JSNN
Joint School of
Nanoscience and Nanoengineering

Nanocellulose at the IMPACT Lab: From Isolation to Biorenewable Composites

Dr. Michael L. Curry, Ph.D.

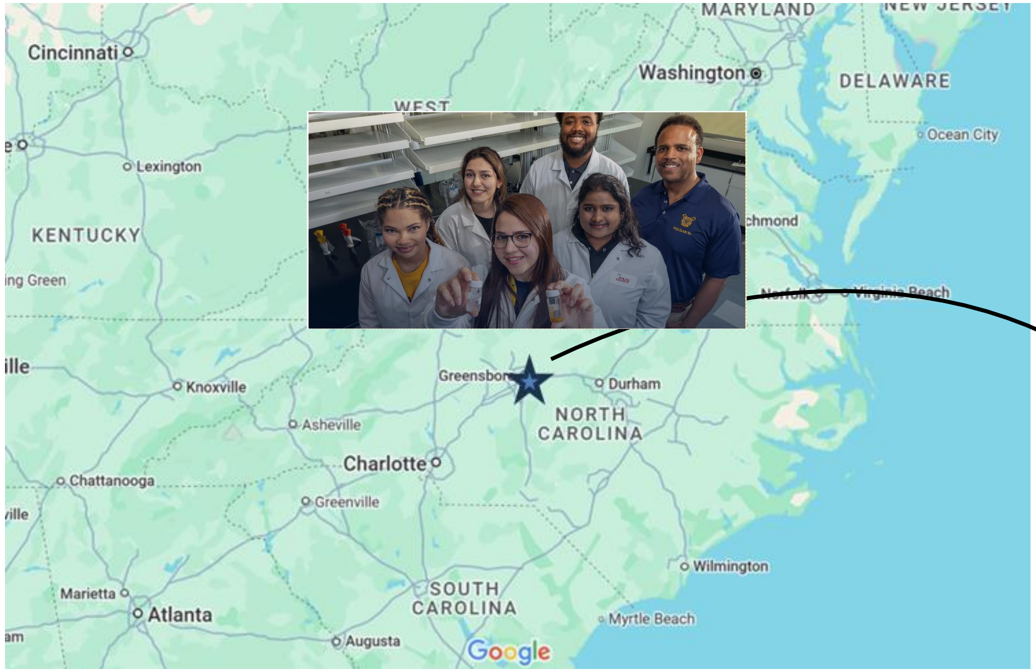
Professor and Graduate Program Director

Department of Nanoengineering, Joint School of Nanoscience and Nanoengineering

Inaugural Faculty Fellow, Center for Excellence in Entrepreneurship and Innovation

Committee Member, North Carolina A&T State University's Patent Committee

Texas Southern University
Thursday, February 19, 2026



Gateway Research Park

IMPACT Lab – Meet Our Team

Dr. Michael L. Curry
Principal Investigator

Dr. Demetrius A. Finley
NSF eFellows Postdoctoral Researcher

Dr. Niya S. King
Lab Collaborator/ Researcher

?

Amber Kinnebrew
3rd Year PhD Student

Kayla Morgan
2nd Year PhD Student

Imani Phillips
1st Year PhD Student

Adejoke Olowookere
1st Year PhD Student

Vaishnavi Kandula
1st Year PhD Student

Muhammad Ikram
1st Year PhD Student

Oluwatosin Folorunsho
2nd Year PhD Student

Dominque Davis
1st Year PhD Student

John Olayinka
1st Year Master Student

Hoda Motaghed
2nd Year PhD Student

Ritika Mishra
1st Year PhD Student

Oluseyi Paseda
1st Year PhD Student

To learn more about our research lab connect with us!

Academic Programs

Cross-disciplinary graduate programs in:

- Synthetic biology
- Materials science
- Computational nanotechnology
- Environmental science and sustainability

Comprehensive degree offerings:

- M.S. and Ph.D. in Nanoengineering
- Six graduate certificates including Medical Sciences and Instrumentation

Notable achievements:

- 40% enrollment increase (2020-2024)
- 150% funding increase (2020-2024)
- Only HBCU offering graduate degrees in Nanoengineering

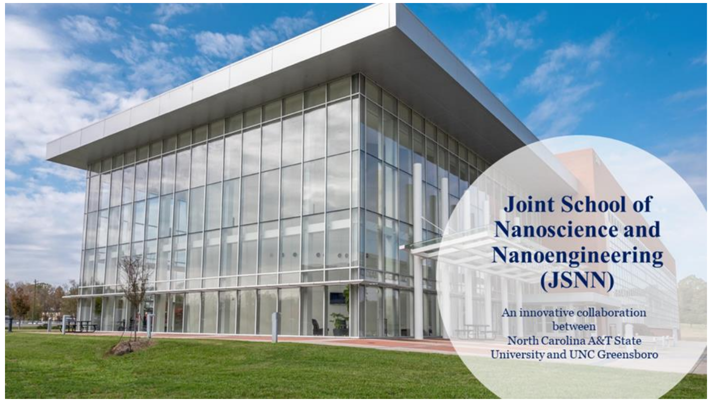
> 192 JSNN Graduate Students (95 in Nanoengineering)

JSNN Facilty

•One of few nationwide with combined semiconductor and biological cleanrooms. (7,000 sq ft. - ISO Class 5/6.}

•Advanced biological research capabilities:
- •BSL-2 and BSL-3 laboratories
- •Full suite of cell/tissue culture resources

•Modern High-Performance Computing:
- •PowerWulf ZXR1+ Cluster
- •Head Node: 64 AMD EPYC cores at 2.6 GHz
- •20 Compute Nodes with 128 cores each
- •GPU Node with 4 NVIDIA RTX 3090 GPUs
- •Parallux Storage Platform with 216TB raw
- •storage

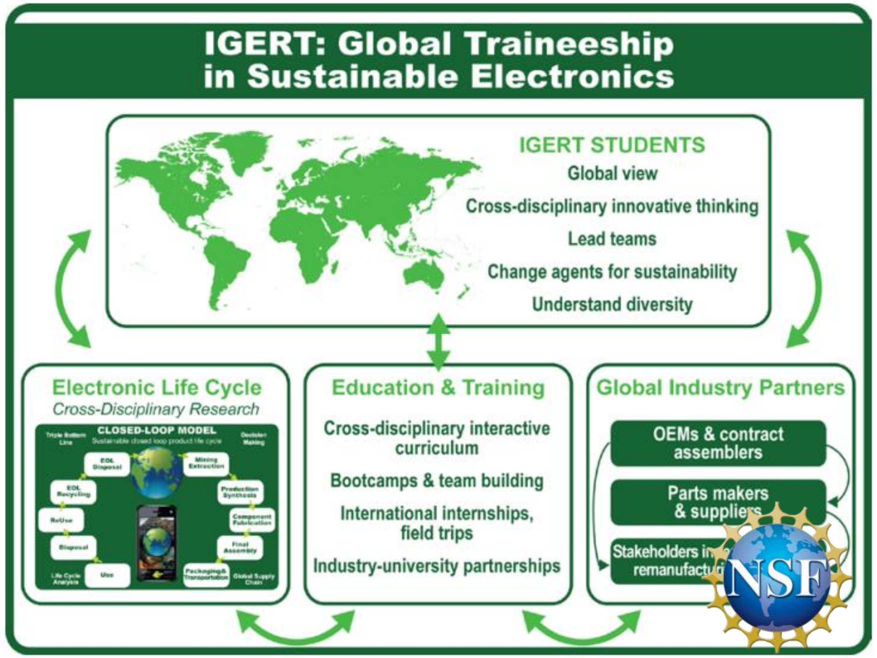


•Advanced nanolithography capabilities:
- •Electron-beam system (operational Summer 2025)
- •Sub-10 nm line resolution capability

•Comprehensive analytical suite:
- •X-ray analysis facilities
- •Advanced spectroscopy tools
- •Materials characterization equipment
- •Micro-CT scanner for high-resolution 3D imaging

Dr. Kristy Crews

Dr. Chemar Huntley



Purdue University (2012)

University of Wisconsin – Madison (2015)

Dr. Donald White

Dr. Shariful Islam

"Don't choose cellulose. Select a different material."

Nanocellulose in a Circular Economy: Renewable & Waste-Derived, Biodegradable & Eco-Friendly, High Performance

RESEARCH MOTIVATION

c&en | WEEKLY NEWSLETTER NOVEMBER 5, 2025

The week's most essential chemistry news, distilled to your inbox.
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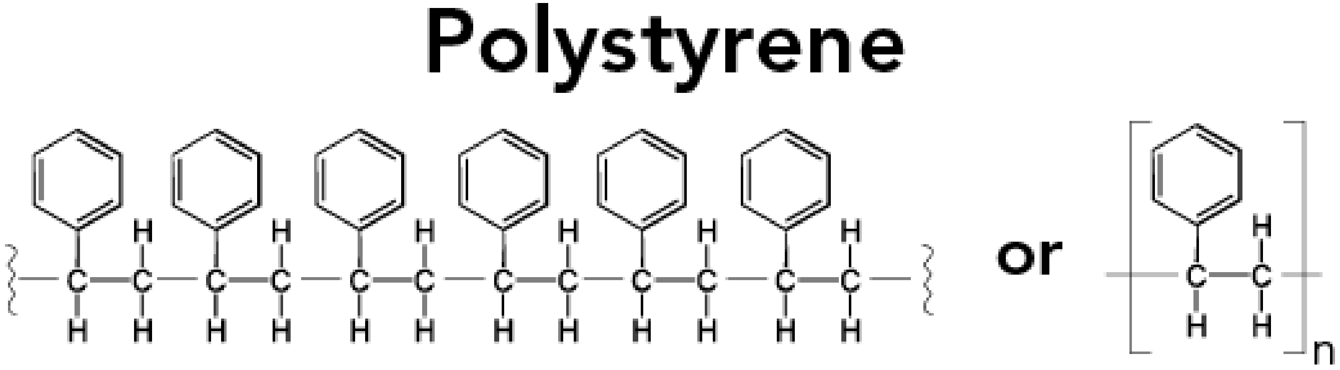
Plastic recycling is in trouble

Many large consumer product companies like Coca-Cola, PepsiCo, and Danone are falling short of the plastics recycling targets they set several years ago. Observers say this failure has contributed to hard times for recyclers. Some experts say voluntary commitments aren't enough and call for stronger regulations.

Read more ›

REMEDIATION OF SYNTHETIC POLYMERS

The unique structure of petroleum polymers increases their stability.



Linear carbon backbone with alternating backbone atoms attached to phenyl moieties.

COMMON COMPOUNDED POLHMERS

The plastic industry produces > 400 tons of plastics per year (50% in single-use).

- **Polypropylene (PP) -** Food containers, appliances, car fenders (bumpers)
- **Polystyrene (PS) -** Packaging foam, food containers, disposable cups, plates, and CD boxes.
- **High impact polystyrene (HIPS)-** Fridge liners, food packaging, vending cups.
- **Acrylonitrile butadiene styrene (ABS)-** Electronic equipment cases such as computer parts, drainage pipes, etc.
- **Polyethylene Terephthalate (PET)-** Carbonated drink bottles, jars, plastic films, and microwavable packaging.
- **Polyester (PES)-** Fibers, textiles.
- **Polyamides (PA) (Nylons)-** Fibers, toothbrush bristles, fishing line, under-the-hood of car engines.
- **Poly Vinyl Chloride(PVC)-** Plumbing pipes, guttering, shower curtains, and window frames.
- **Polyurethanes (PU)-** Cushioning foams, thermal insulation foams, surface coatings, printing rollers.
- **Polycarbonate (PC)-** Compact discs, eyeglasses, security windows, traffic lights, lenses.
- **Poly vinylidene chloride (PVDC)-** Food packaging
- **Polyethylene(PE)-** Wide range of inexpensive uses including supermarket bags, plastic bottles
- **Polycarbonate/Acrylonitrile Butadiene Styrene(PC/ABS)-** Car interior and exterior parts.

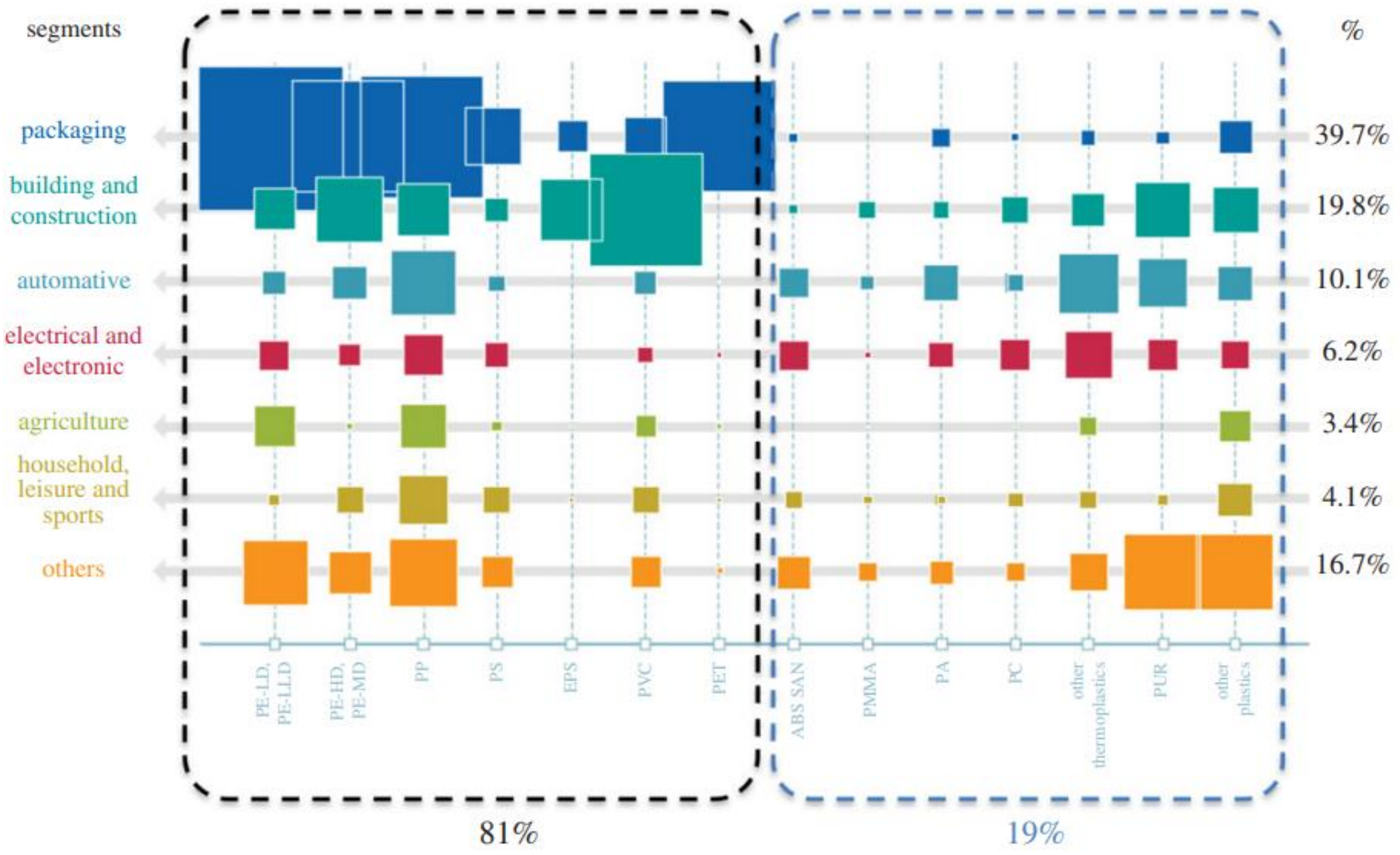
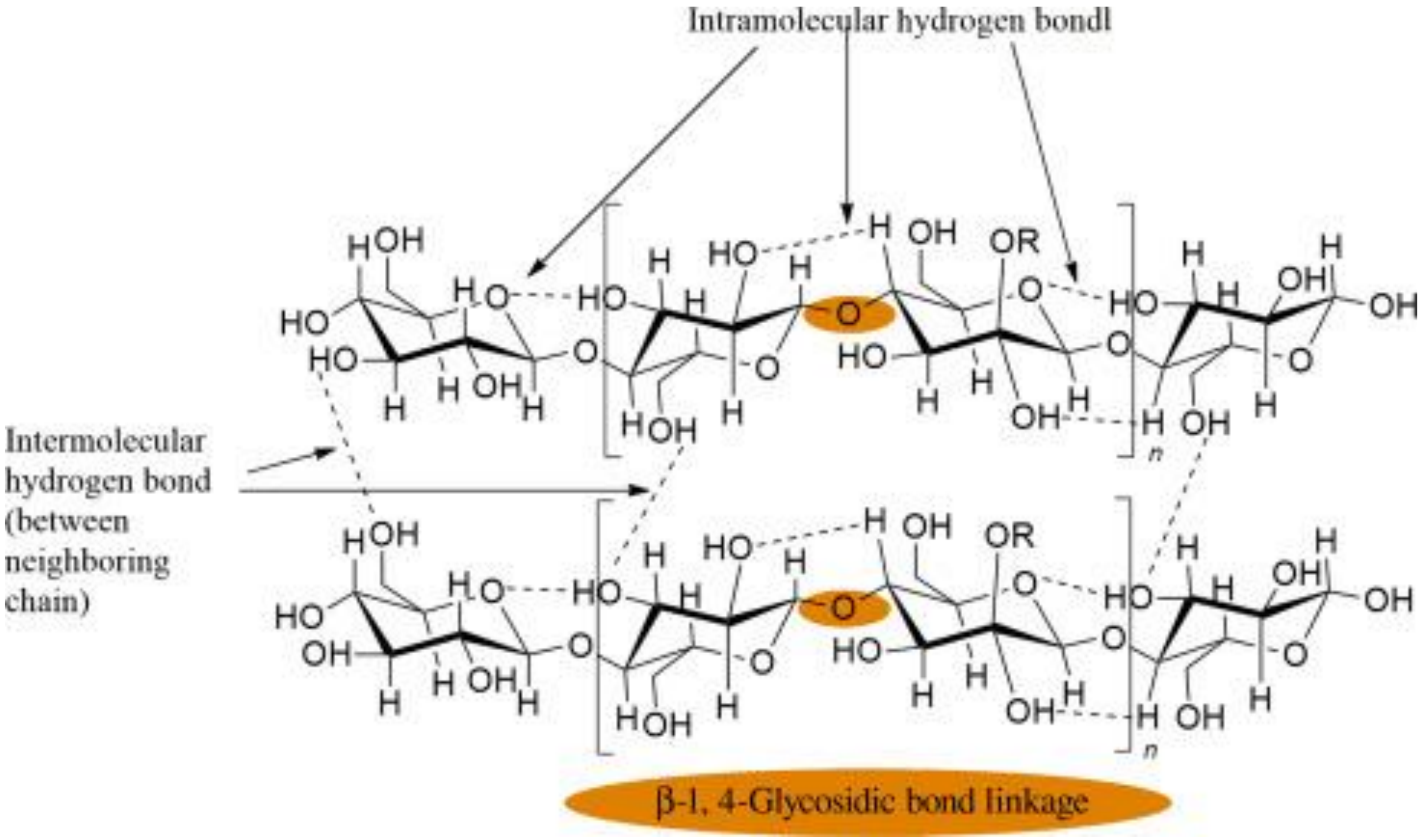


