



# Highly Transparent Cellulose Films for Electronic Applications

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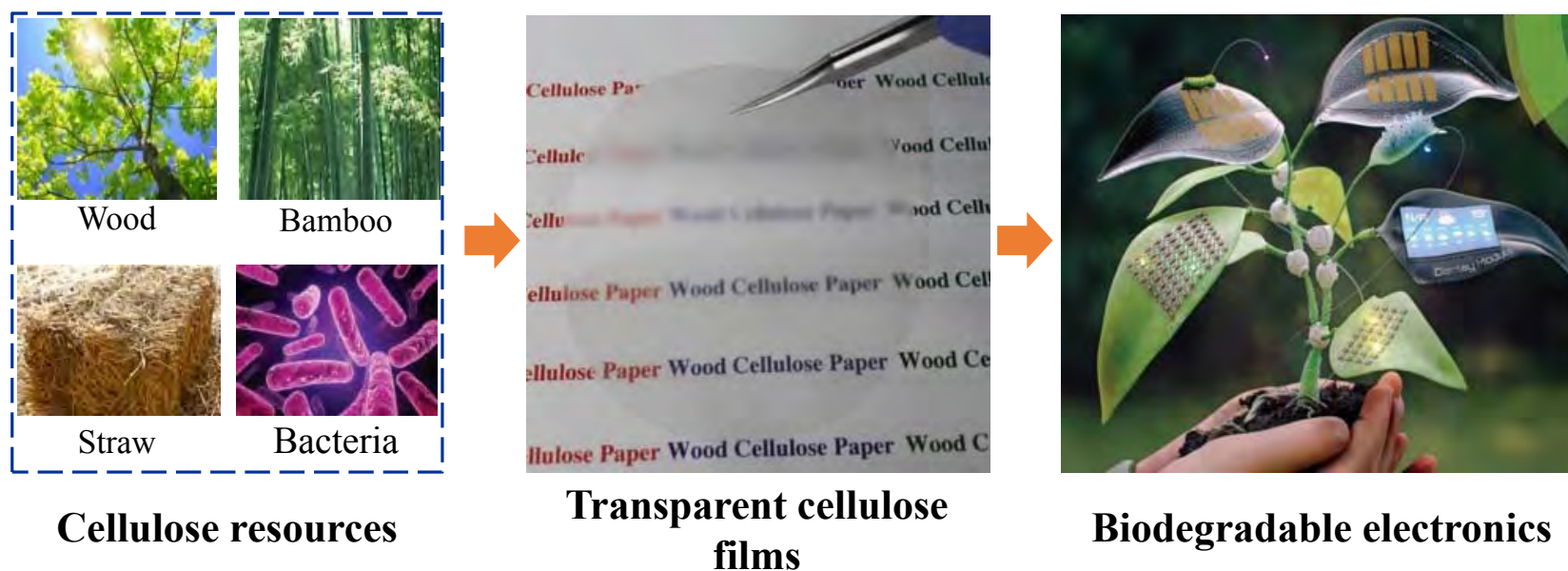
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**South China University of Technology**



# Personal introduction





## Research interests



Toward a Sustainable Society---**Biodegradable electronics**

# Content

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-  **Background**.....
-  **Transparent cellulose films**.....
-  **Electronic applications**.....
-  **Conclusion and Perspectives**.....

# 1 Background

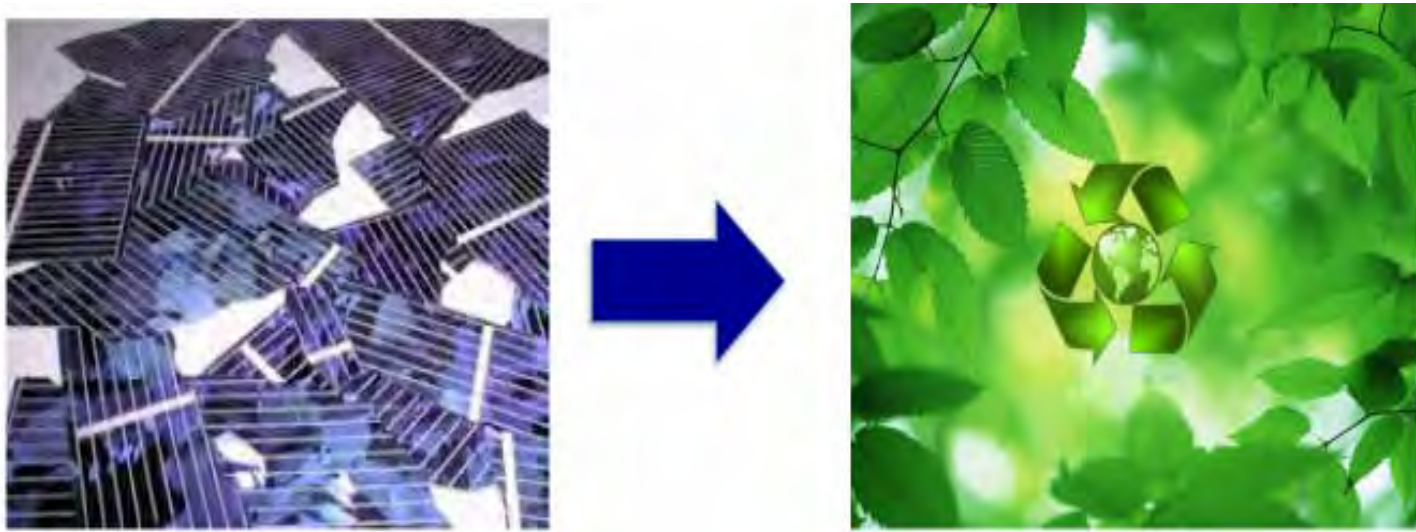
## Ever-Growing E-waste is a Problem



About **50 million** tons of E-waste in 2017

# 1 Background

**A Transformation for Electronics is Imperative**



**Moving from Petroleum Chemistry to Naturally-derived Materials**



# 1 Background

## Emerging Substrate for Electronics---Transparent cellulose films



Transparent films

### Advantages:

- 1 Earth abundance
- 2 Renewability
- 3 Environmental friendliness
- 4 Easy modifications
- 5 Biodegradability

.....

## 2 Transparent cellulose films

### 2.1 Raw materials



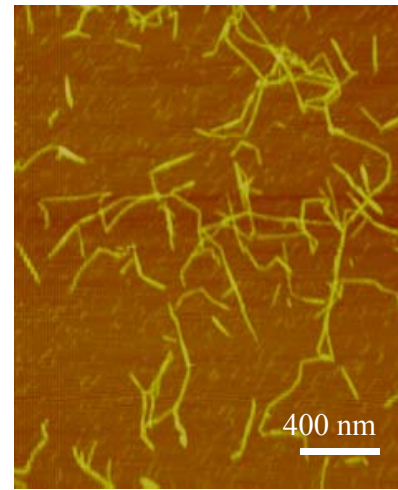
Wood fibers



Treated wood  
fibers



Treated wood fibers



Nanofibrillated cellulose (NFC)



