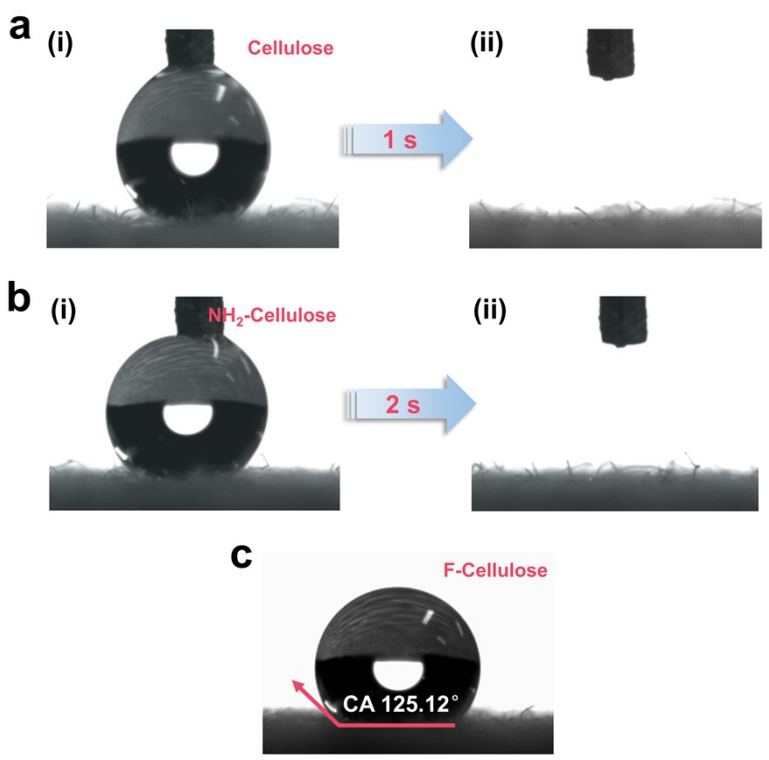

Fig. S2. The water contact angles of (a) cellulosic textiles, (b) NH_2-Cellulose and (c) F-Cellulose.

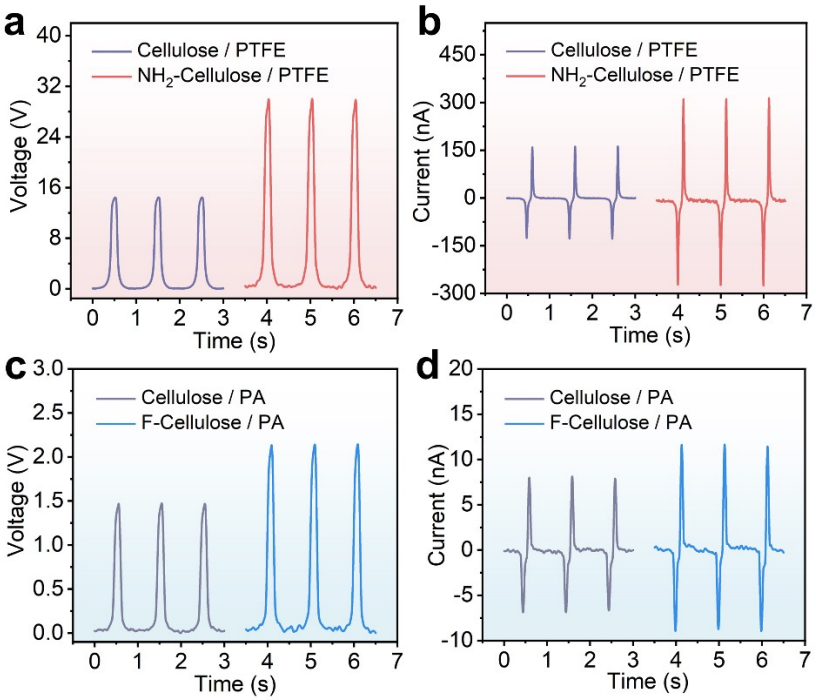

Fig. S3. (a, b) Open-circuit voltage and short-circuit current generated by contact separation between PTFE and cellulosic textile, NH_2-Cellulose. (c, d) Open-circuit voltage and short-circuit current generated by contact separation between PA and cellulosic textile, F-Cellulose.