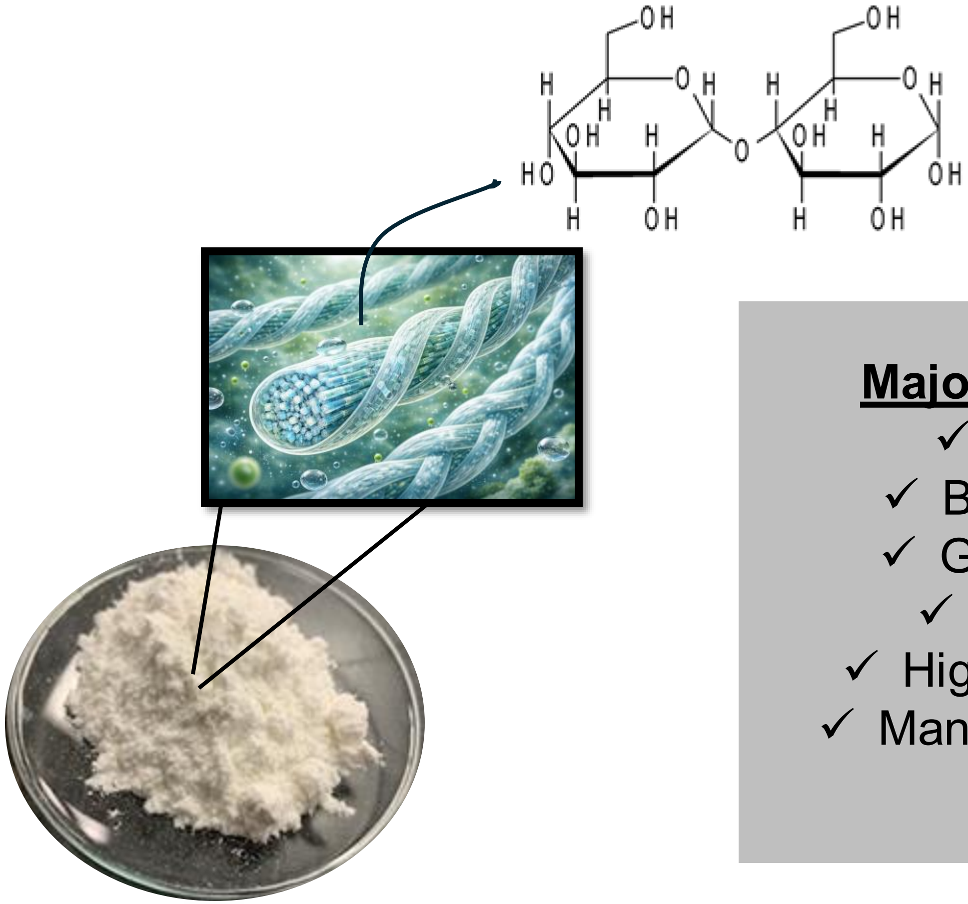
Image reproduced from Bucknall DG. 2020 Plastics as a materials system in a circular economy. Phil. Trans. R. Soc. A 378: 20190268

CELLULOSE

- Made up of glucose subunits that are linked together through β-1,4-glycosidic bonds.
- Degree of polymerization and the length of the cellulose chain can vary
- Exists in two forms, crystalline and amorphous



SUSTAINABLE ALTERNATIVE



Nanocellulose

<u>Major Advantages</u>

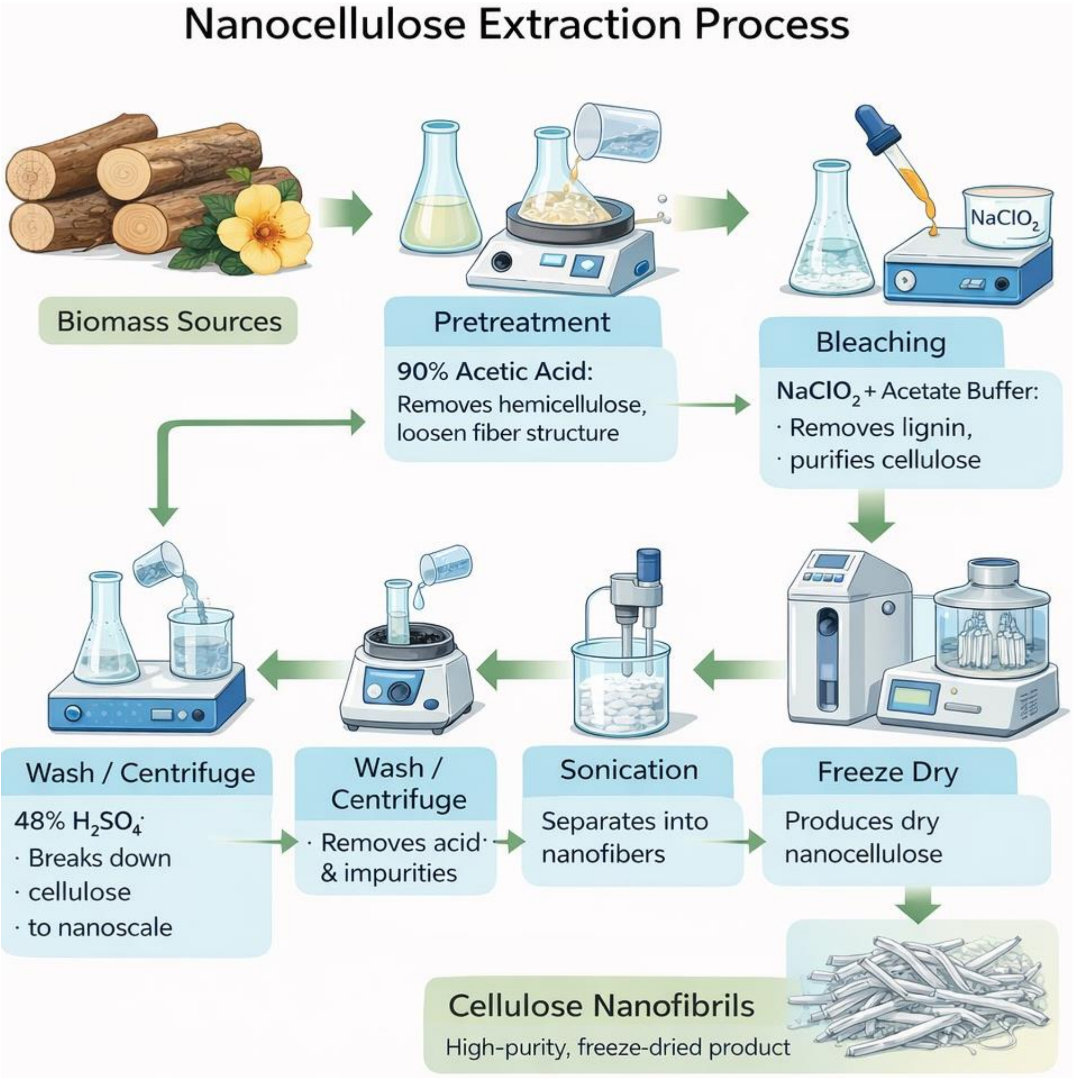
- ✓ Abundant
- ✓ Biodegradable
- ✓ Great Strength
- ✓ Renewable
- ✓ High Surface Area
- ✓ Many Active Surface Sites

NANOCELLULOSE EXTRACTION

Isolation and down-scaling of cellulose for composite applications.

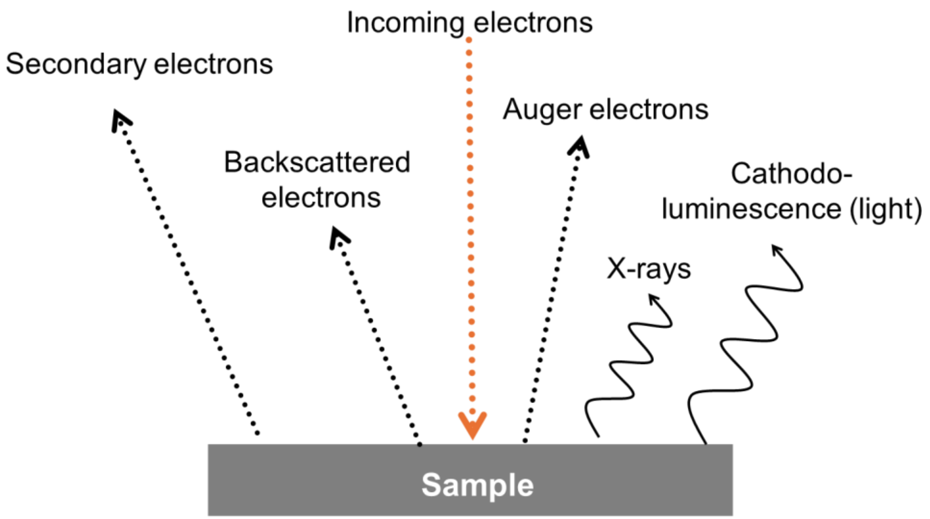
Chemical : Alkaline and Bleaching

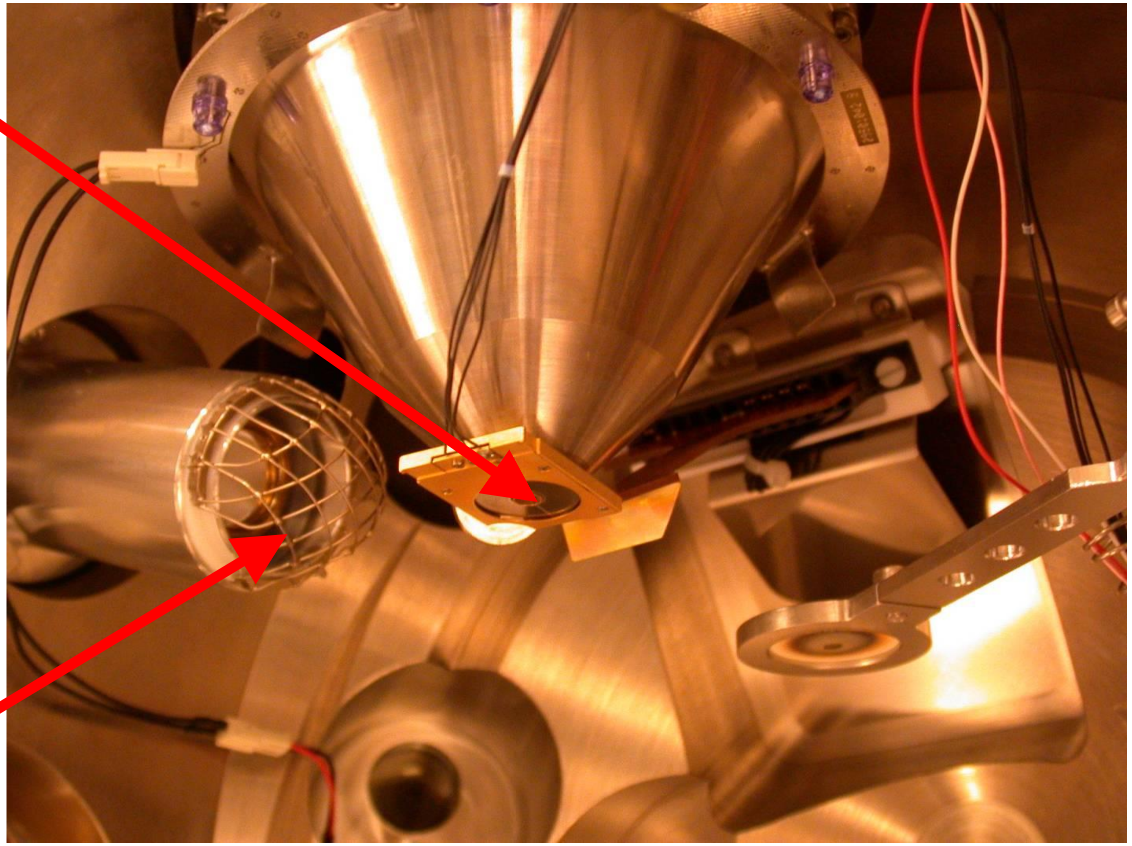
Mechanical: shear forces and friction


Nanocellulose Extraction Process
Biomass Sources
Pretreatment
90% Acetic Acid:
Removes hemicellulose, loosen fiber structure
NaClO2
Bleaching
NaClO2 + Acetate Buffer:
· Removes lignin,
· purifies cellulose
Wash / Centrifuge
48% H2SO4:
· Breaks down
· cellulose
· to nanoscale
Wash / Centrifuge
· Removes acid· & impurities
Sonication
Separates into nanofibers
Freeze Dry
Produces dry nanocellulose
Cellulose Nanofibrils
High-purity, freeze-dried product

SCANNING ELECTRON MICROSCOPY

Backscattered electron detector:
(Solid-State Detector)

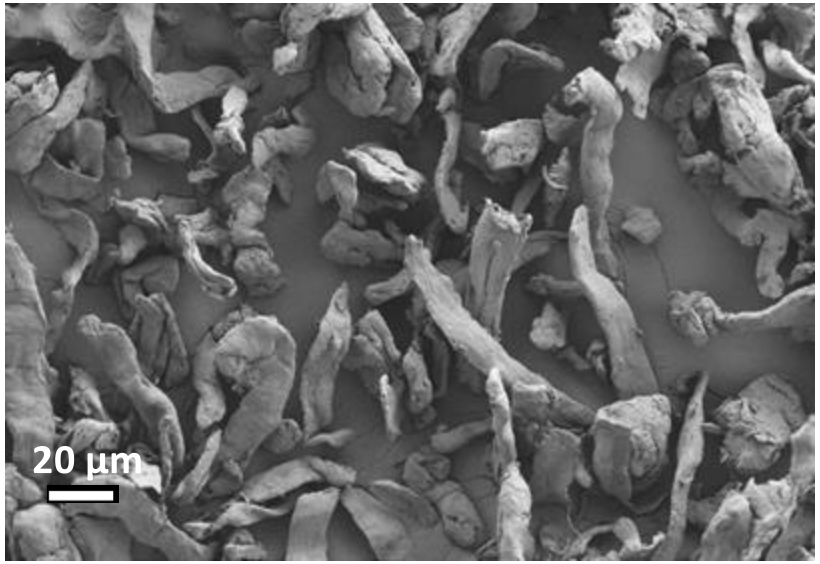




Secondary electron detector:
(Everhart-Thornley)

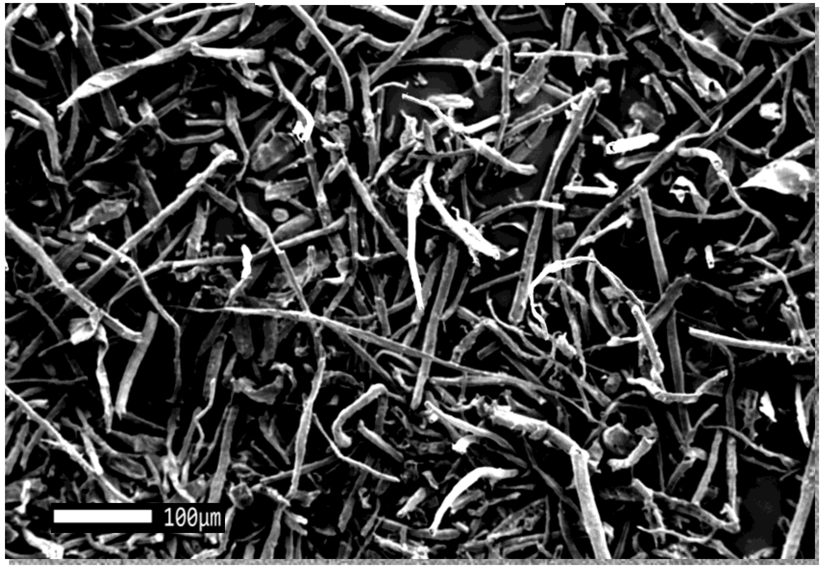
NANOCELLULOSE

SEM Image



Microcrystalline Cellulose (MCC)