**Micro-scale cellulose fibers**

**Nano-scale cellulose fibers**

## 2 Transparent cellulose films

### 2.2 Category

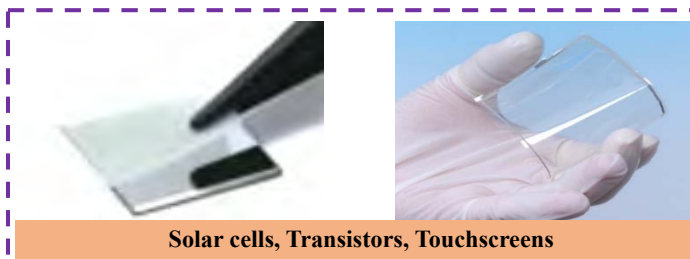
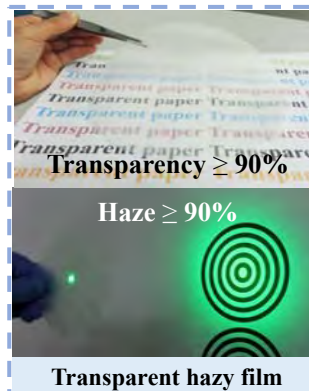
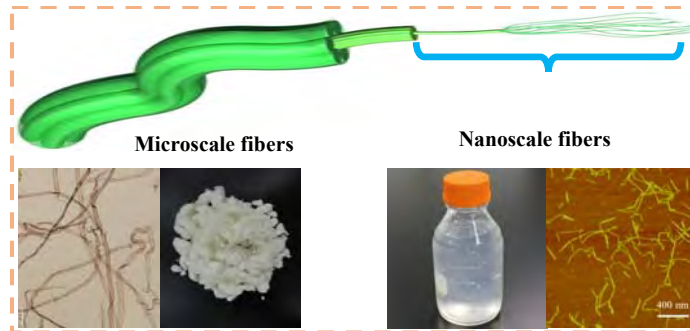
Multiscale cellulose  
fibers



Transparent films



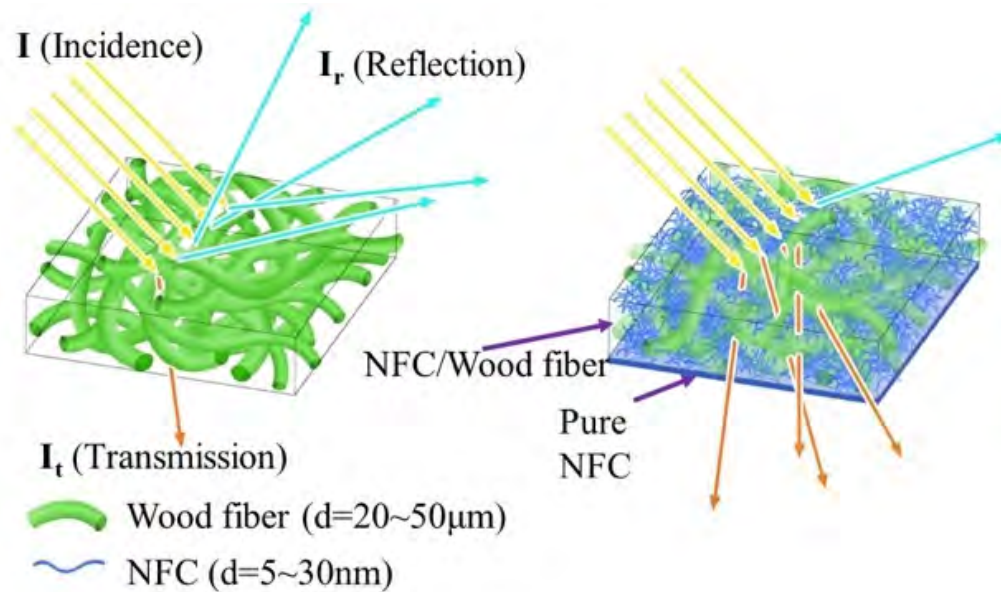
Biodegradable  
electronics





## 2 Transparent cellulose films

Transparent and hazy film: **1<sup>st</sup> generation**

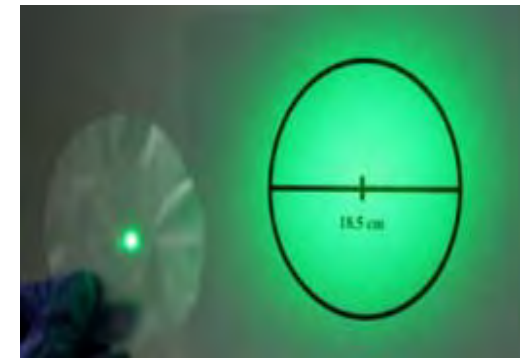
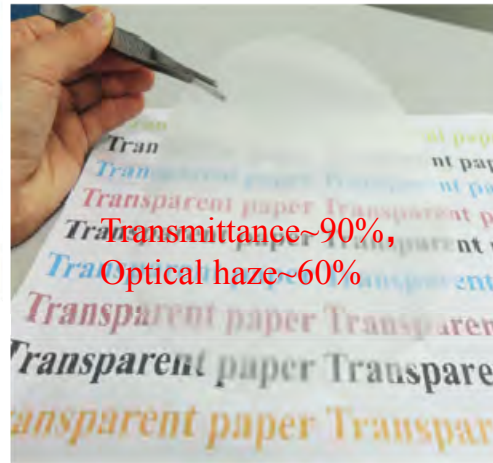
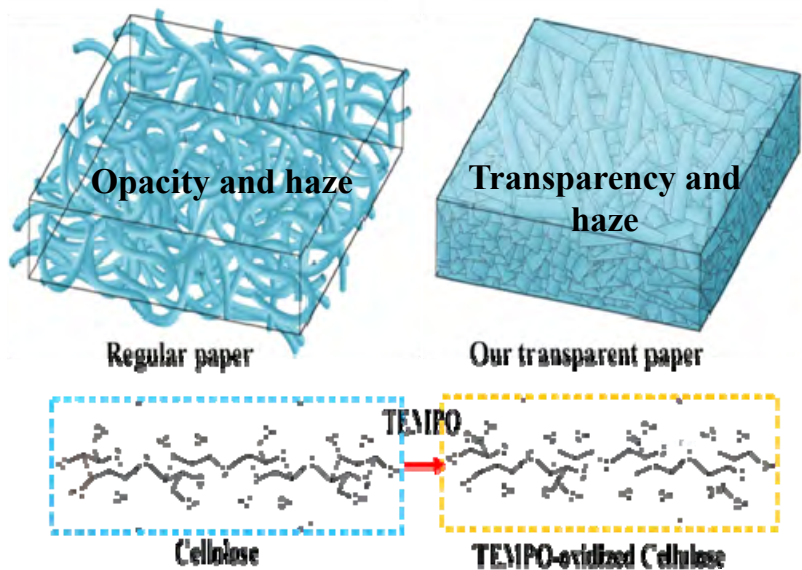