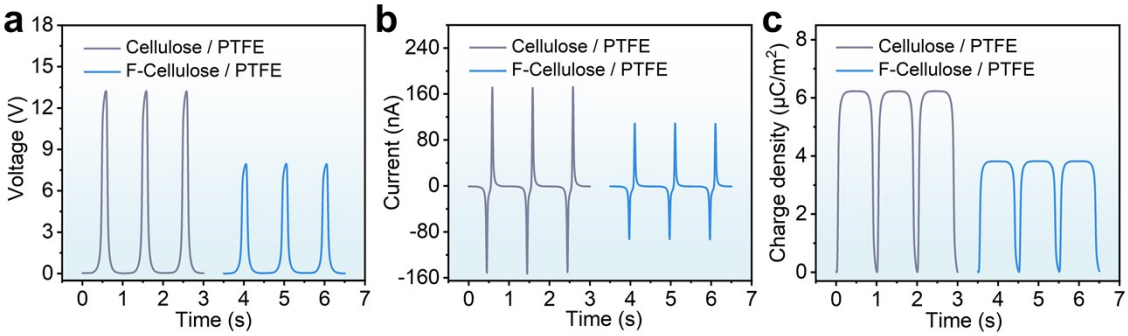

Fig. S4. Comparison of (a) open-circuit voltage, (b) short-circuit current, (c) charge transfer density between cellulose/PTFE and F-Cellulose/PTFE.

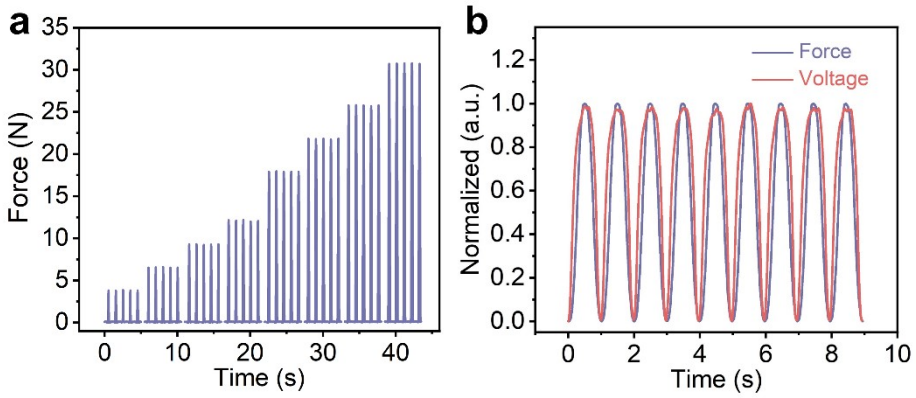

Fig. S5. (a) Curve of force changing with time. (b) Signal curve of force and voltage.

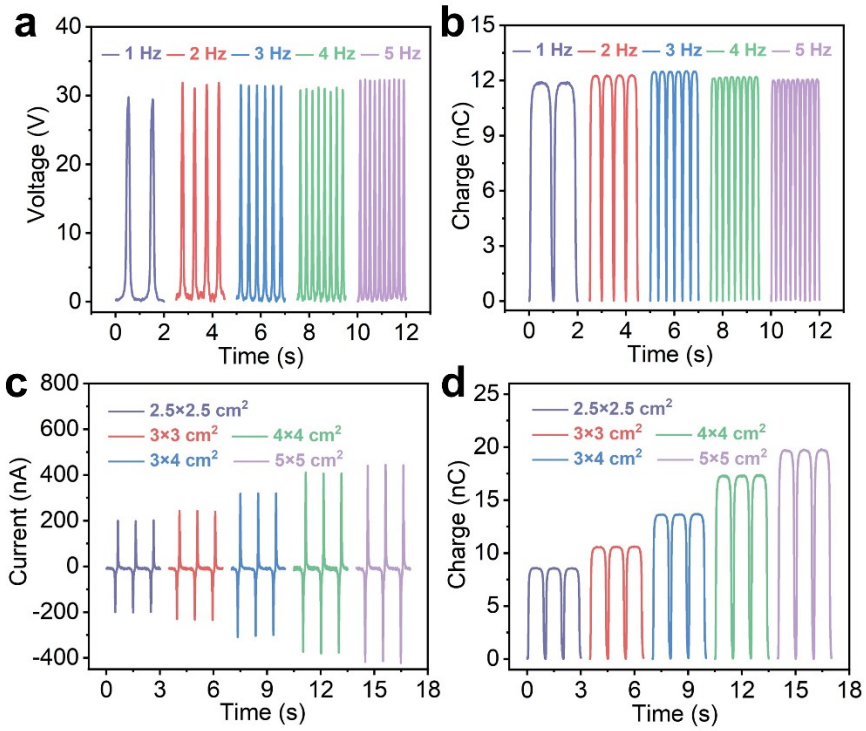

Fig. S6. (a, b) Open-circuit voltage and transfer charge of NH_2-Cellulose/PTFE with a vertical force of 10 N at different frequencies (1-5 Hz). (c, d) Short-circuit current and transfer charge of NH_2-Cellulose/PTFE with different contact areas (2.5×2.5 cm^2-5×5 cm^2) at a frequency of 1 Hz with a force of 10 N.