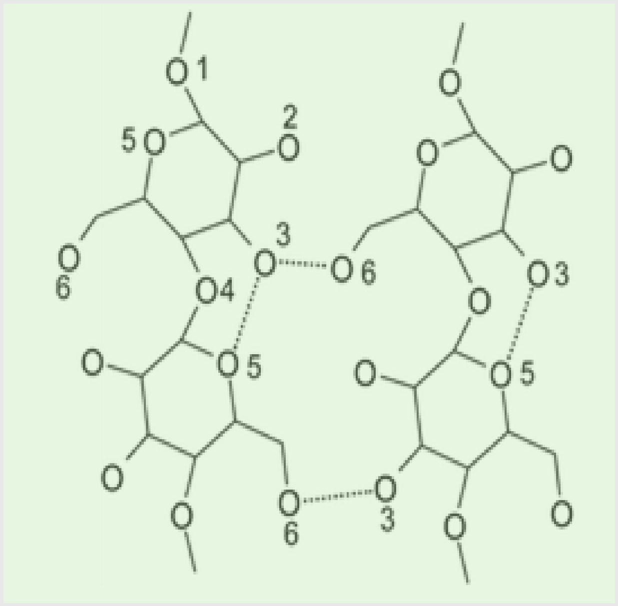
SEM Image



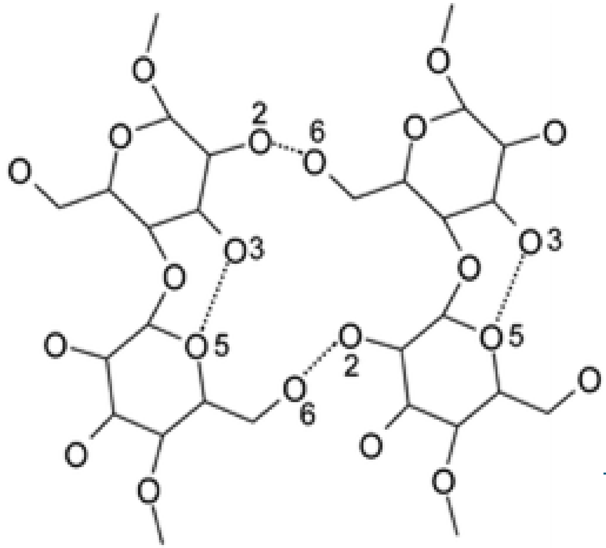
Nanocrystalline Cellulose (CNF)

NANOCELLULOSE STRUCTURE

Feature	Cellulose I (CI)	Cellulose II (CII)
Chain Orientation	**Parallel** arrangement of adjacent chains.	**Anti-parallel** arrangement of adjacent chains.
Stability	Metastable form (natural form).	More stable, lower-energy form (regenerated or mercerized form); the conversion from CI to CII is irreversible.
Hydrogen Bonding	Has a specific, ordered hydrogen bond network (primarily an intermolecular O6H···O3 bond).	Possesses a more extensive and complex network of inter- and intra-chain hydrogen bonds, which contribute to its greater stability. The specific interchain bonds include O2···O6 and O6···O2.
Packing	Less dense packing, which makes it slightly less stable but also allows for more van der Waals interactions between chains.	Denser crystal lattice packing, leading to stronger overall interchain electrostatic interactions and thus greater stability.
Hydroxymethyl Group Conformation	The C6 hydroxymethyl group is typically in the *tg* conformation.	The C6 hydroxymethyl group is typically in the *gt* conformation.

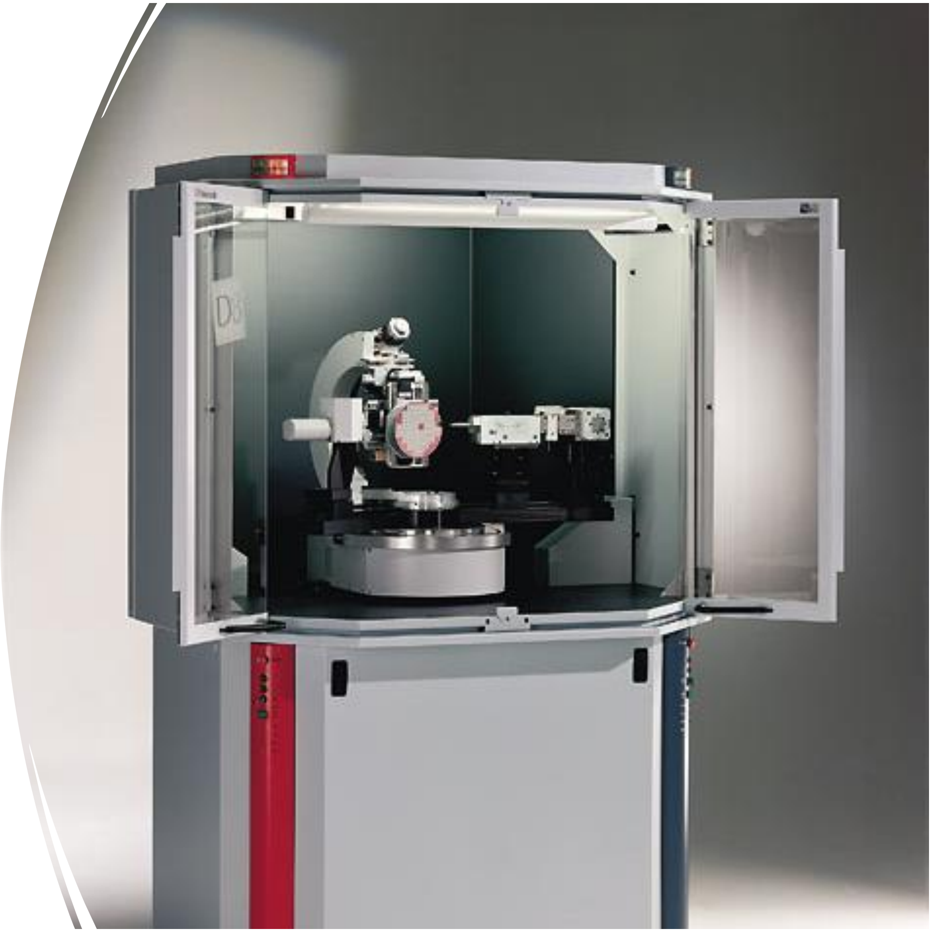


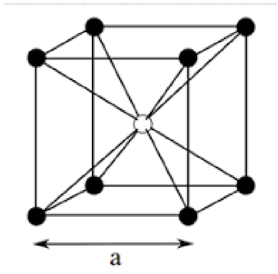
CI Allomorph: trans-gauche

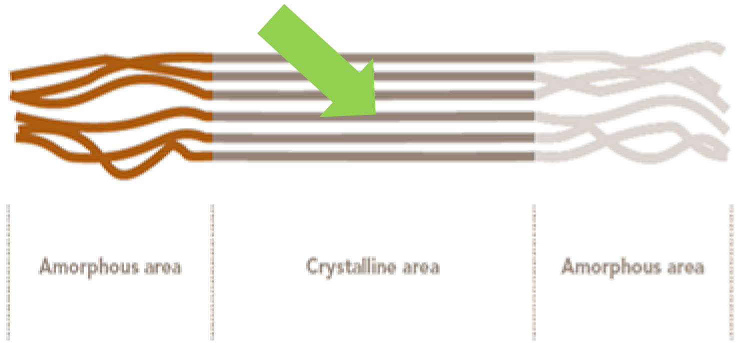


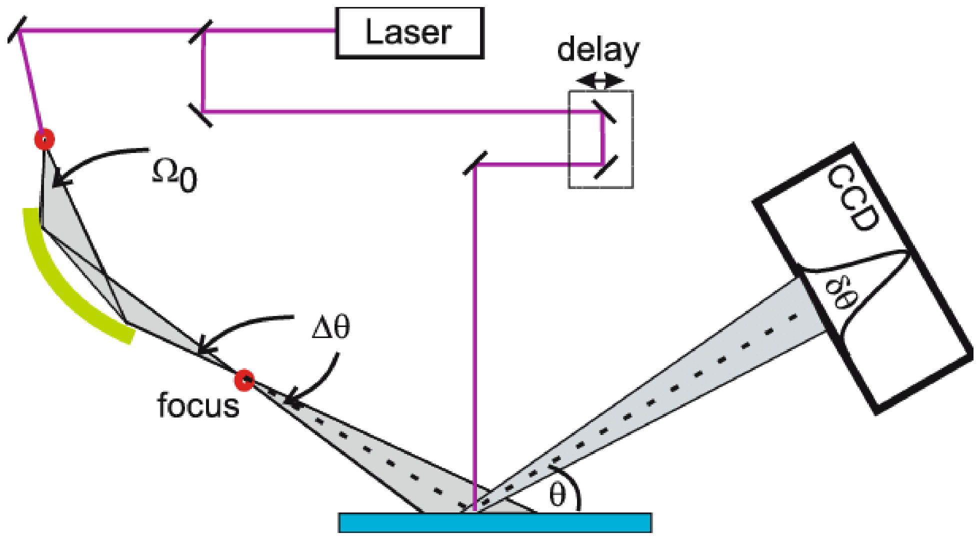
CII Allomorph: gauche-trans

X-RAY DIFFRACTION ANALYSIS (XRD)





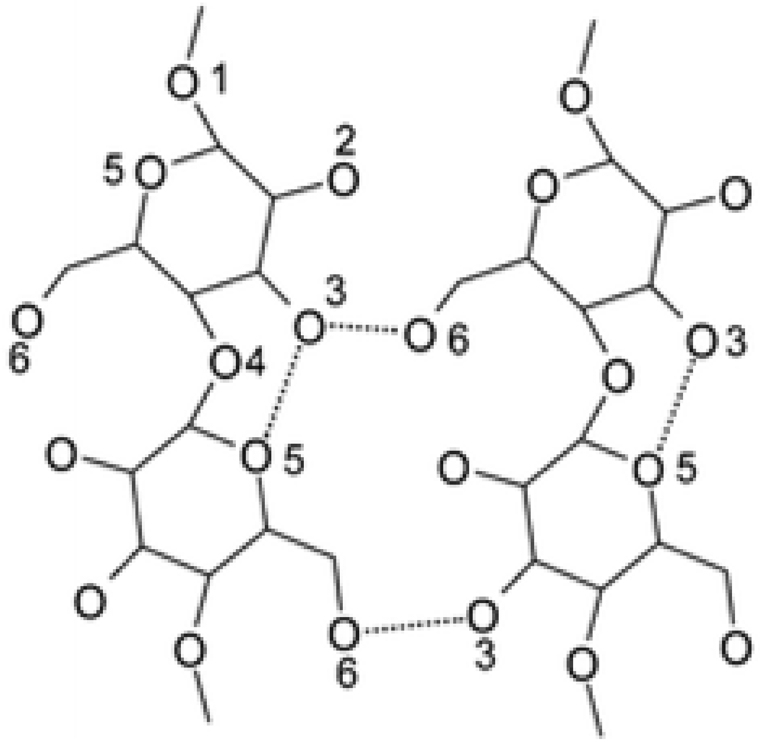




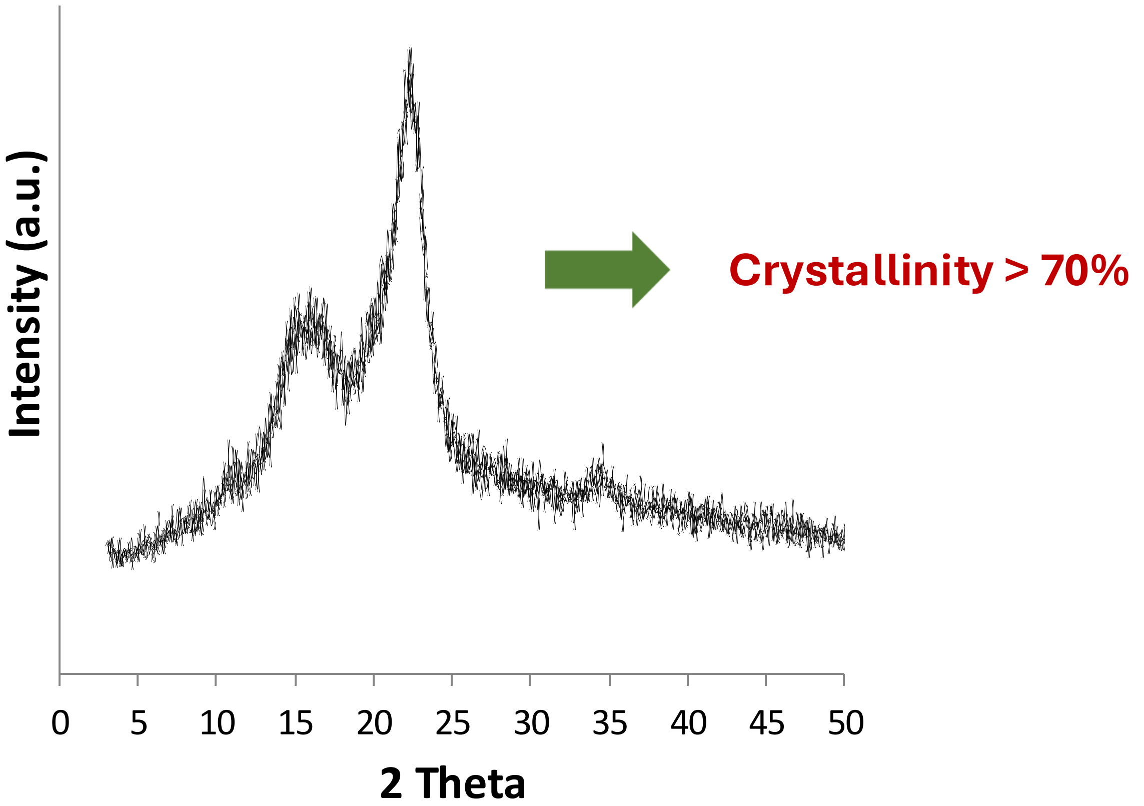
Diffraction occurs only when Bragg's Law is satisfied N ƛ = 2d sinθ

CELLULOSE ALLOMORPH: XRD ANALYSIS

CI Allomorphic Structure



XRD Spectrum

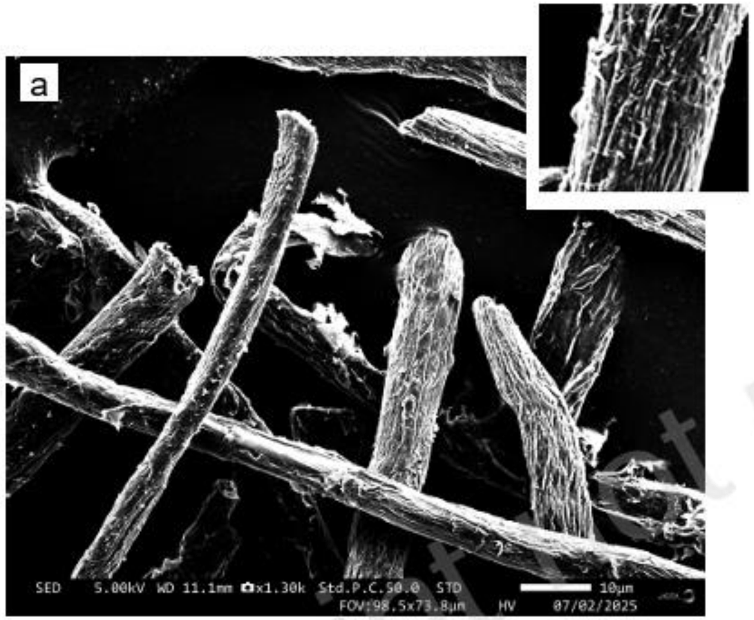


Major diffraction peaks at 2θ = 15º, 22º, and 34º

First Look
Materials Today Family of Journals

Short Communication: Biomass-Dependent Allomorphs in Nanocellulose: Direct CII Isolation from Softwood and Hibiscus