Optical transmission: 90%

**Low production efficiency**

## 2 Transparent cellulose films

Transparent and hazy film: **2<sup>nd</sup> generation**

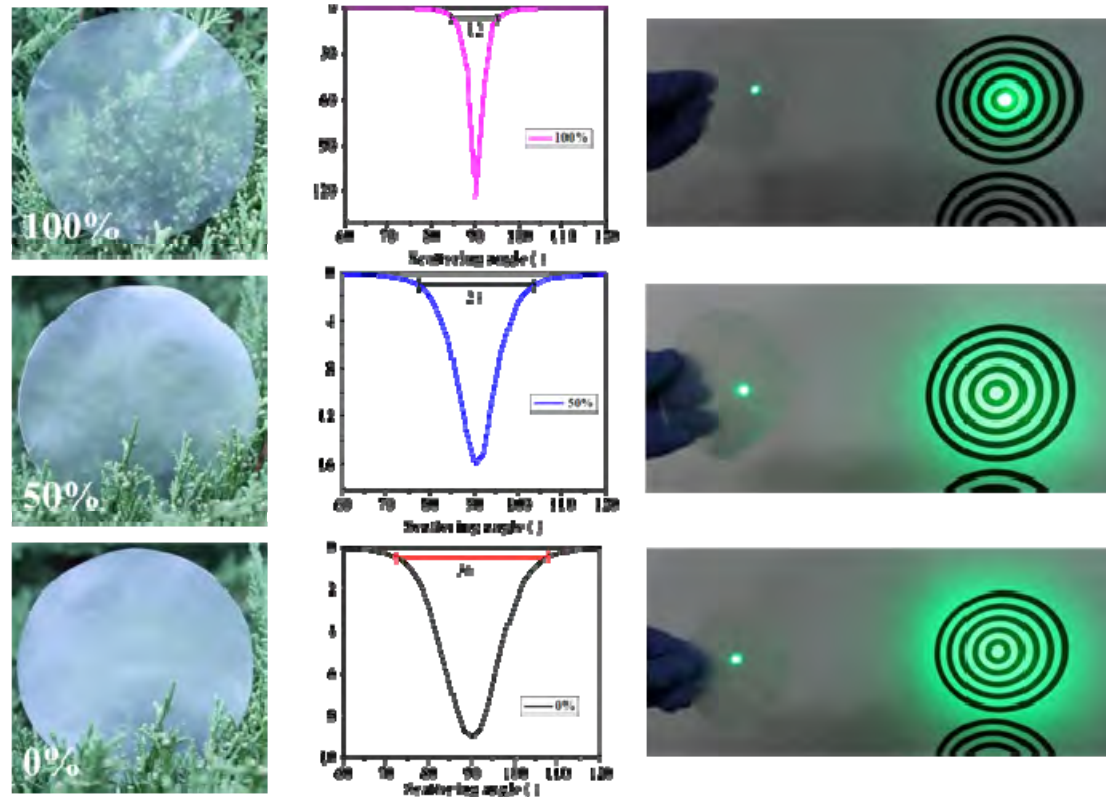


Strong light scattering effect

High production efficiency and good tensile strength

## 2 Transparent cellulose films

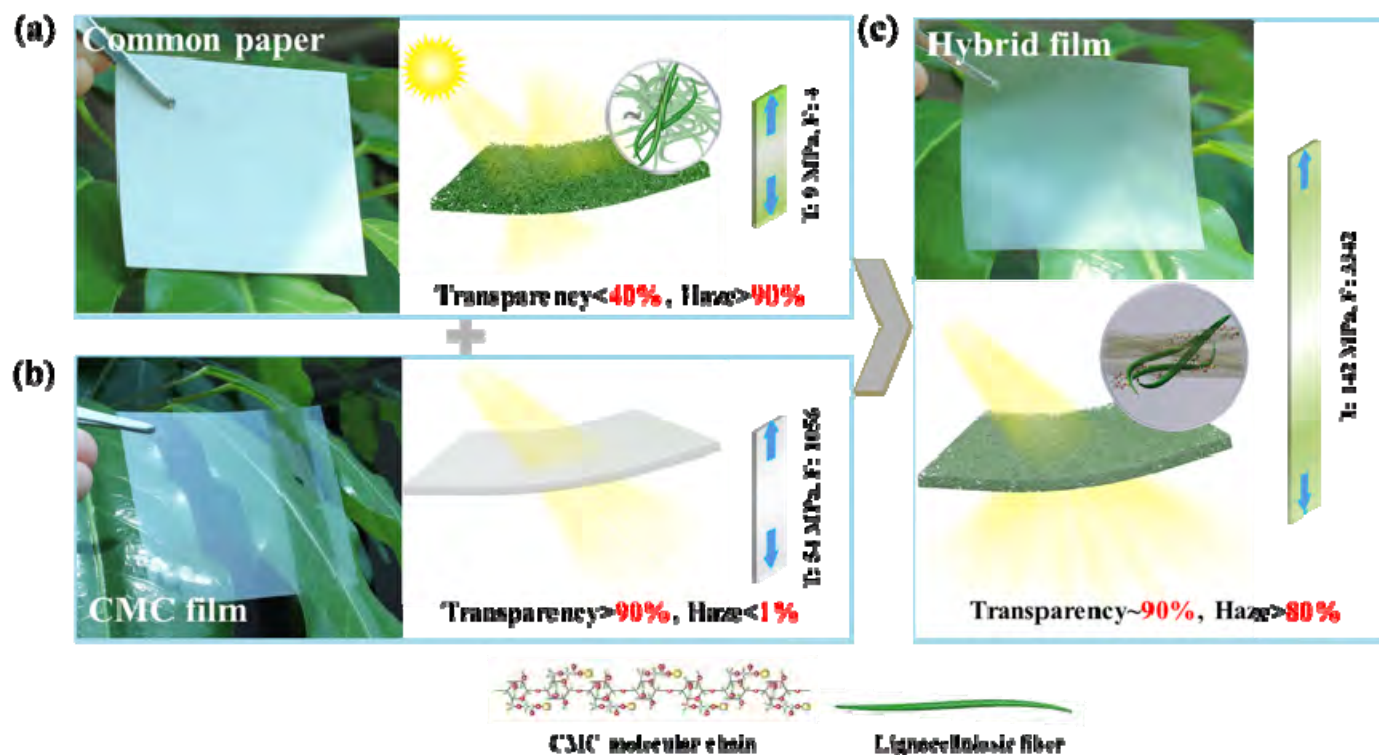
Transparent and hazy film: 3<sup>rd</sup> generation



Highly transparent paper with tunable optical haze

## 2 Transparent cellulose films

Transparent and hazy film: 4<sup>th</sup> generation

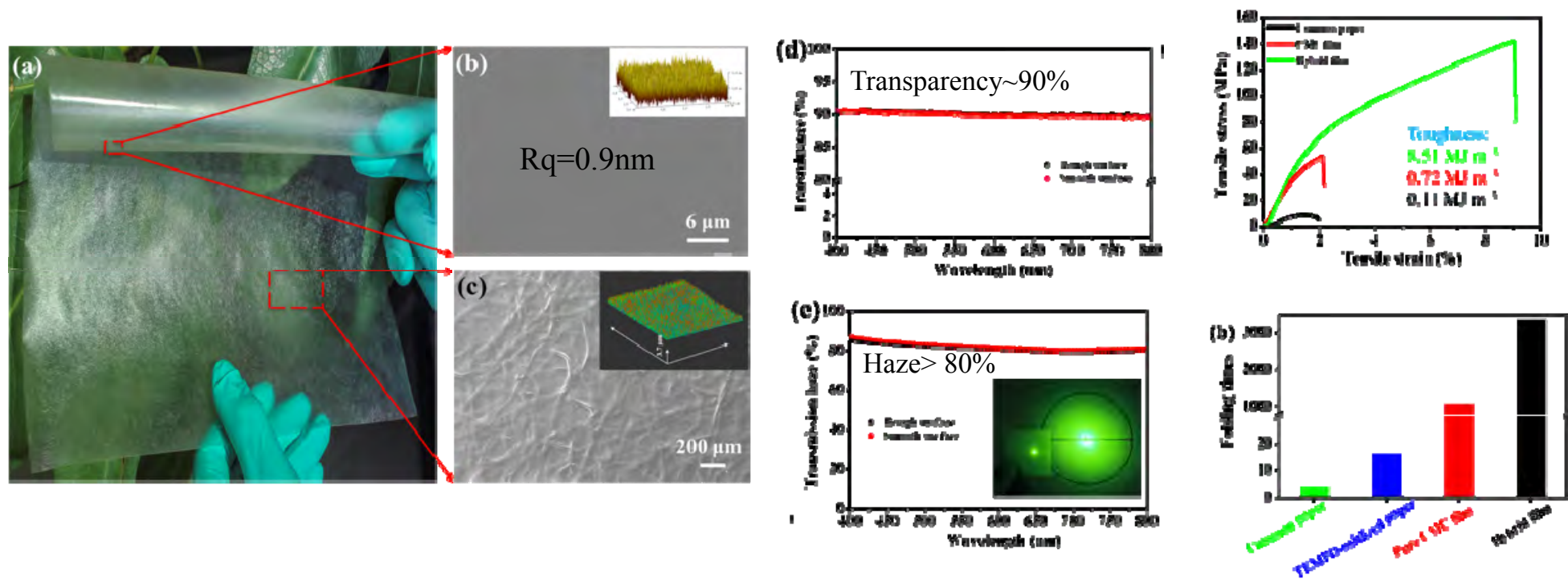


Excellent optical properties, superior mechanical strength, good thermal properties