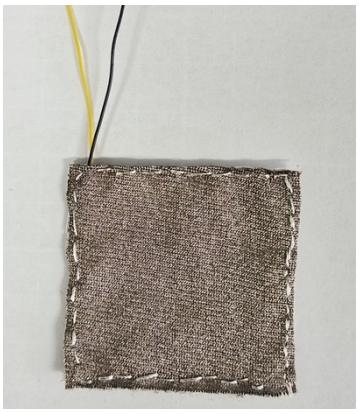

Fig. S7. The photograph of NH_2-Cellulose/F-Cellulose.

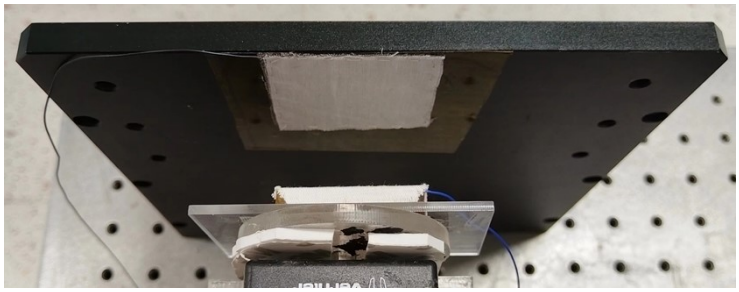

Fig. S8. The photograph of NH_2-Cellulose/F-Cellulose during testing.

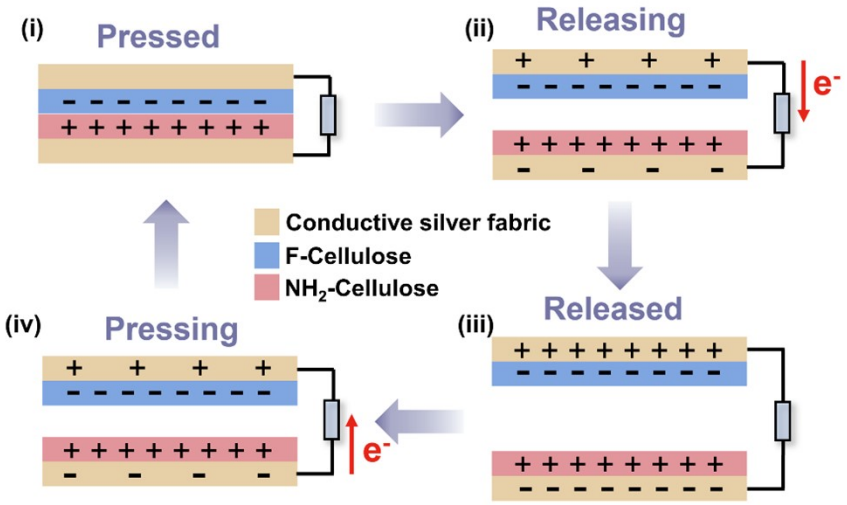

Fig. S9. Schematic of the operation mechanism of the NH_2-Cellulose/F-Cellulose in a vertical contact-separation mode.

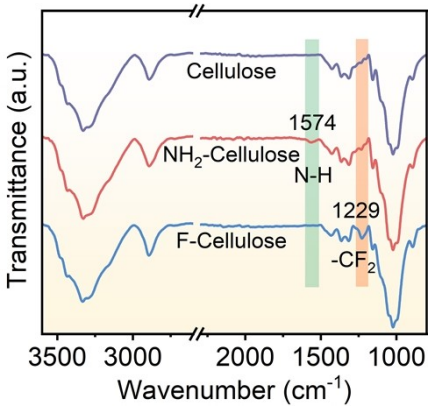

Fig. S10. ATR-FTIR spectra of original cellulosic textiles, NH_2-Cellulose and F-Cellulose after washing for 24 hours.

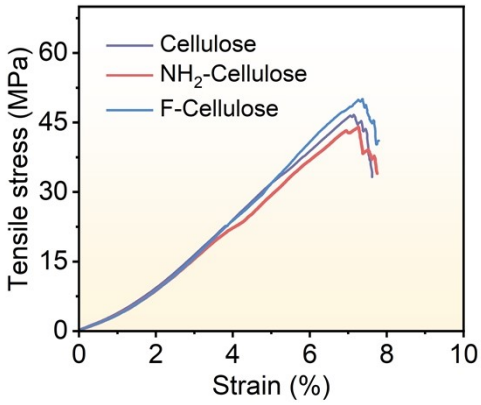

Fig. S11. Tensile properties of original cellulosic textiles, NH_2-Cellulose and F-Cellulose after washing for 24 hours.