Materials Today

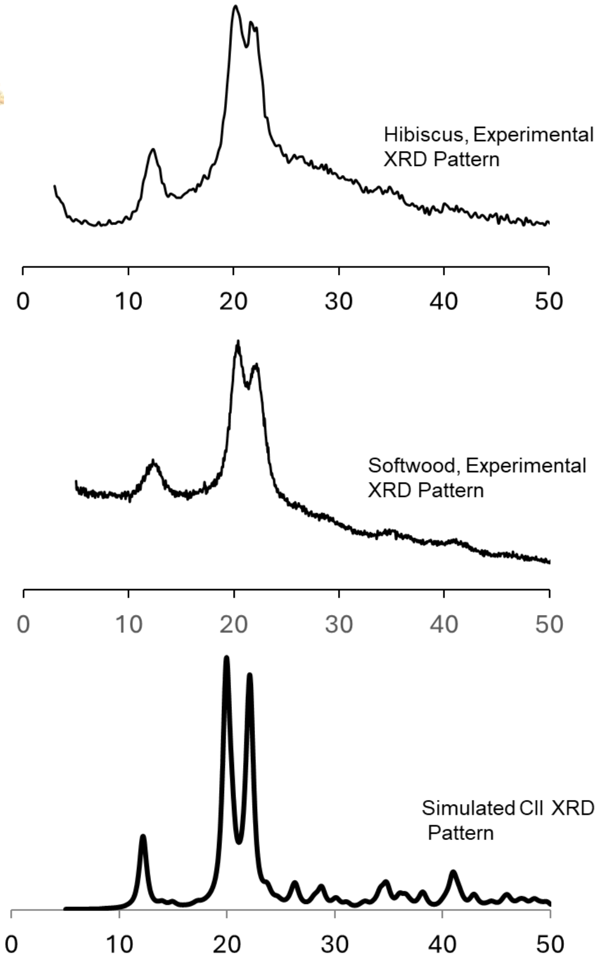


CI Allomorph: trans-gauche

CII Allomorph: gauche-trans

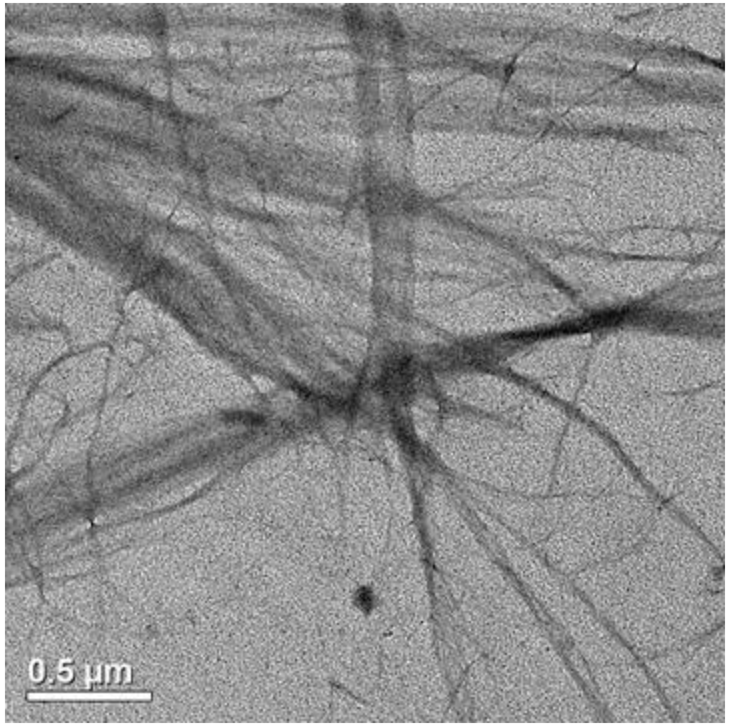
Softwood

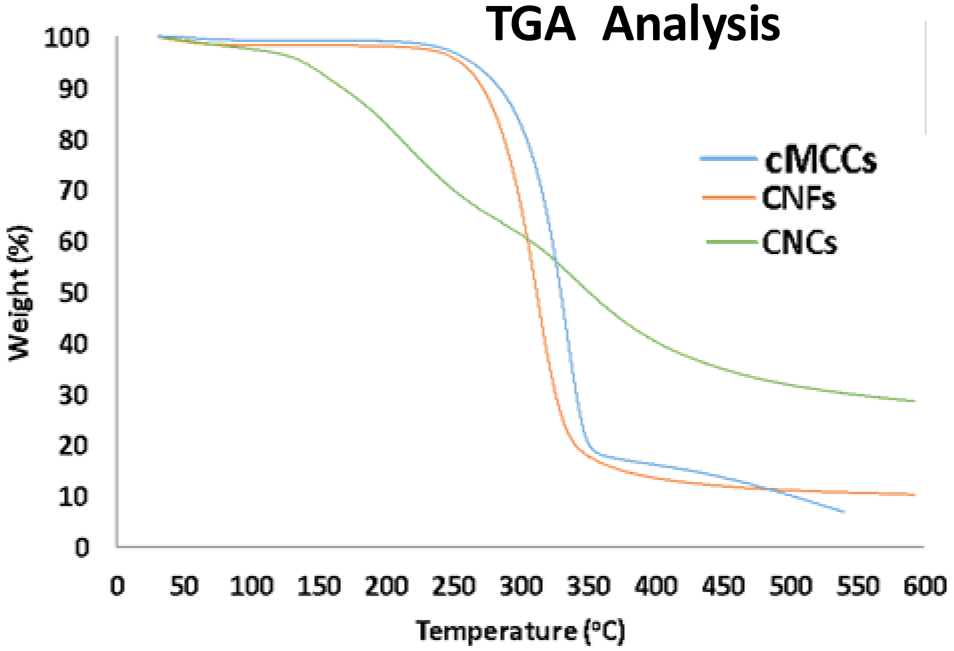
Hardwood



TGA of hydrolyzed CNFs showed no change in thermal performance.

TEM Image: CNFs





Cellulose Sample	Max Decomp (°C)	Decomp Rate (%/°C)	Residue (%)
Commercial (cMCC)	333.37 ± 0.61	1.75 ± 0.07	7.01 ± 0.22
CNF	311.81 ± 0.56	1.58 ± 0.02	10.18 ± 0.03
CNC	Less stable	——	——

Composite Fabrication: Cellulose-reinforced Plastics

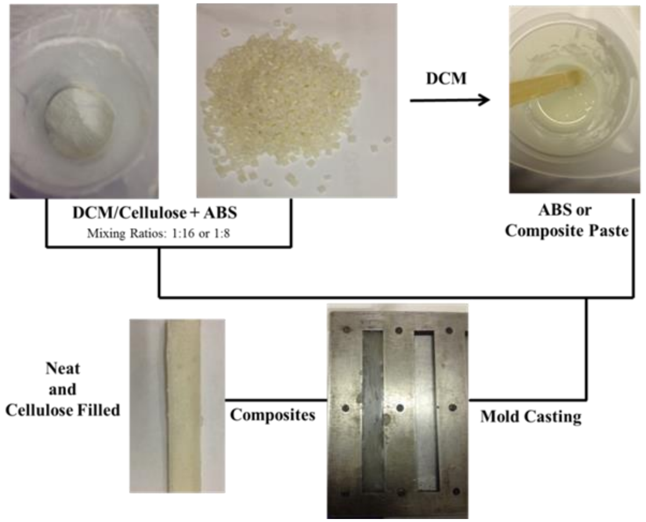
AGGIES DO

North Carolina Agricultural and Technical State University

COMPOSITE MANUFACTURING

IGERT: Global Traineeship in Sustainable Electronics

Mold Casting

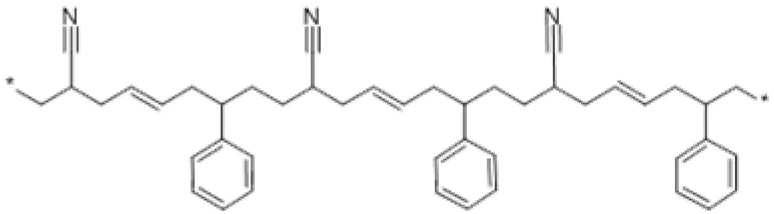


Thermal Extrusion

NANOCELLULOSE-BASED COMPOSITES

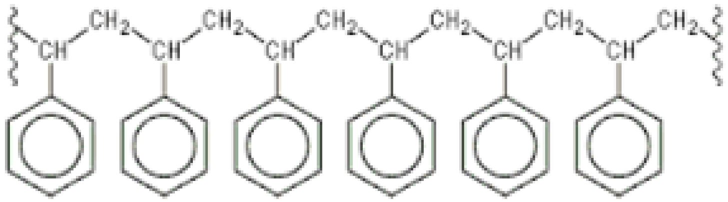
ABS

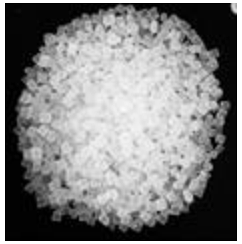
Thermal Decomposition Temperature (°C): 400 ± 50
Rate of Decomposition (%/°C): 1.95 ± 0.80
Residue (%): 0.45 ± 0.50



HIPS

Thermal Decomposition Temperature (°C): 390 ± 50
Rate of Decomposition (%/°C): 1.83 ± 0.80
Residue (%): 0.33 ± 0.50

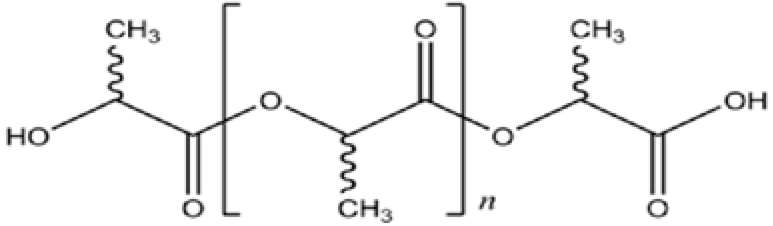




PHA, PLA or PVA

Thermal Decomposition Temperature (°C): 320 ± 50
Rate of Decomposition (%/°C): 2.83 ± 0.80
Residue (%): 0.73 ± 0.50

Extrude temperature: 180 to 260 °C



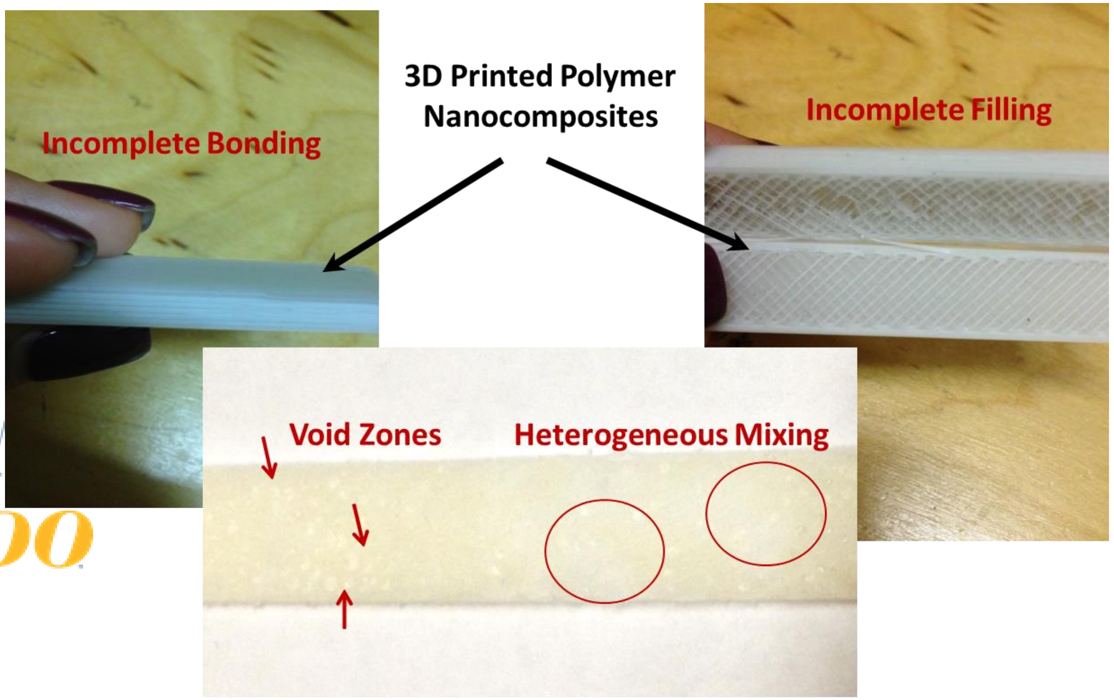
Synthetic Polymer
(Petroleum-derived)

Nanocellulose
(Natural Polymer)

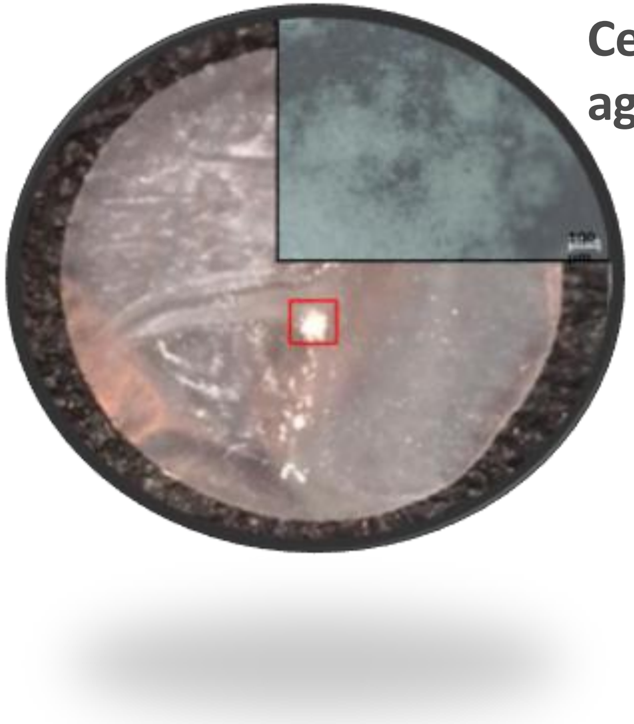
Cellulose-reinforced Composites

Nanocellulose usually does not disperse well in hydrophobic polymers.

Low interfacial adhesion



Optical Micrograph



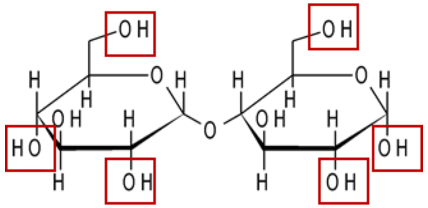
Cellulose aggregation

The Challenge

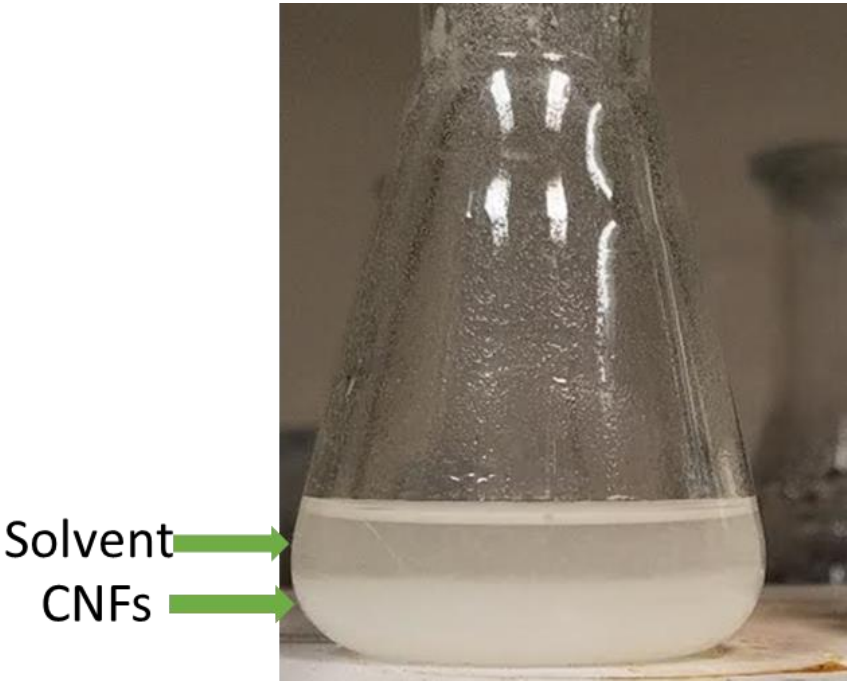
Problems associated with using cellulose in composite fabrication

Hydrophilic Behavior

(Absorbs Moisture)



Solvent Compatibility



Increasing Hydrophobicity

www.rsc.org/nanoscale

REVIEW

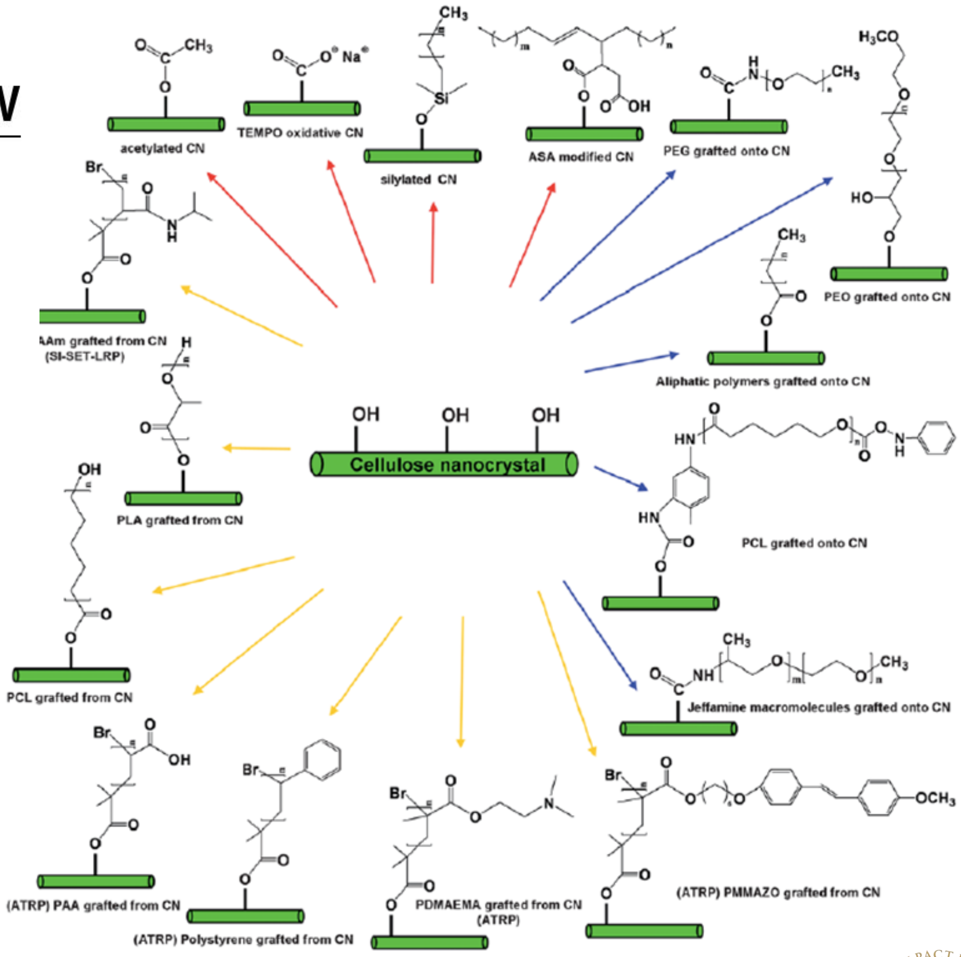
Preparation, properties and applications of polysaccharide nanocrystals in advanced functional nanomaterials: a review