## 2 Transparent cellulose films

Transparent and hazy film: 4<sup>th</sup> generation

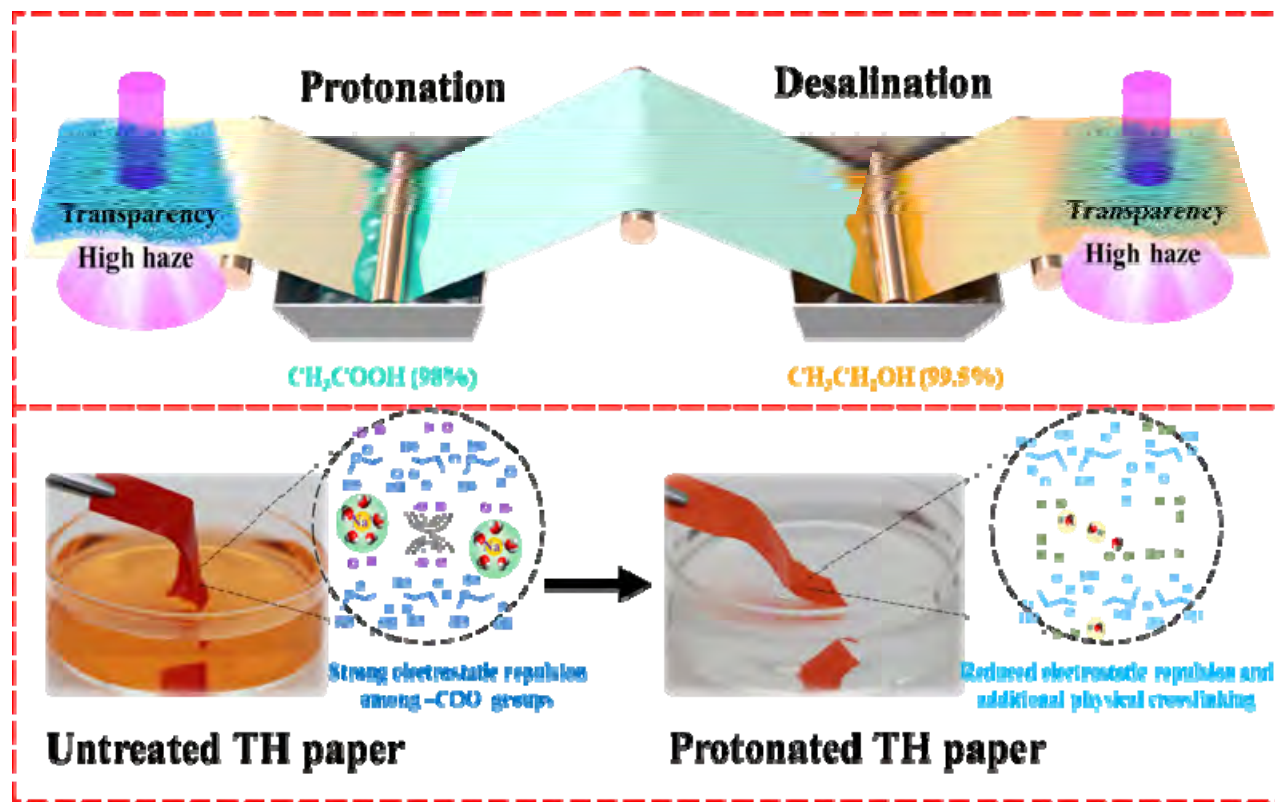


Nanoscale surface roughness (0.9nm), 91% transmittance, 82% haze  
Strong tensile strength (140 Mpa), high folding endurance (3342)



## 2 Transparent cellulose films

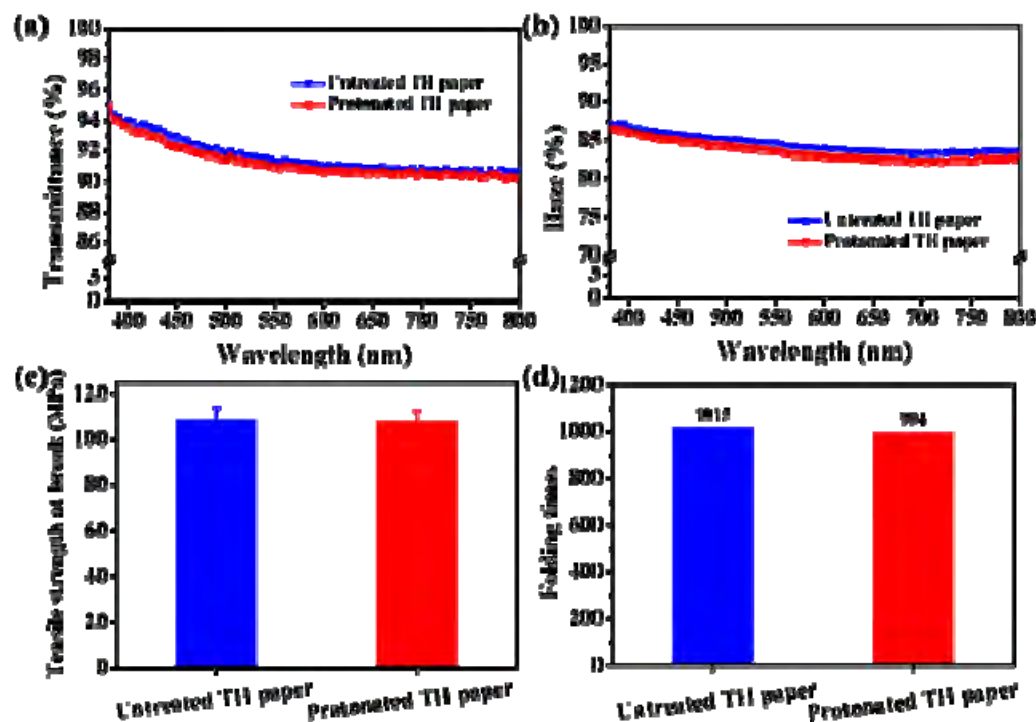
Transparent and hazy film: 5<sup>th</sup> generation