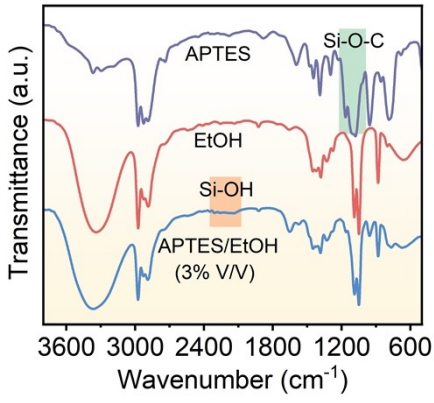

Fig. S12. TR-FTIR spectra of APTES, EtOH and APTES/EtOH (3% V/V).

Fig. S13. The photograph of the linear motor (LinMot E1100).

Fig. S14. The photograph of the electrostatic meter (Keithley 6514).

Table S1. Extraction of cellulose.

Ref	Source	Extraction method
[1]	Rice husk	Alkaline treatment Bleaching process Acid hydrolysis
[2]	Wheat straw	Treatment with acidic sodium chlorite Treatment with alkaline hydrogen peroxide
[3]	Bamboo	Preparation of cellulose from bamboo fibers Delignification of bamboo fiber Mercerization
[4]	Abaca pseudo stem	Preparation of Abaca fiber Isolation of cellulose
[5]	Waste cotton fabrics	Concentrated sulfuric acid hydrolysis Deionized water dialysis

Table S2. Compared with the increase degree of transfer charge in other work.

Ref	Modified materials	Positive modification	Increase in the amount of transfer charge (%)	Negative modification	Increase in the amount of transfer charge (%)
[6]	AEAPDMS	□	75%		
[7]	PDOTES			□	30%
[8]	CNT	□	43%		
[9]	EPI/EDA	□	16.7%		
This work	APTES NFTES	□	100%	□	45%

References

[1] Johar, N.; Ahmad, I.; Dufresne, A., Extraction, preparation and characterization of cellulose fibres and nanocrystals from rice husk. Industrial Crops and Products 2012, 37, 93.

[2] Qasim, U.; Ali, Z.; Nazir, M. S.; Ul Hassan, S.; Rafiq, S.; Jamil, F.; Al-Muhtaseb, A. a. H.; Ali, M.; Khan Niazi, M. B.; Ahmad, N. M.; Ullah, S.; Mukhtar, A.; Saqib, S., Isolation of Cellulose from Wheat Straw Using Alkaline Hydrogen Peroxide and Acidified Sodium Chlorite Treatments: Comparison of Yield and Properties. Advances in Polymer Technology 2020, 2020, 1.

[3] Liew, F. K.; Hamdan, S.; Rahman, M. R.; Rusop, M.; Lai, J. C. H.; Hossen, M. F.; Rahman, M. M., Synthesis and Characterization of Cellulose from Green Bamboo by Chemical Treatment with Mechanical Process. Journal of Chemistry 2015, 2015, 1.

[4] Saragih, S. W.; Wirjosentono, B.; Eddyanto; Meliana, Y., Extraction and Characterization of Cellulose from Abaca Pseudo Stem (Musa textile). Journal of Physics: Conference Series 2019, 1232, 012018.

[5] Ruiz-Caldas, M.-X.; Carlsson, J.; Sadiktsis, I.; Jaworski, A.; Nilsson, U.; Mathew, A. P., Cellulose Nanocrystals from Postconsumer Cotton and Blended Fabrics: A Study on Their Properties, Chemical Composition, and Process Efficiency. ACS Sustainable Chemistry & Engineering 2022, 10, 3787.

[6] Nie, S.; Cai, C.; Lin, X.; Zhang, C.; Lu, Y.; Mo, J.; Wang, S., Chemically Functionalized Cellulose Nanofibrils for Improving Triboelectric Charge Density of a Triboelectric Nanogenerator. ACS Sustainable Chemistry & Engineering 2020, 8, 18678.

[7] Zhu, Q.; Wang, T.; Sun, X.; Wei, Y.; Zhang, S.; Wang, X.; Luo, L., Effects of Fluorine-Based Modification on Triboelectric Properties of Cellulose. Polymers 2022, 14, 3536.

[8] Wang, Z.; Chen, C.; Fang, L.; Cao, B.; Tu, X.; Zhang, R.; Dong, K.; Lai, Y.; Wang, P., Biodegradable, conductive, moisture-proof, and dielectric enhanced cellulose-based triboelectric nanogenerator for self-powered human-machine interface

sensing. Nano energy 2023, 107, 108151.

[9] Sheng, Z.; Qiuxiao, Z.; Tingting, W.; Xuchong, W.; Xiaoping, S.; Yuhe, W.; Lianxin, L., Contact electrification property controlled by amino modification of cellulose fibers. Cellulose 2022, 29, 3195.