Ning Lin,[a] Jin Huang[b] and Alain Dufresne*[a]

Received 2nd February 2012, Accepted 20th March 2012
DOI: 10.1039/c2nr30260h

Modification of polysaccharide nanocrystals:

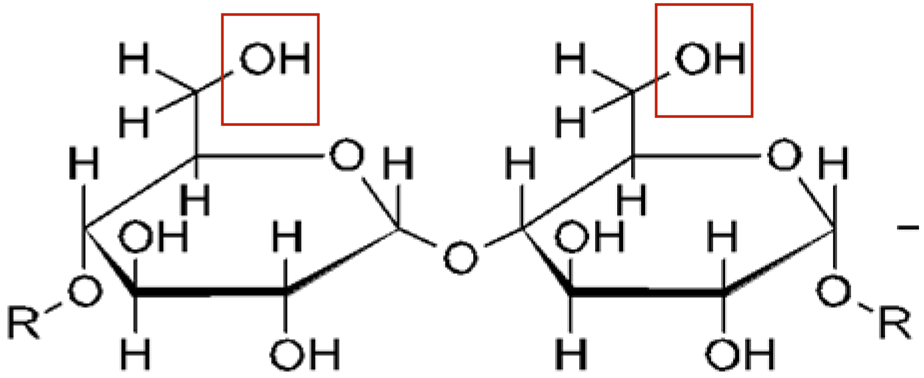
- Substitution of surface hydroxyl groups with small molecules



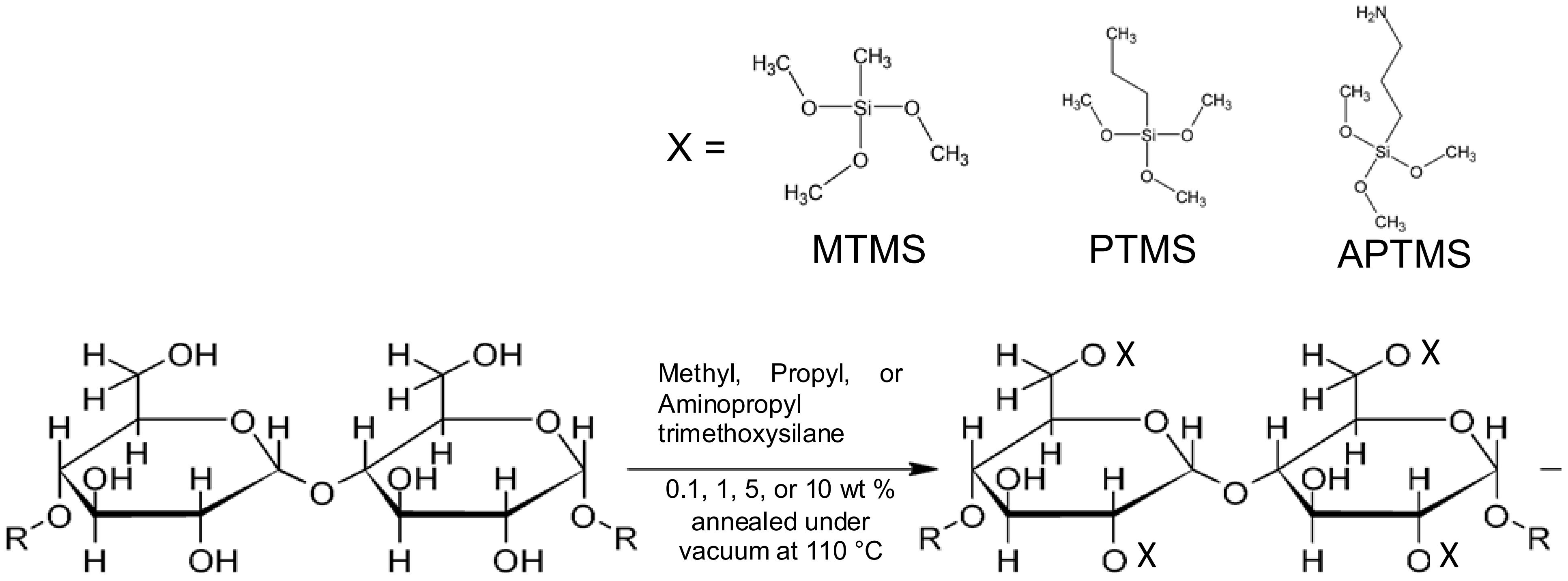
Accessing OH groups to increase solvent compatibility

Chemical Functionalization	Functional Group or Compound Introduced
Acetylation's	Acetyl
Acylation's	Acyl
Esterification's	Ester
Oxidation	Carbonyl or Aldehyde
Polymer Grafting	Polymer
Reduction	Hydrogen's
Silanization	Silane
Methylation	Methyl ($-CH_3$)
Olefination	Alkene (C=C)

Less than 1% available



NANOCELLULOSE MODIFICATION

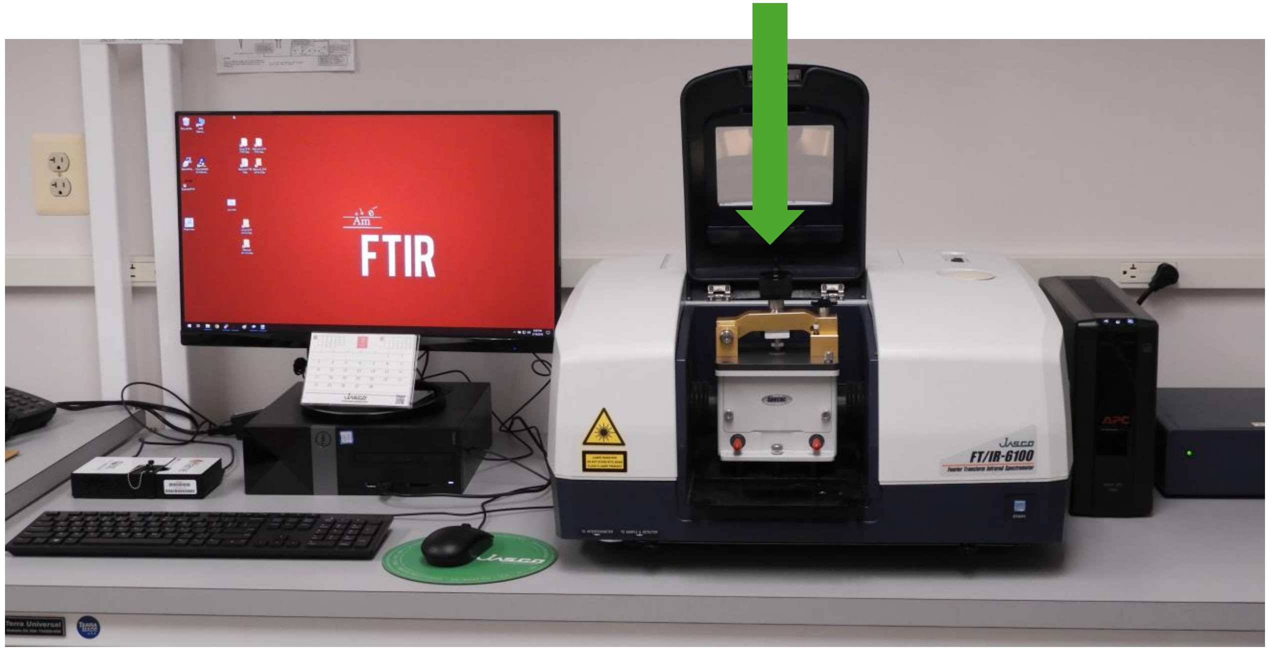


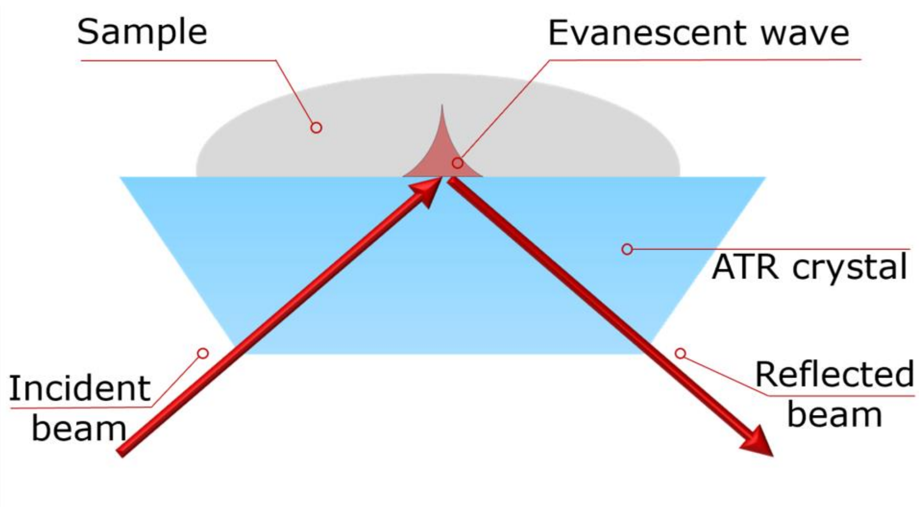
Fairbrother Group
Johns Hopkins University
Center for Sustainable Nanotechnology

Xie, Y.; Hill, C. A. S.; Xiao, Z.; Militz, H.; Mai, C., Silane coupling agents used for natural fiber/polymer composites: A review. *Composites Part A: Applied Science and Manufacturing* **2010,** *41* (7), 806-819.

ATR-FTIR Measurements

Sample Compartment



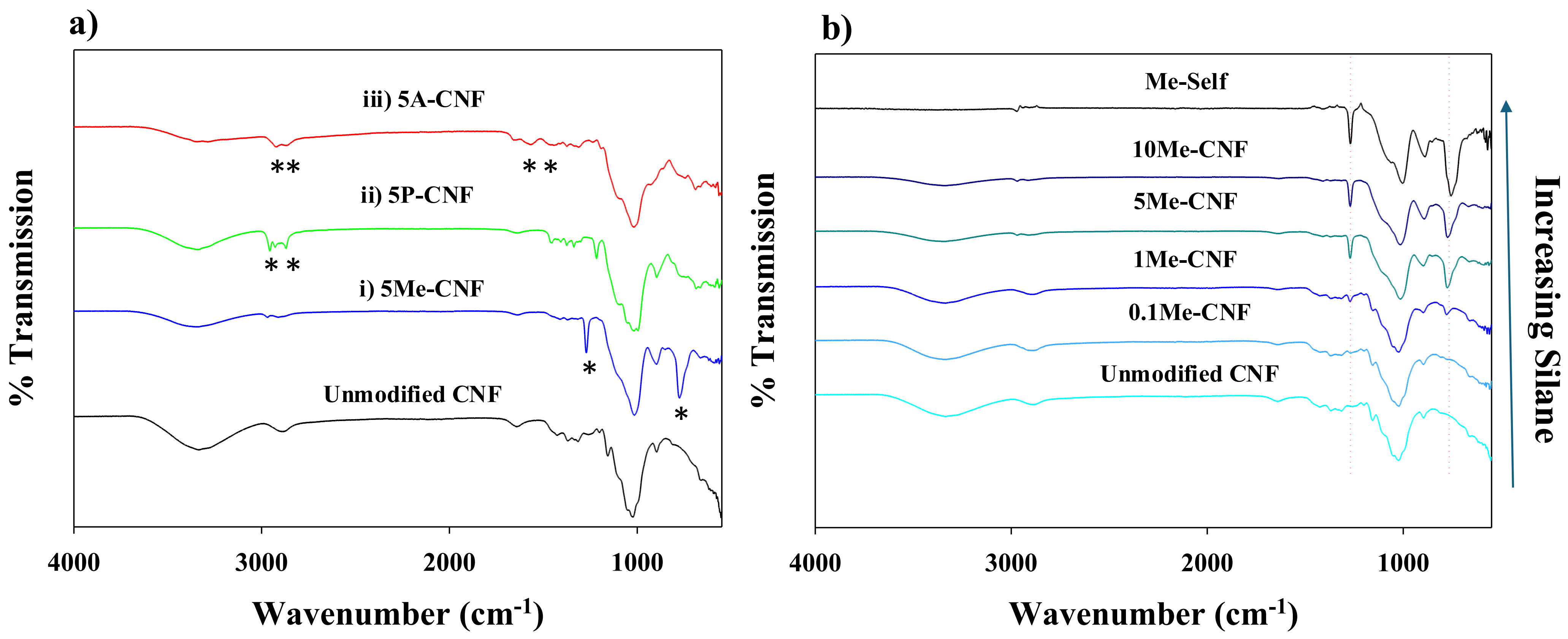


ATR-FTIR Analysis: CNFs Silanization

Si–CH3 symmetrical deformation (766 cm-1 and 1270 cm-1) MTMS-modified CNF

Methylene stretching peaks at 2880 cm-1 and 2950 cm-1 for PTMS-modified

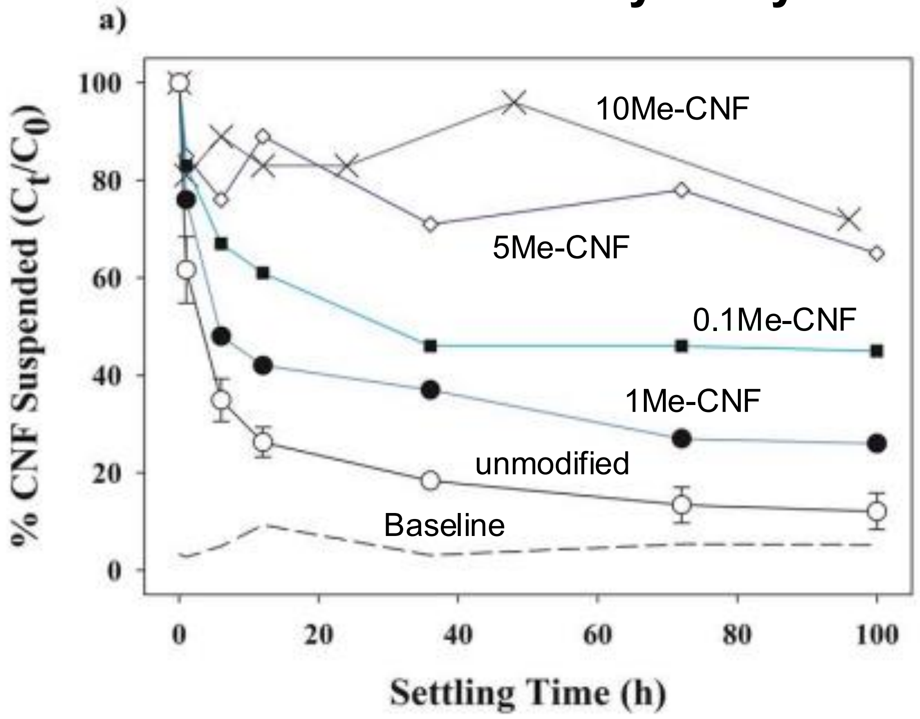
Methylene stretching modes (2920 cm-1 and 2860 cm-1 , as well as N–H scissoring at 1580 cm-1 and symmetric deformation of NH3 + at 1480 cm-1) for APTMS-modified



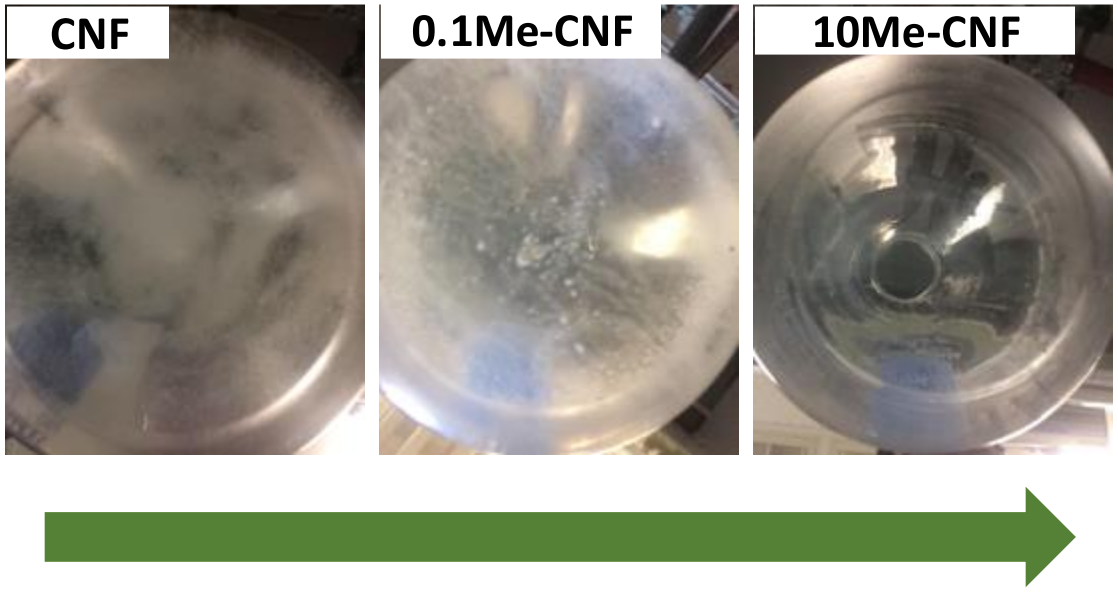
Frank et al. Impact of Silanization on the Structure, Dispersion Properties, and Biodegradability of Nanocellulose as a Nanocomposite Filler ACS Appl. Nano Mater. 2018, 1, 12, 7025–7038

Dispersibility of Modified Cellulose

Mass Loss Recovery Analysis

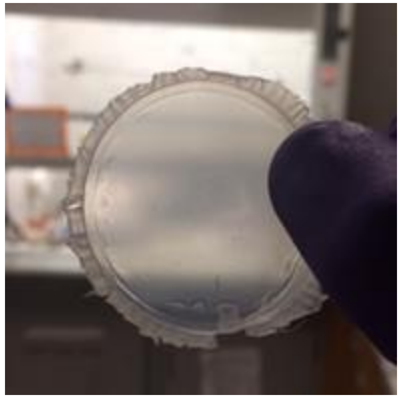


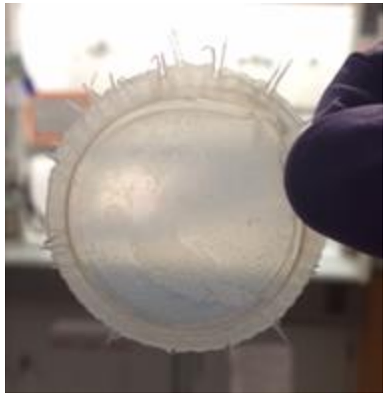
Dispersion in Chloroform



Frank et al. Impact of Silanization on the Structure, Dispersion Properties, and Biodegradability of Nanocellulose as a Nanocomposite Filler *ACS Applied Nano Materials* **2018,** ***12***, 7025-7038.