Water resistance

## 2 Transparent cellulose films

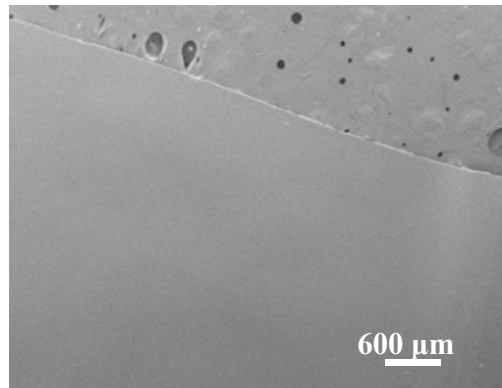
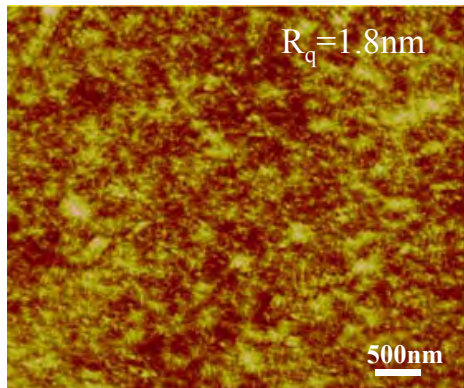
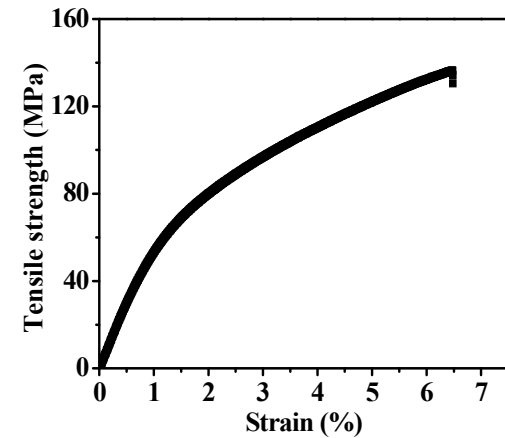
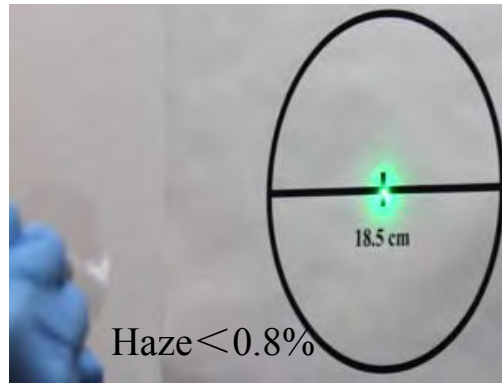
Transparent and hazy film: 5<sup>th</sup> generation



Well-preserved optical and mechanical properties after protonation

## 2 Transparent cellulose films

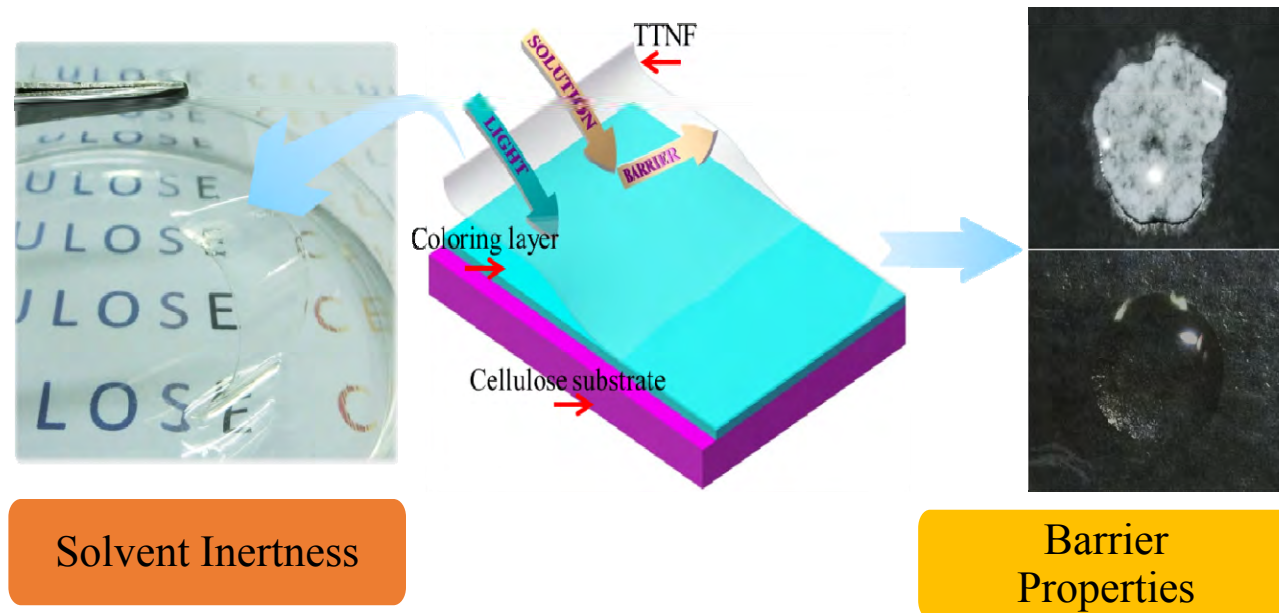
Transparent and clear film: 1<sup>st</sup> generation



Minimum bending radius is 2 mm

## 2 Transparent cellulose films

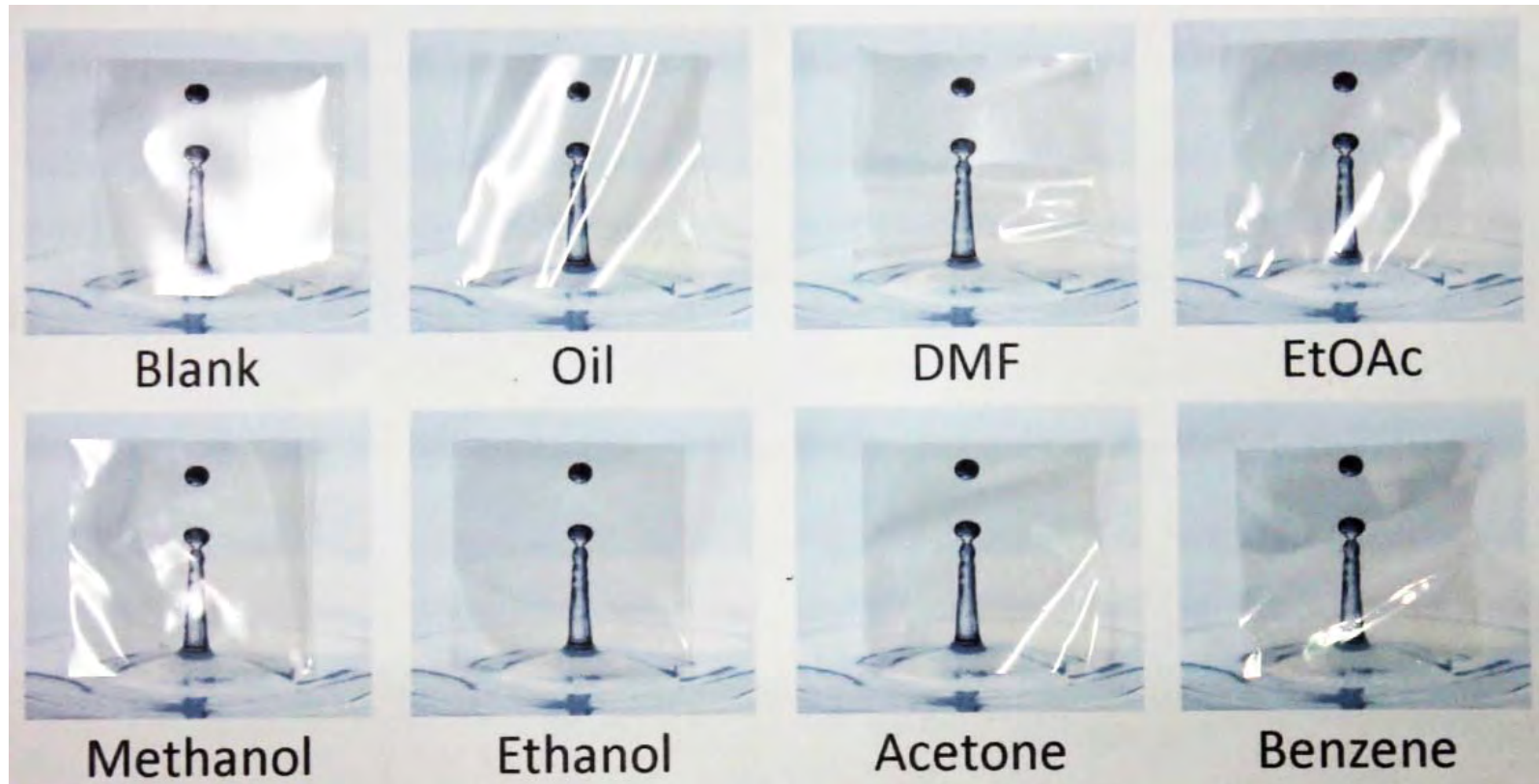
Transparent and clear film: 1<sup>st</sup> generation