Silane Functionalization: Impact on Distribution



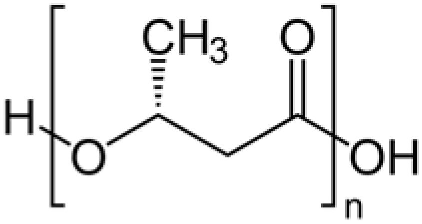


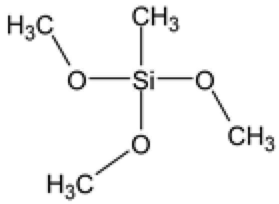
Pure PHA

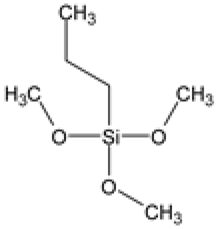
MTMS Modified Nanocellulose

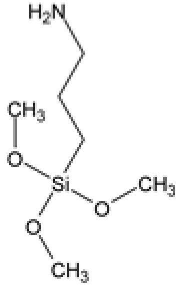
PTMS Modified Nanocellulose

APTMS Modified Nanocellulose







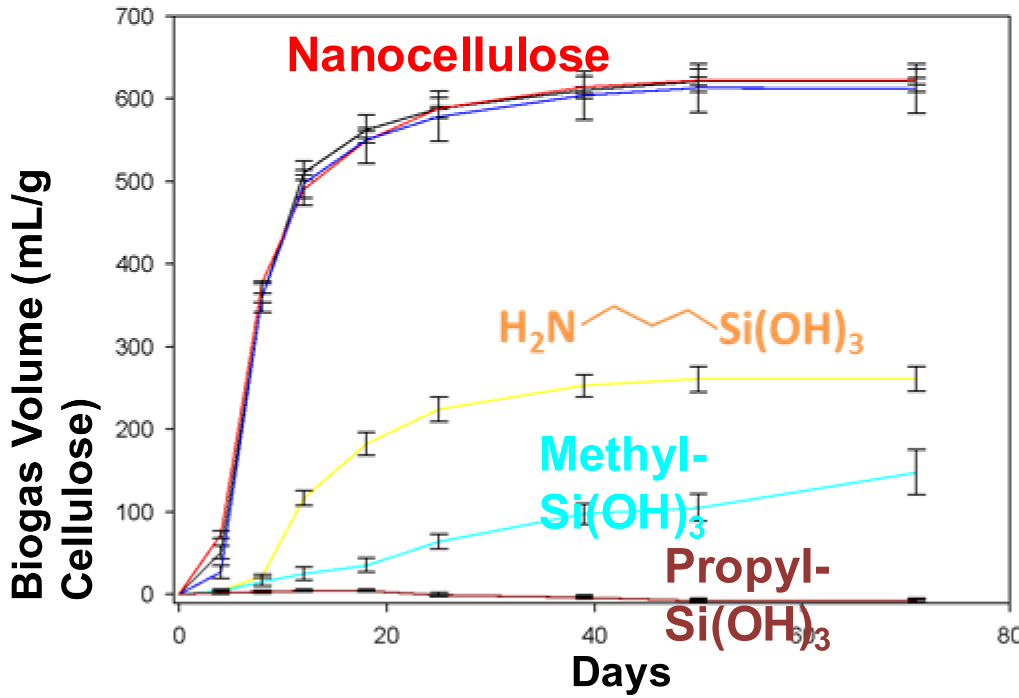


Modified Cellulose Biodegradability

Altering functionalization of nanocellulose powder impacts biodegradability

Key Issues

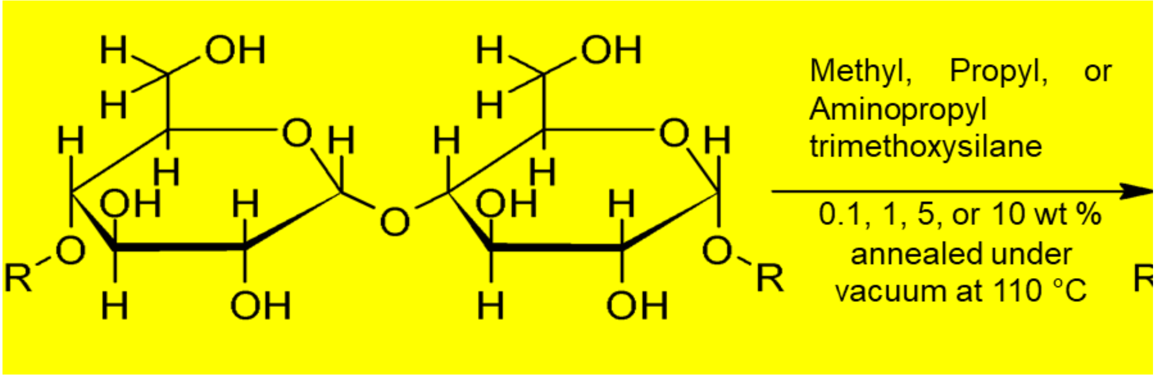
- Functionalized nanocellulose to extreme degree, impacted biodegradation
- Still biodegradable even with extreme functionalization
- Next: decreasing degree of functionalization to hit balance between hydrophobicity and biodegradability

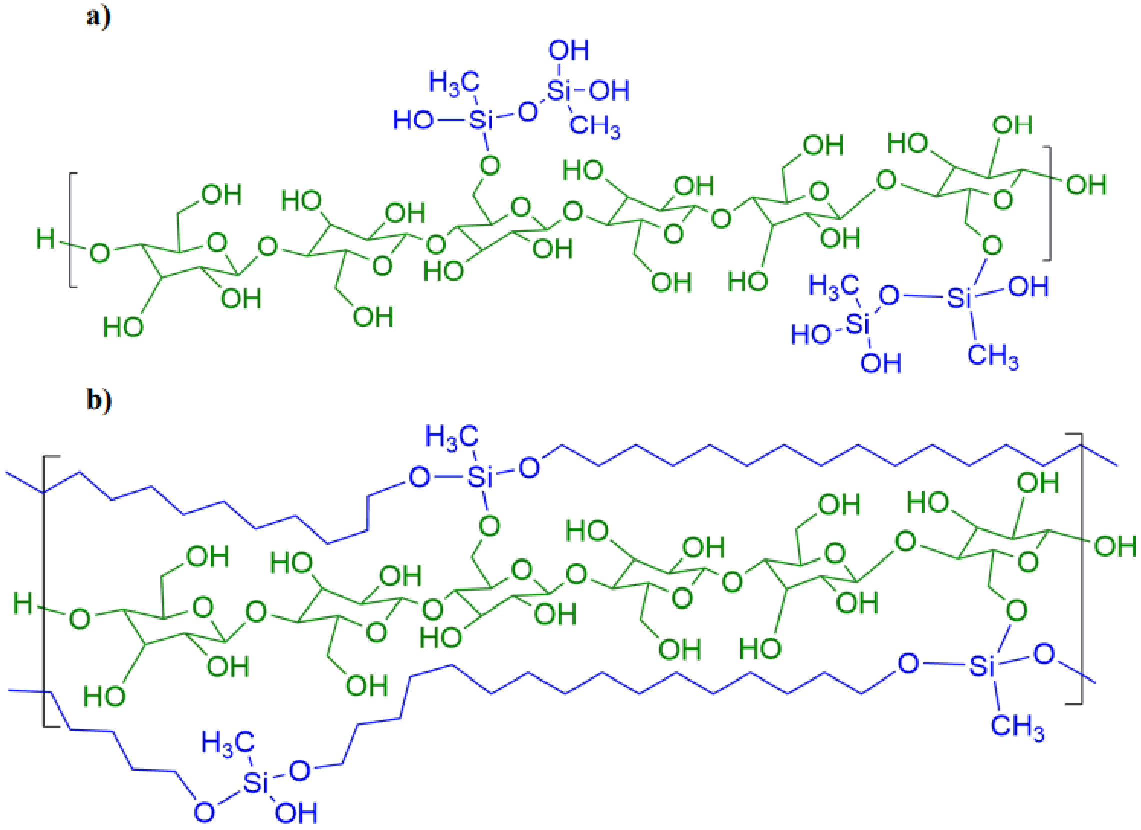


Figures adapted from Frank et al. *ACS Appl. Nano Mater.* 2018, 1, 12, 7025–7038

Most companies and certified programs are pursuing at least 30% of their composite materials as a "biobased product."

Limited Degree of Modification





At a low degree of silanization (0.1Me-CNF), a small portion of the CNFs is covered by siloxane. As the degree of silanization increases, the CNFs are essentially coated with siloxane (10Me-CNF). The blue chain around the fibril should be assumed to be repeat SiO2(OH)(CH3) siloxane units

“Cellulose cannot be used without modification.”

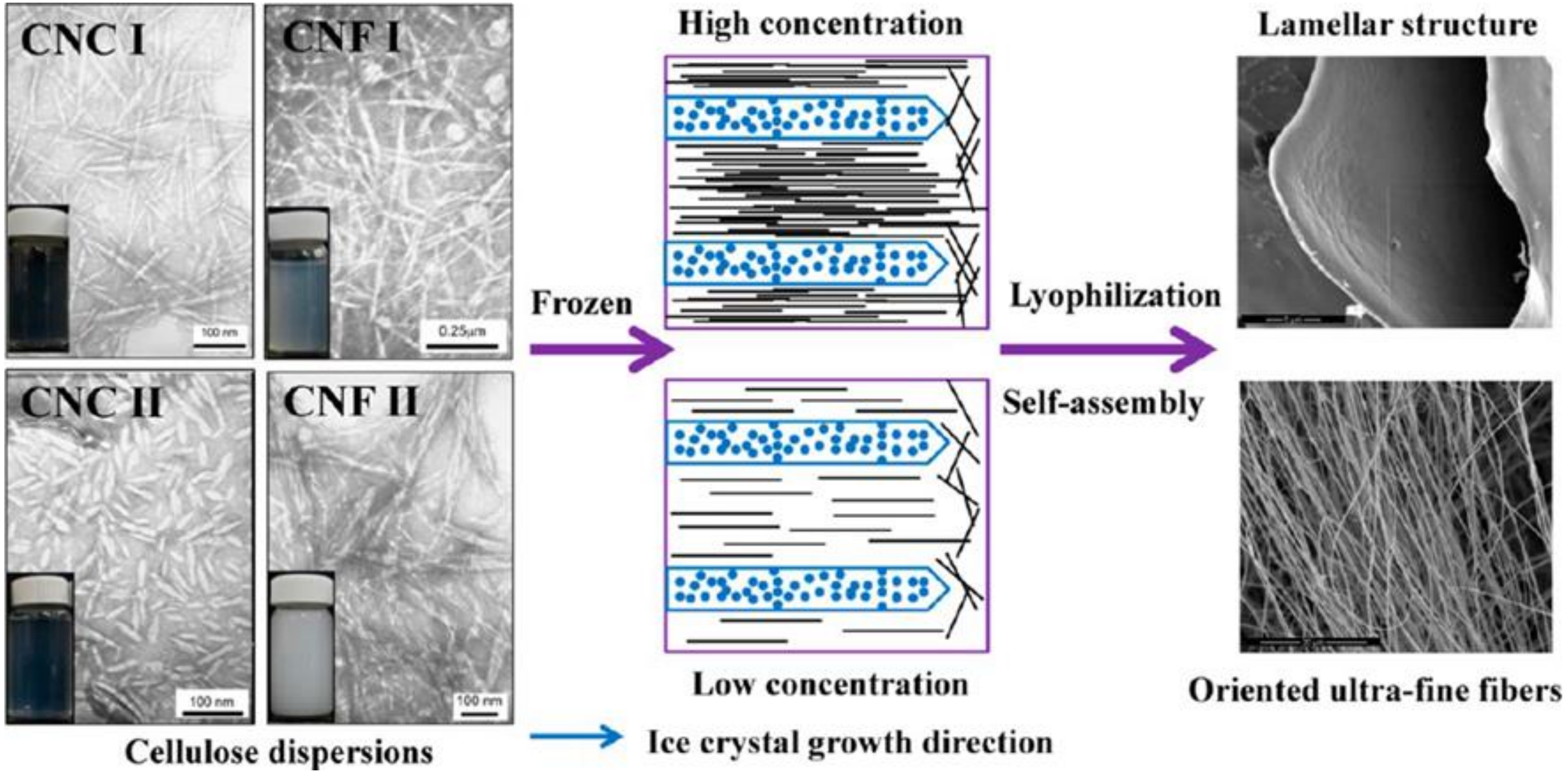
Solvent Compatibility

Solvent

CNFs

AGGIESDO

Self-Assembly Behavior of Cellulose Nanoparticles



The suspension concentration, particle size, crystal structure, and surface charge impact the self-assemble behavior of cellulose during Lyophilization “freeze-drying” processing – a lyophilization-induced self-assembling behavior of the cellulose suspensions.

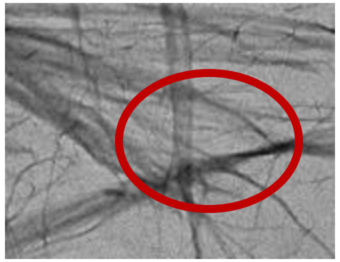
Jingquan Han et al. Biomacromolecules 2013, 14, 1529–1540

The Curry-White DS-I Method

Mechanism I: Chiral Center Alignment of the Nancellulose

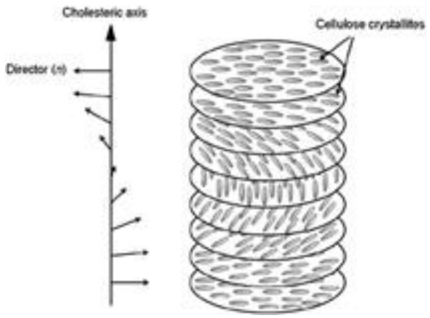
Acid catalyzed Hydrolysis

Conversion to Nanocellulose



Lyophilization-induced self-assemply

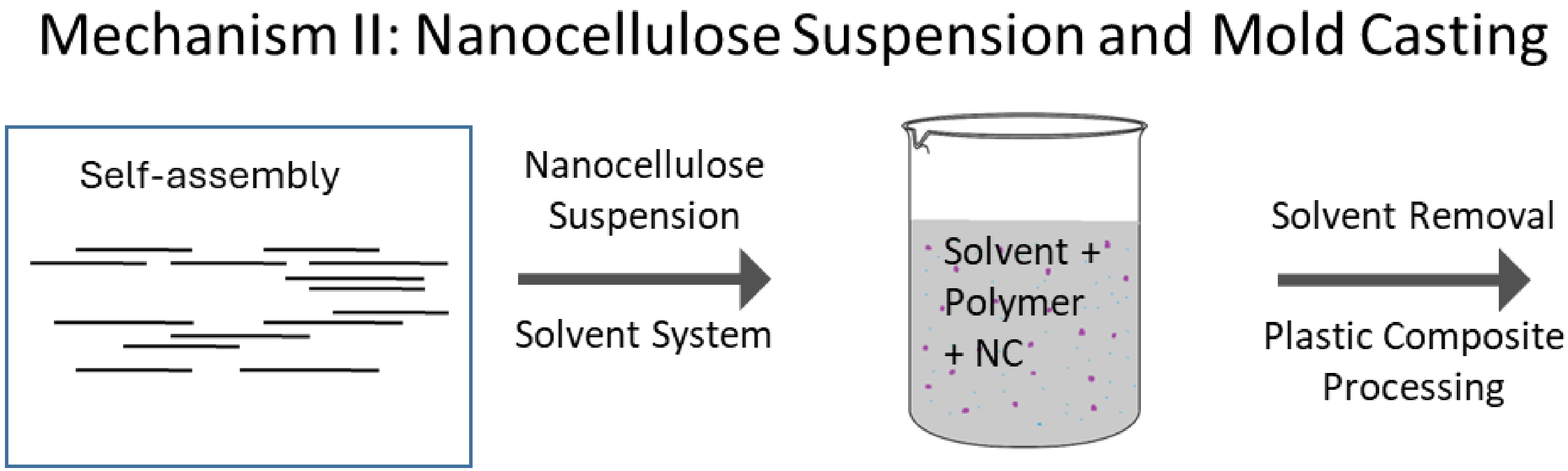
Chiral Center Alignment



(a) mechanism of chiral alignment and (b) mechanism of suspension of the nanocellulose required in the production of uniformly dispersed nanocellulose within the matrix of the polymer composite.