**Excellent Solvent Resistance**

## 2 Transparent cellulose films

Transparent and clear film: 1<sup>st</sup> generation

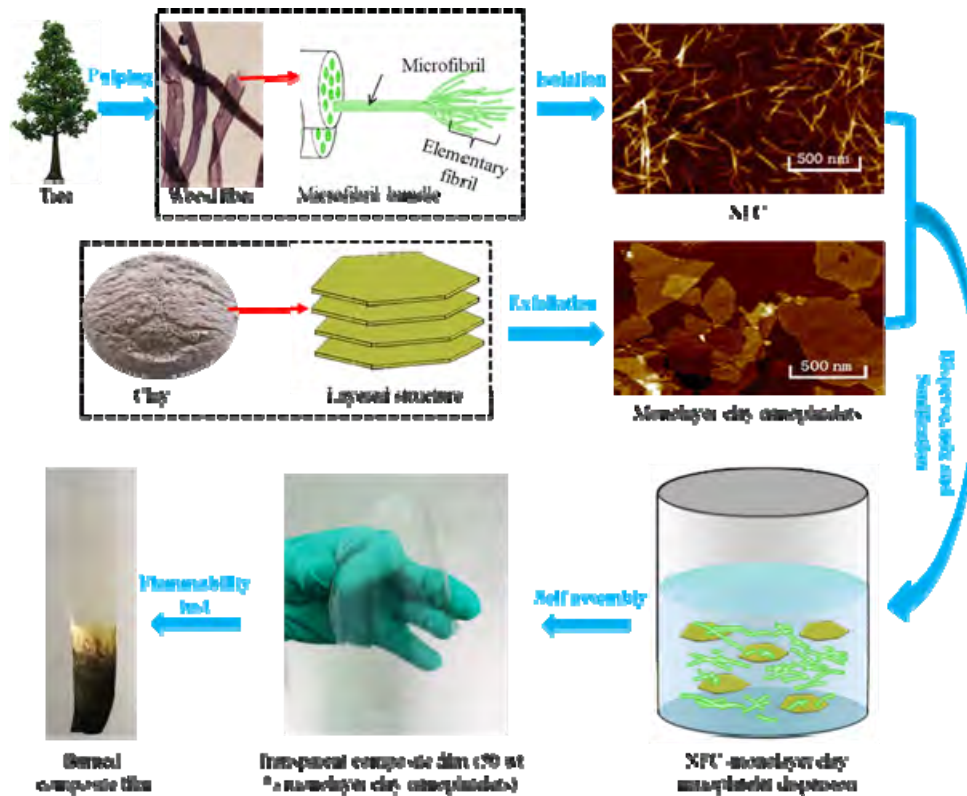


Excellent solvent inertness

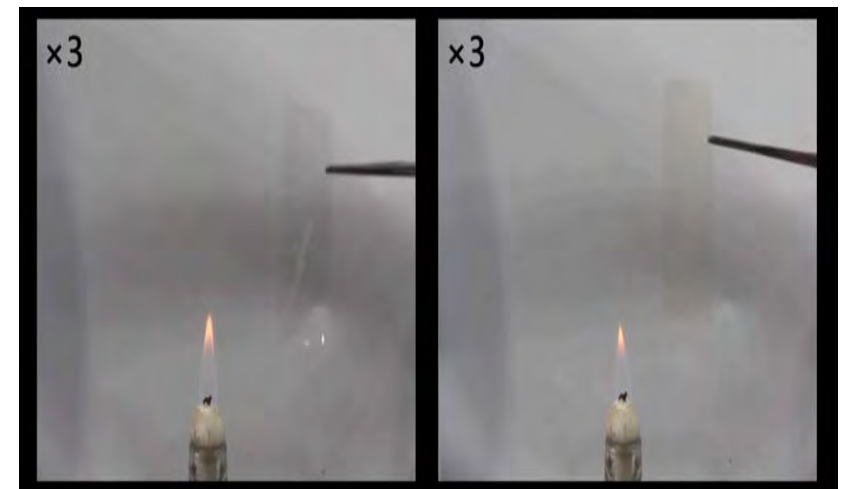


## 2 Transparent cellulose films

### Transparent CNF/MTM film: 2<sup>nd</sup> generation



LOI : 60%  
UL94-5VA



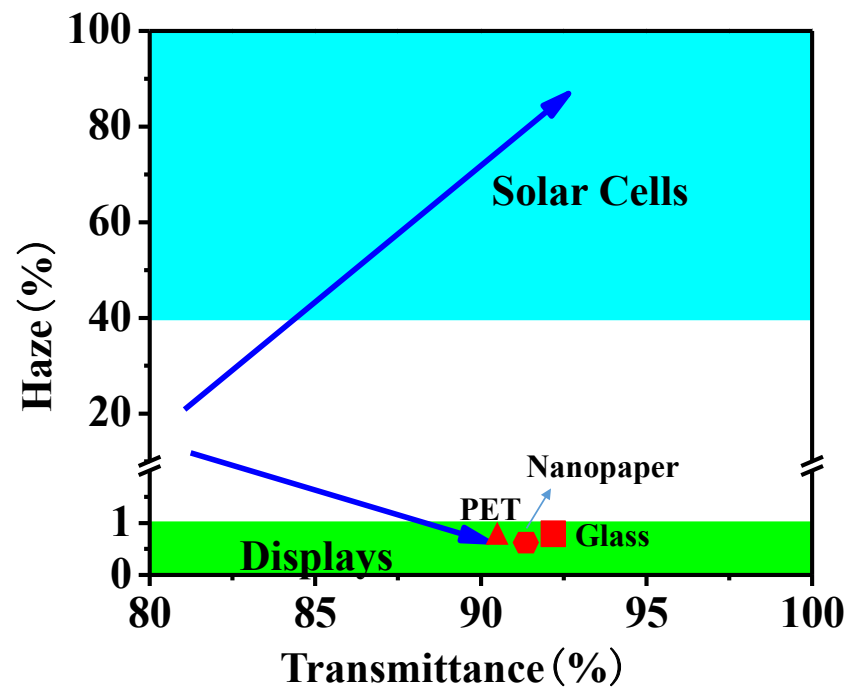
Pure CNF film

CNF/MTM film

Self-extinguishing performance

### 3 Electronic applications

#### Potential electronic applications of transparent cellulose films



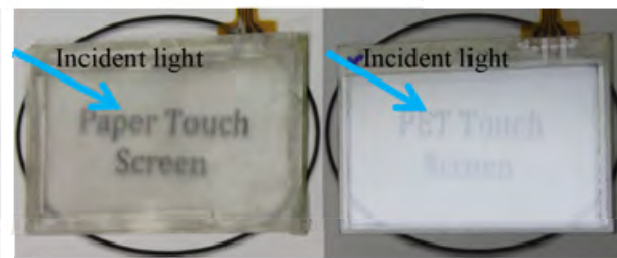
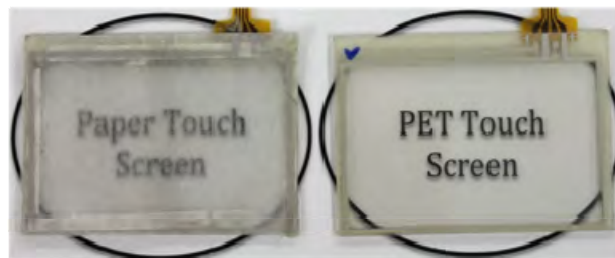
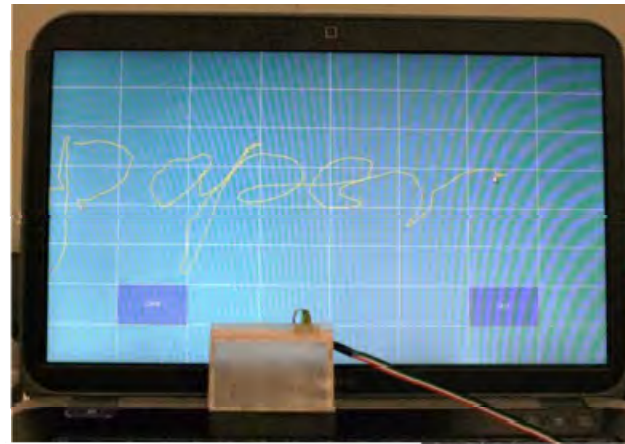
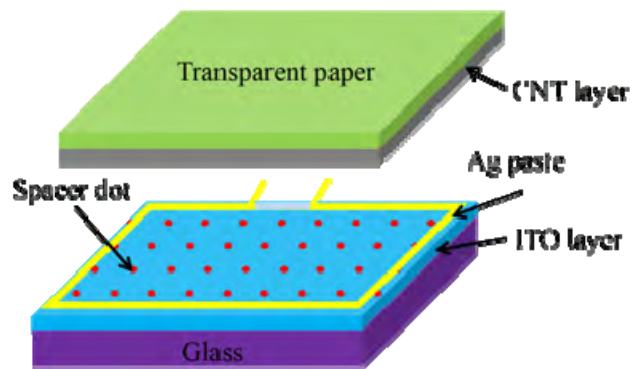
Solar cells



Flexible displays

### 3 Electronic applications

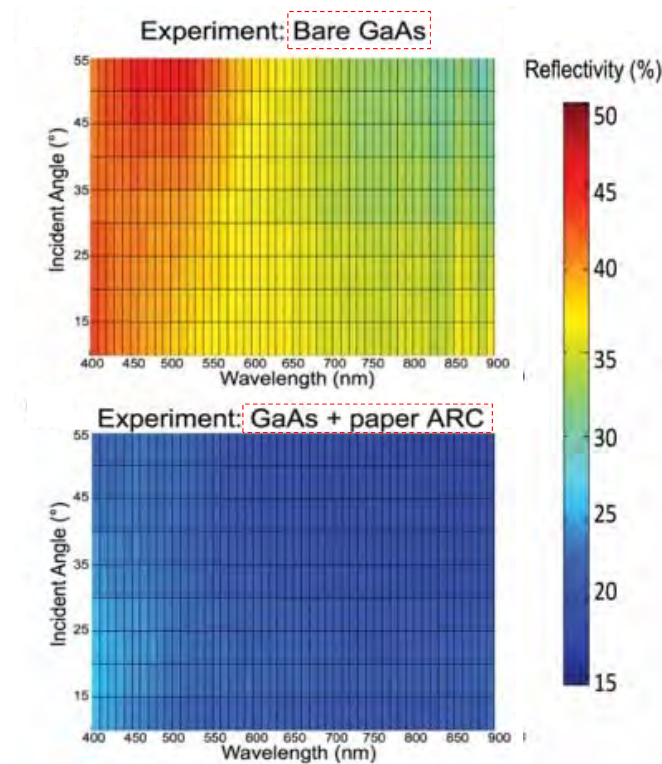
#### Transparent and hazy films-Touchscreen