Alignment image reproduced from http://pubs.rsc.org/en/Content/ArticleHtml/2010/JM/c0jm01022g

The Curry-White DS-I Method



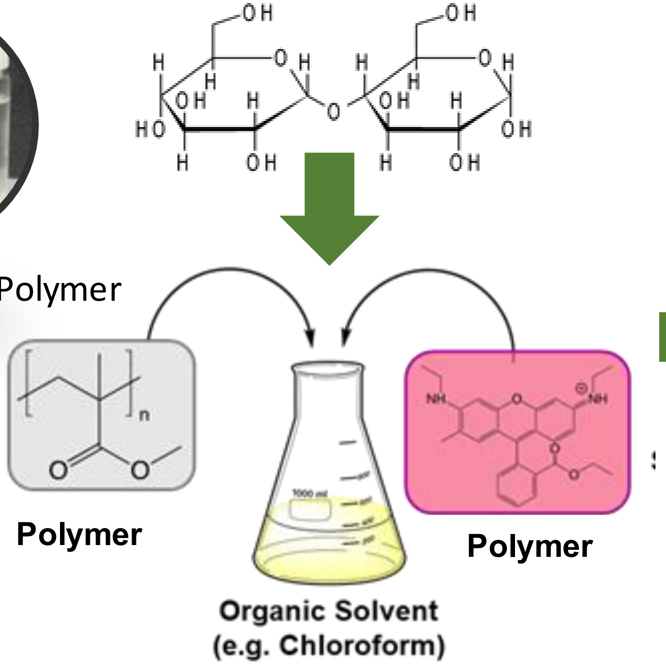
(a) mechanism of chiral alignment and (b) mechanism of suspension of the nanocellulose required in the production of uniformly dispersed nanocellulose within the matrix of the polymer composite.

Alignment image reproduced from http://pubs.rsc.org/en/Content/ArticleHtml/2010/JM/c0jm01022g

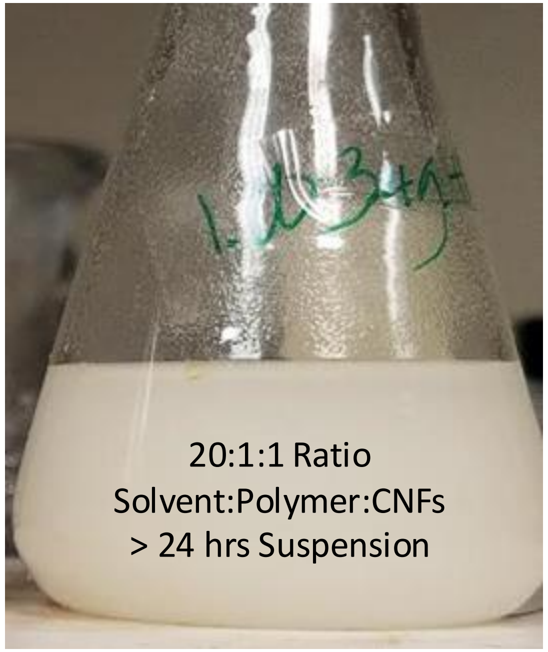
The Discovery

At critical concentrations, freeze-dried CNFs uniformly suspends

20:1 – Solvent/Polymer



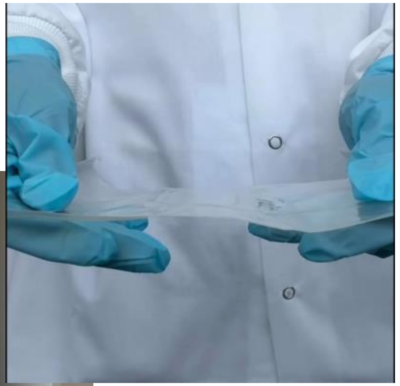
Suspended CNFs



Curry et al.: US Patent #11,084,907 B2 2021

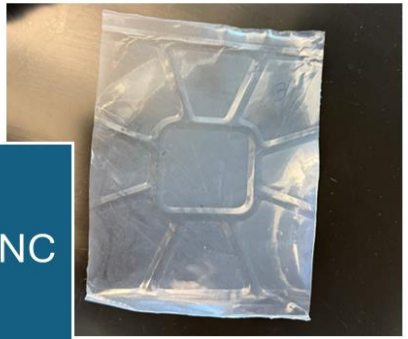
Cellulose Reinforced Bioplastics

Flexible Thin Films



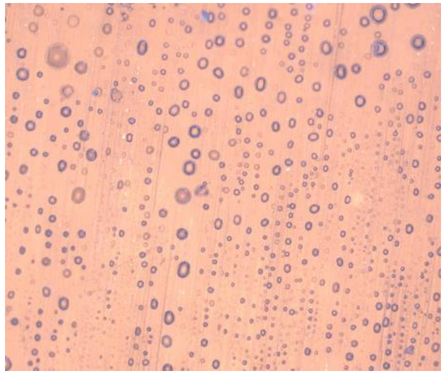
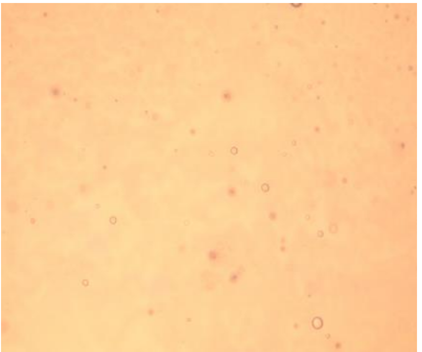

Savana Green
(Patent Under Preparation)

PVA/ CNC



PVA/CNC/ Cross Linkers

GSPACS Processed Films

Optical Imaging

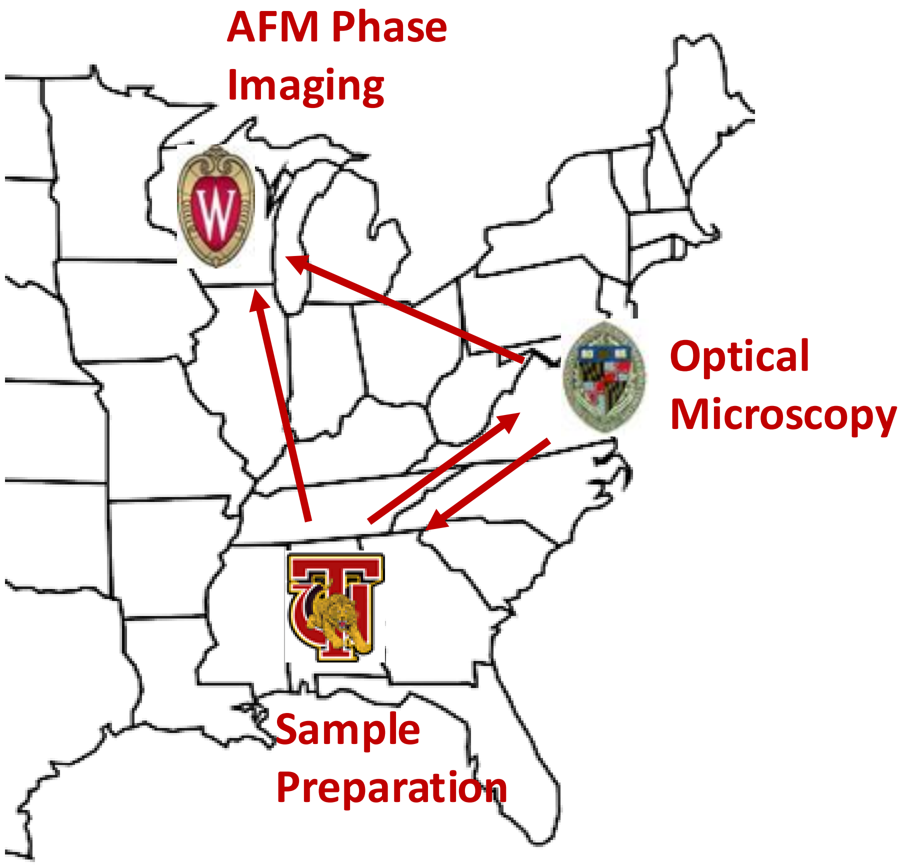
“Impossible Claims”

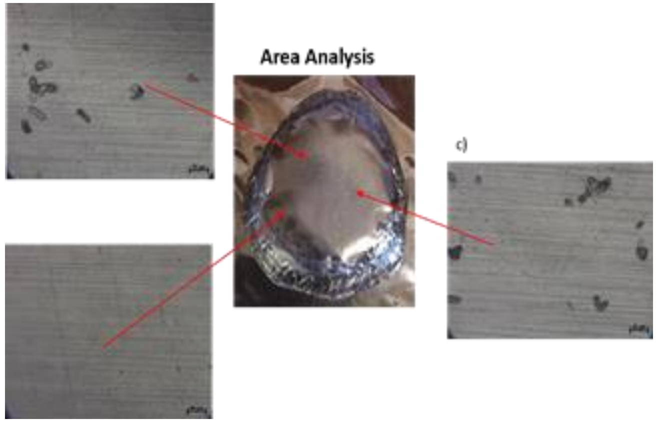
AGGIES DO

Dispersion Validity

Tripled-blind study using phase imaging and optical microscopy

Tuskegee Samples

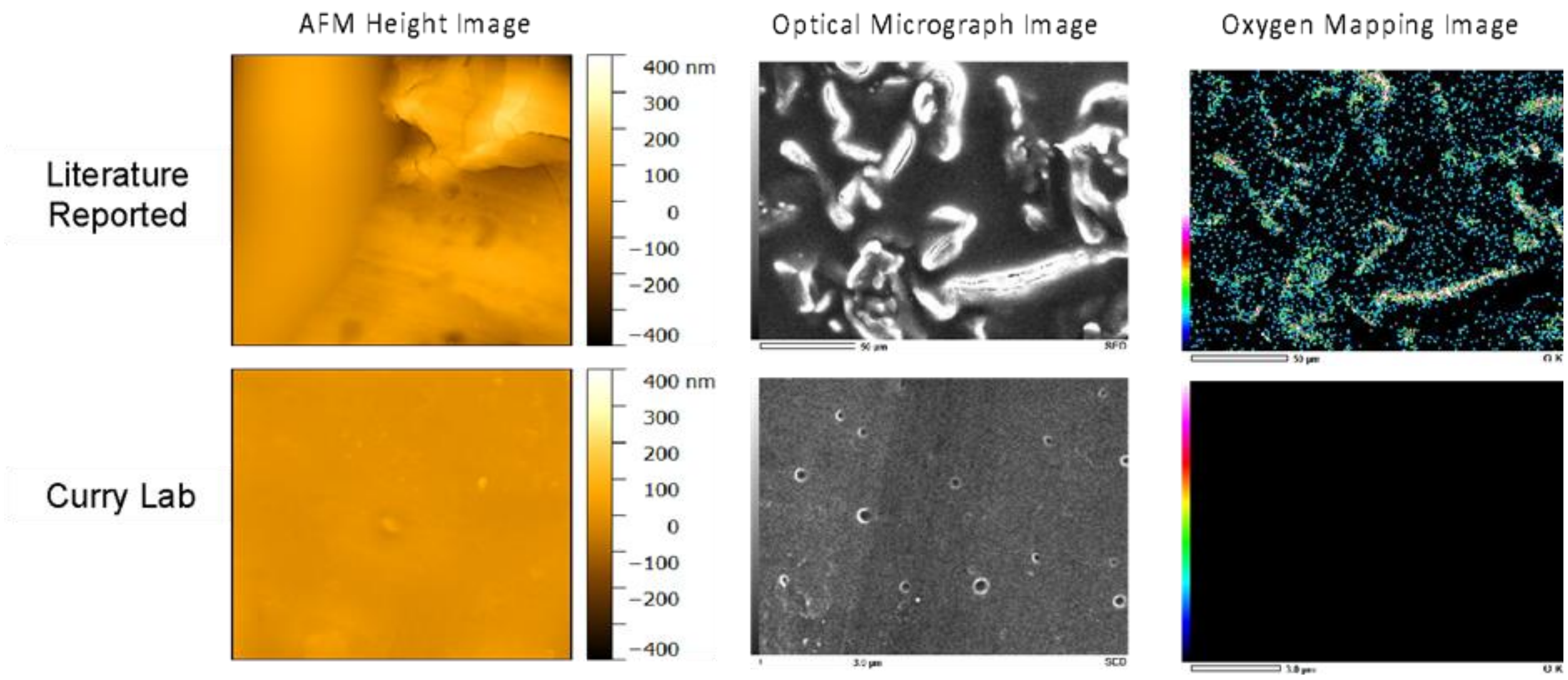




To ensure consistency, analysis were carried out using the same identified composite areas.

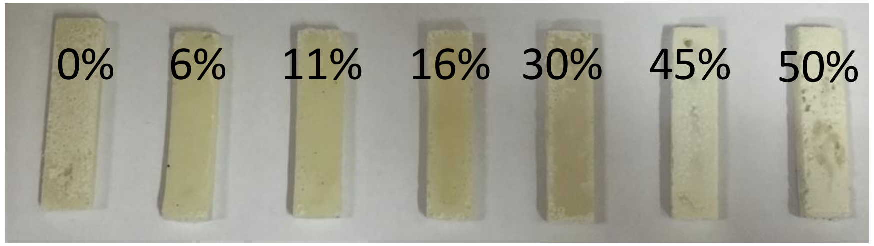
Tuskegee's Dispersion Results

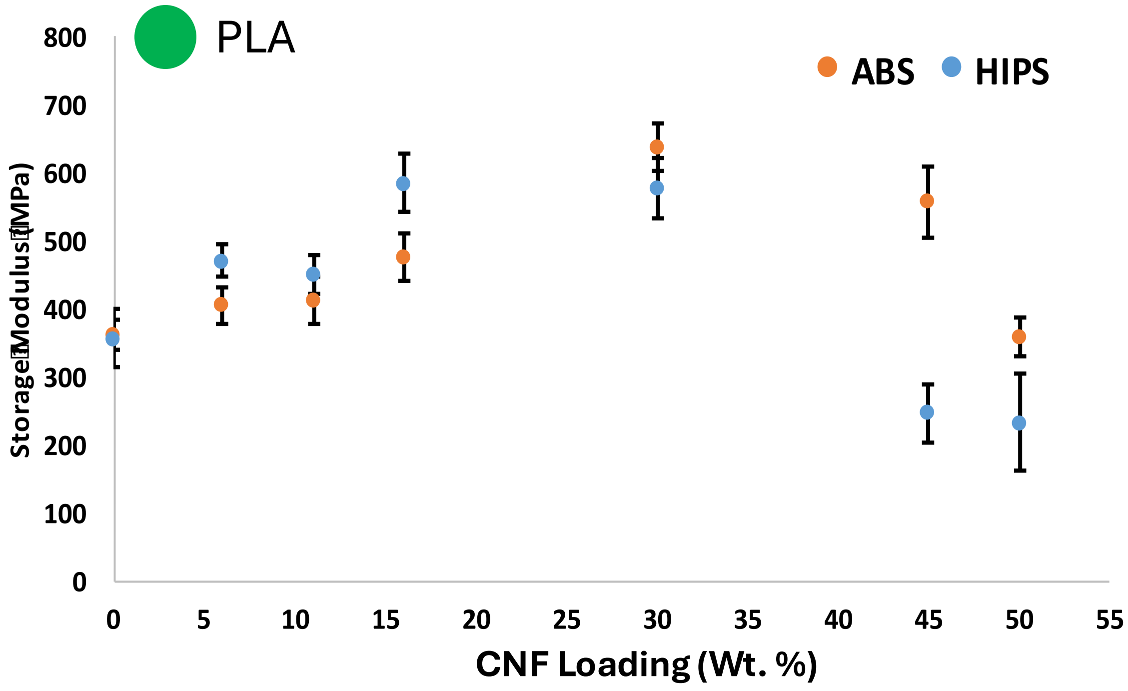
UWM-JHU Triple-blind Study revealed Tuskegee CNFs uniformly dispersed