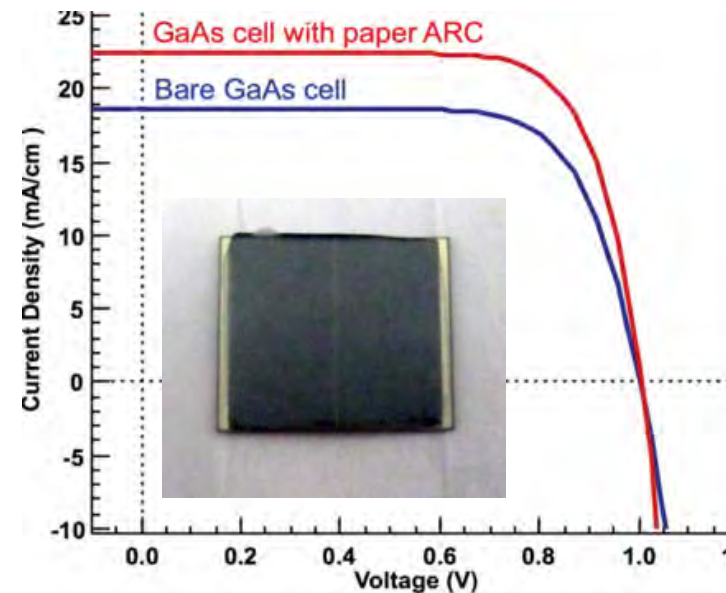
Anti-glaring property

### 3 Electronic applications

#### Transparent and hazy films-Solar cells



#### Gallium arsenide solar cells



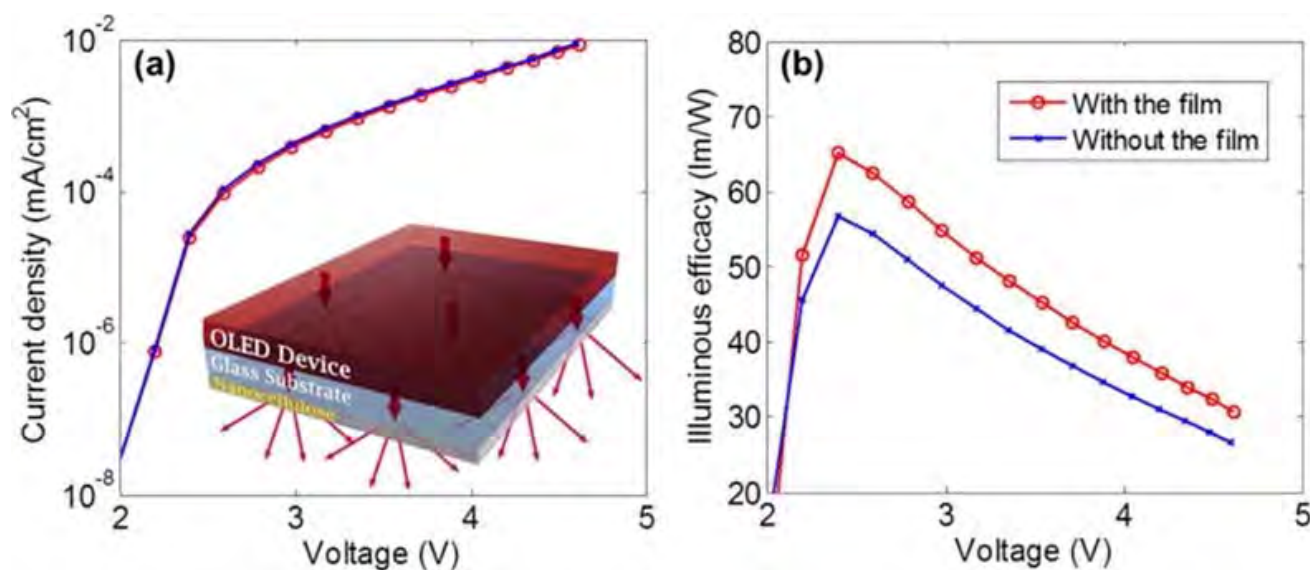
13.6% → 16.8%

Enhanced power conversion efficiency

*Adv Energ Mater.* 2014, 4, 1301804. *IEEE J Photovolt.* 2015, 5(2):577-583.

### 3 Optoelectronic applications

#### Transparent and hazy films-OLEDs

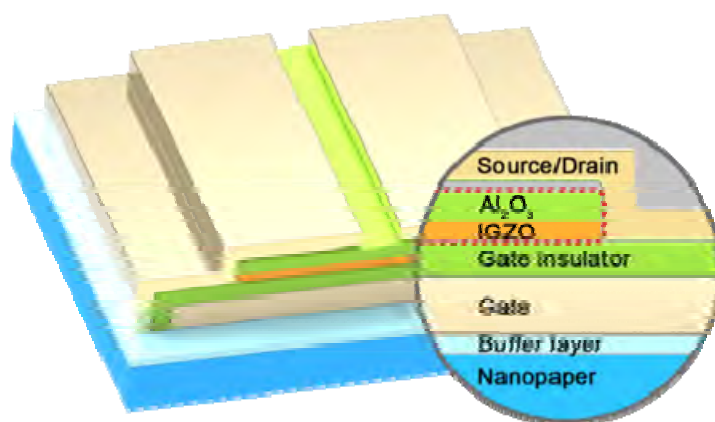


Improved light output power and illuminous efficacy

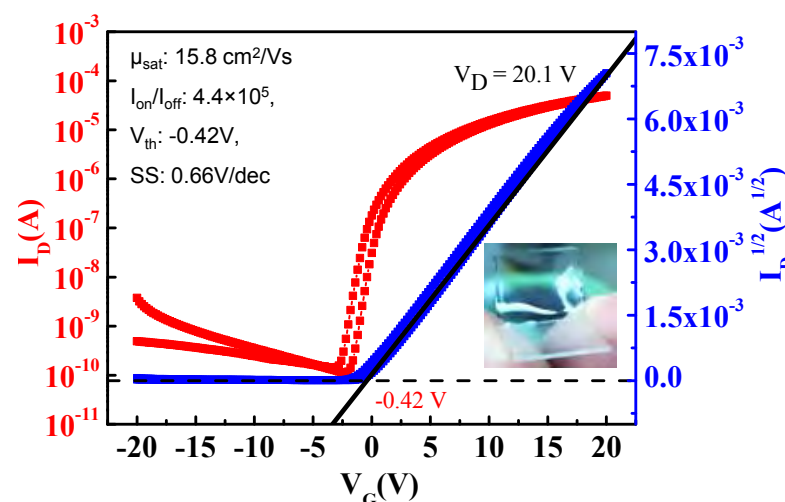


### 3 Electronic applications

#### Transparent and clear cellulose films-**Thin film transistors**



Structure of thin film transistor (TFT) on transparent and clear paper

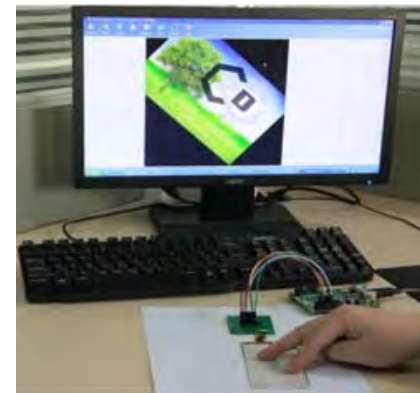
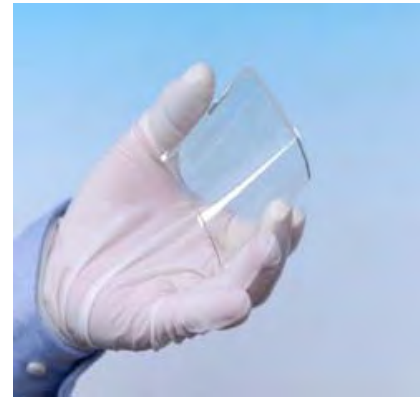
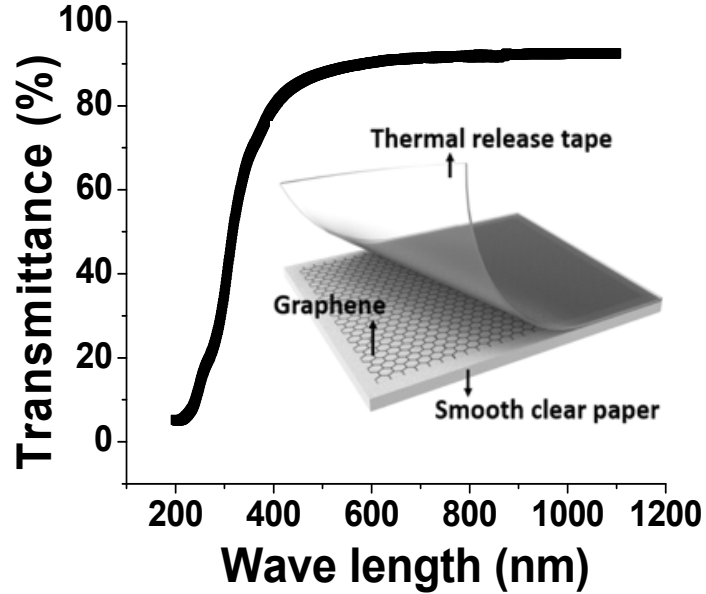


Transfer characteristics of high performance paper TFT without thermal treatment

#### Room temperature fabrication of high performance TFT on transparent and clear cellulose film

### 3 Electronic applications

Transparent and clear cellulose films-**Flexible touchscreen**



## 4 Conclusion & perspectives

### Conclusion

- ❑ Transparent and hazy cellulose films have potential applications in optoelectronics (*e.g.*, solar cells, OLEDs) as a active layer.
- ❑ Transparent and clear cellulose films may be used as a green substrate for electronic applications such as thin film transistors and touchscreen.
- ❑ Integrating functional nanomaterials into transparent cellulose films enable the introduction of novel functionality such as electrical conductivity and self extinguishing.

### Perspectives

- ❑ Many endeavors should be devoted to enhancing the mechanical properties (such as toughness and folding endurance) and weather stability of transparent cellulose films.
- ❑ Economical and scalable production of these transparent cellulose films is a high priority.

## 4 Acknowledge

- I appreciate the support from Prof. Hu, Prof. Chen, Prof. Ning, and Prof. Zhu.
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# Thanks for your attention!

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