DMA: CNF Composites

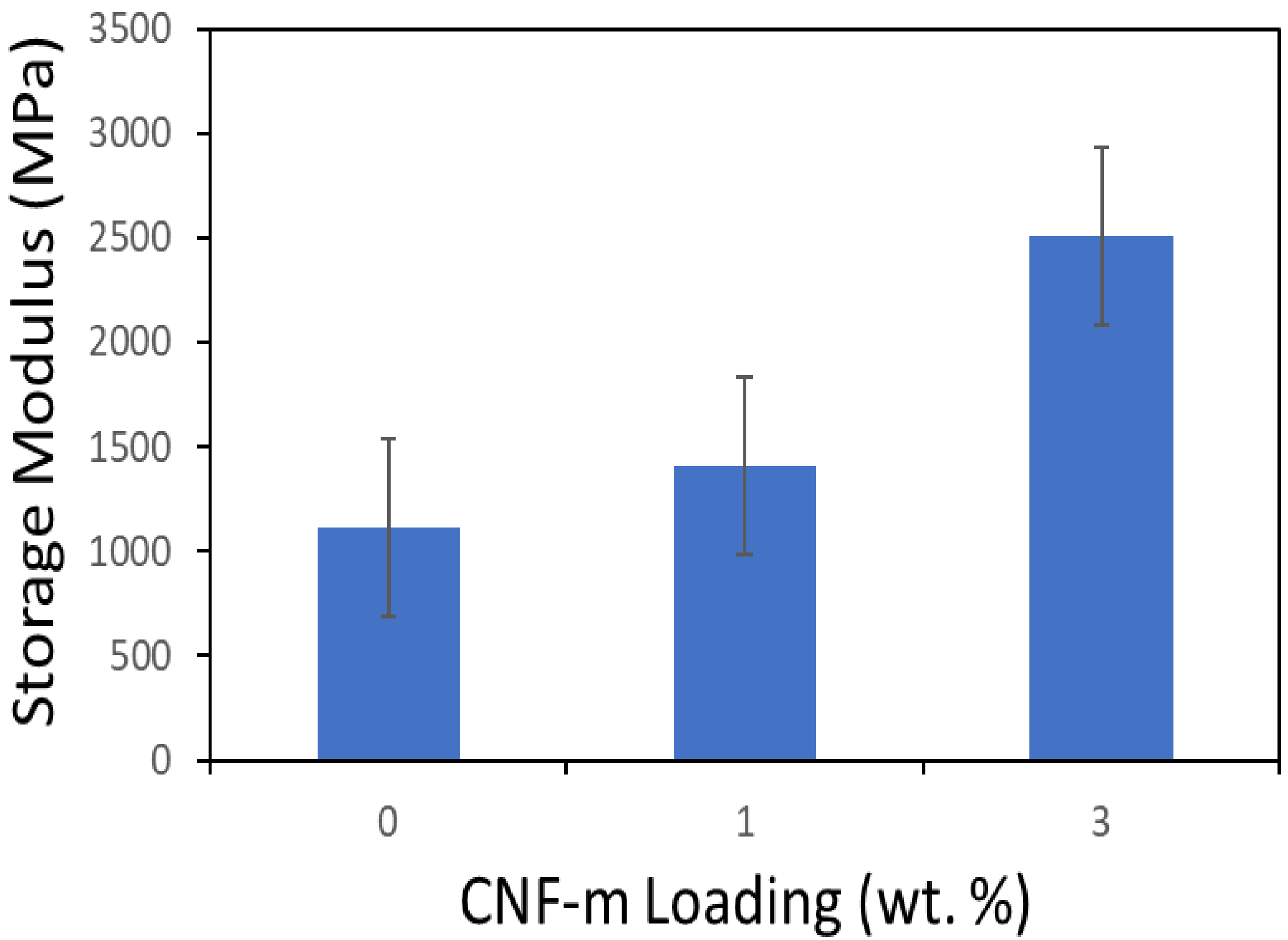
CNF-reinforced Composites



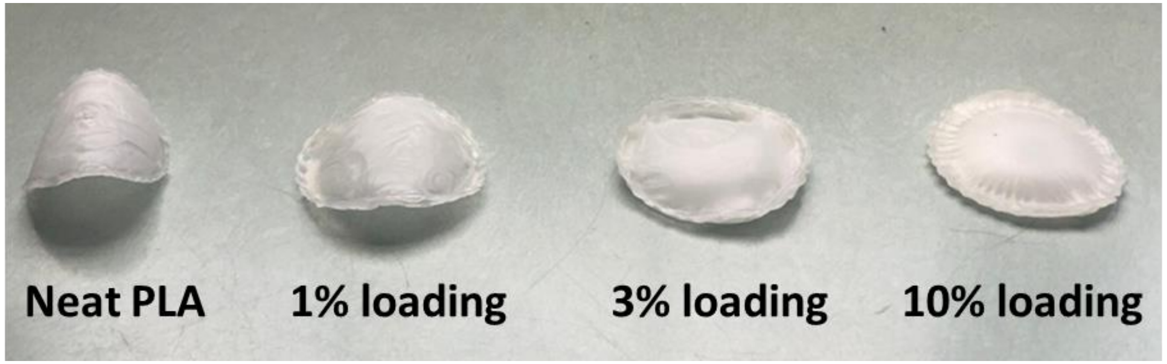


Sample	ABS	HIPS
0 Wt. %	362.32 ± 7.32	356.88 ± 28.64
6 Wt.%	405.67 ± 9.17	471.49 ± 24.67
11 Wt. %	413.23 ± 12.01	451.59 ± 9.18
16 Wt. %	476.68 ± 11.69	584.72 ± 14.20
30 Wt. %	638.63 ± 12.03	578.28 ± 28.64
45 Wt. %	558.10 ± 17.34	246.97 ± 14.37
50 Wt. %	360.14 ± 9.57	201.88 ± 32.01

DMA: CNF-based PLA Composites



CNF-reinforced PLA composites.



TMA: Surface Modified CNF Composites

Addition of CNF significantly lowered composite measured CTE values

Sample	CTE Before the T_g (∝m/m°C)
ABS-HIPS	
Neat	13.69 ± 14.16
30 Wt.%	42.86 ± 55.24
Functionalized	
Albright-Goldman 30 Wt.%	-0.22 ± 8.02
Jones 30 Wt.%	-5.74 ± 10.24
Silylation 30 Wt.%	-7.72 ± 15.22

Cellulose Hydrophilic Behavior (Absorbs Moisture)

TGA: Tuskegee CNF-reinforced Plastics

Increasing CNF compatibility and dispersion stabilizes filler effect on PLA composites

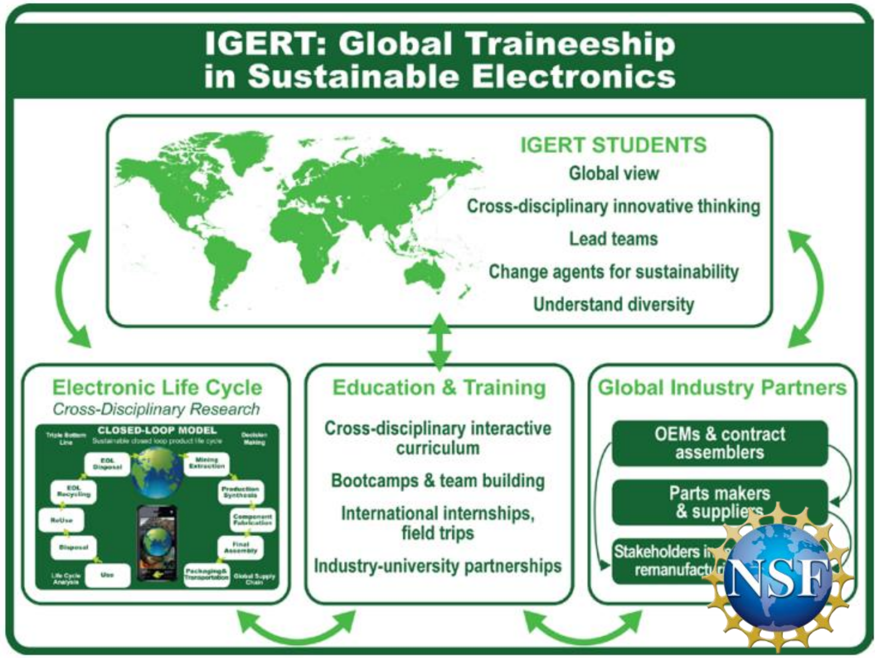
Sample	CNF (wt.%)	Maximum Decomposition Temp Onset (°C)	Rate of Decomposition (wt.%/min)	Residue (wt.%)
PLA	Neat	326	2.55	77.9
	1	331	2.15	66.6
	5	333	2.97	93.0
	10	329	3.09	95.7
ABS	Neat	380	0.185	93.4
	1	387	2.74	99.7
	5	374	2.66	94.0
	10	387	2.17	78.9
HIPS	Neat	336	3.12	98.9
	1	372	2.83	99.1
	5	368	2.87	99.5
	10	342	2.96	95.3

Relative instrument sensitivity ± 0.005

What Did We Do?

- Cellulose has been extracted from different biomass sources with excellent thermal properties
- Surface modification of cellulose show dramatic improvements in its dispersion into otherwise incompatible polymer matrices
- Cellulose-reinforced composites show significant improvements in there thermal and mechanical properties
- Biogas studies reveal that surface functionalization of cellulose significantly lowers biodegradation of cellulose-reinforced composite
- Through "serendipitous discovery", cellulose-reinforced composites can be developed cost effectively and without dramatic changes to its biodegradation behavior

What Did We Do?



Purdue University (2012)

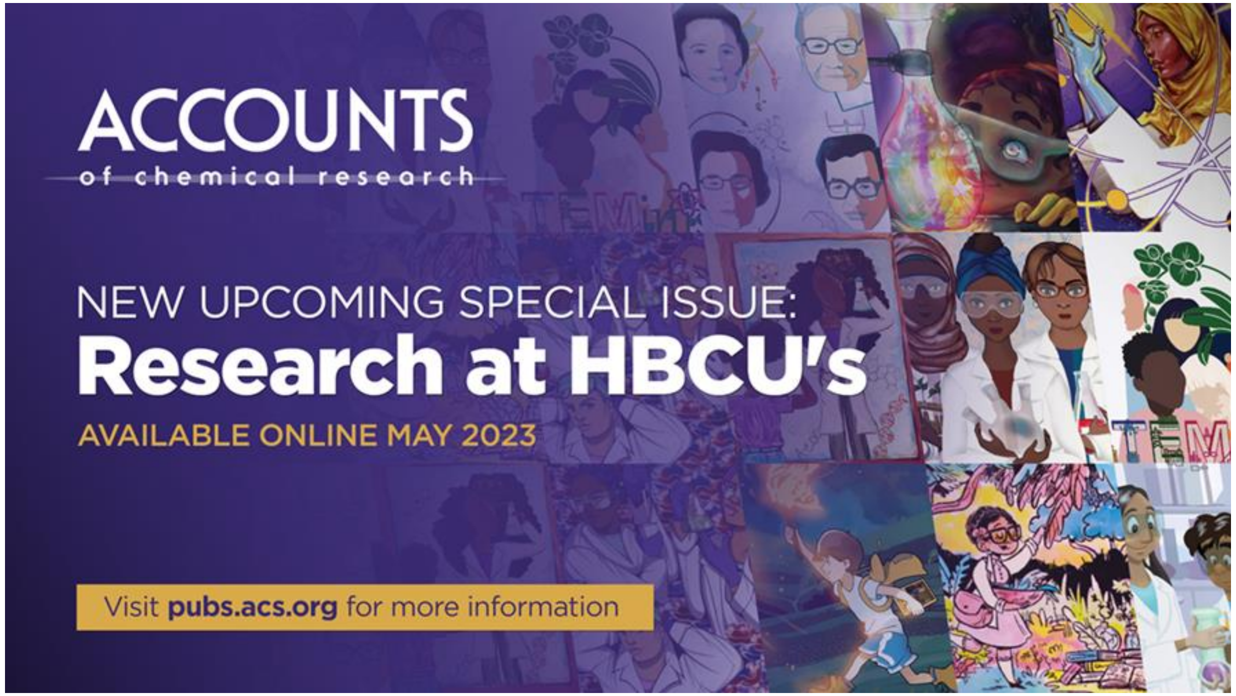
University of Wisconsin – Madison (2015)

"Changed The Seat At The Table."

Creating Platforms that Elevate HBCUs

Cynthia Burrows
Chief Editor of ACR

Robert J. Hamers
Senior Editor of ACR



Guest Editors

Michael Curry
(Lead)

Desmond Stubbs

Carl Bonner

NOBCChE HBCU Pioneers

Editorial Contributor

N. Joyce Payne
TMCF Founder

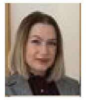
- Highlight research at HBCUs (IF: 25)
- 9 HBCUs featured (Invited 20)
- 11 HBCU publications (ACR avg. 9-10)
- HBCU written editorial and commentary

Changing the Scientific Community

Plastics News

August 08, 2022 12:30 PM | UPDATED 2 HOURS AGO

Tuskegee professor training 'next generation' of Black scientists



SARAH KOMINEK
Staff Reporter

Plastics News Staff

The plastics industry is missing out on innovations from historically Black colleges and universities that could help spur new plastic pollution and climate change solutions, says an associate professor at Tuskegee University.

Acknowledgements

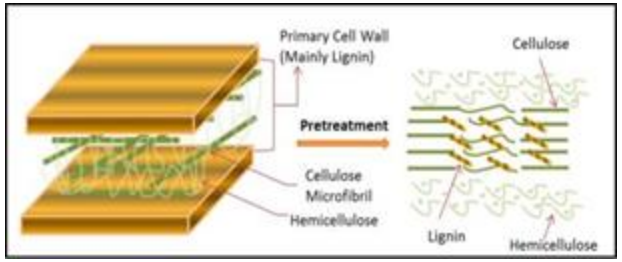
- Enrique Jackson - NASA
- Robert Hamers Group – UWM
- Christy Haynes Group - UM
- Howard Fairbrother Group – JHU
- Department of Chemistry – TU
- Department of MSE - TU
- Center for Advance Materials – TU
- NSF Funding (IGERT and CSN)
- Joint School of Nanoscience and Nanoengineering – NC A&T
- IMPACT Lab – (NC A&T)
- Intelligent Materials Innovation Lab – NC A&T

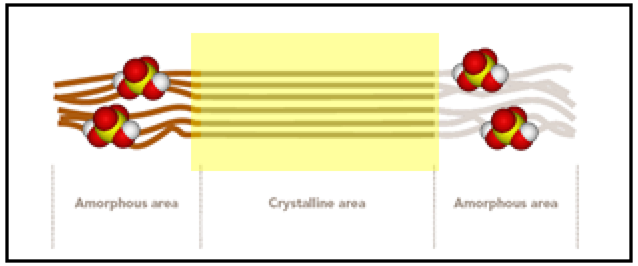
Cellulose Suspension and Loading

Suspension

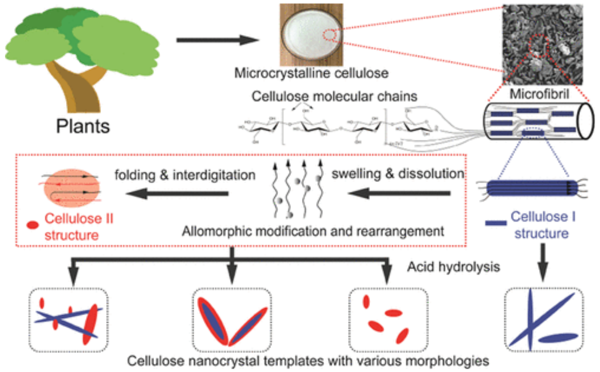
CNF Loading

Nanocellulose: Chemical Processing





Agricultural Waste Product	Acetic Acid Pretreatment + Bleaching Treatment at 70°C $NaClO_2$ + Acetate Buffer	Acid Hydrolysis + Centrifugation + Sonication	Crystalline Cellulose (Micronized or Nanosized)

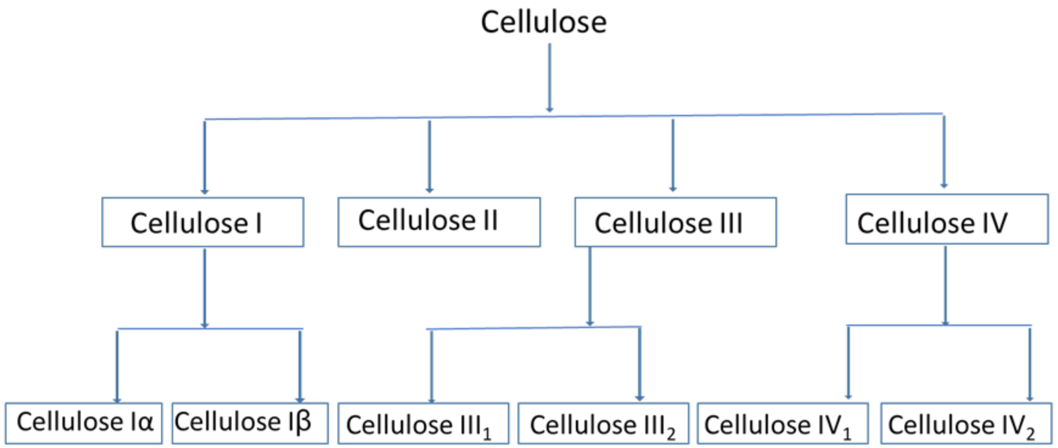


ARTICLE | January 25, 2022

Efficient Shaping of Cellulose Nanocrystals Based on Allomorphic Modification: Understanding the Correlation between Morphology and Allomorphs

Jie Gong, Yishan Kuang, Xi Zhang, Pengcheng Luan, Pengyang Xiang, Kai Liu, Lihuan Mo, Jun Xu, Jun Li*, and Jinquan Wan*

Possible Polymorphic Structures



<u>Properties Impacted</u>

- ✓ Thermal Stability
- ✓ Mechanical Performance
- ✓ Surface Area
- ✓ Available Surface Sites

Adapted from Österberg et. al. “Cellulose—model films and the fundamental approach.”; *Chem. Soc. Rev.*,35 **(2006)** 1287-1304

Hydrolysis

Cellulose → 64(wt)% H_2SO_4 → CNCs

Cellulose → 48(wt)% H_2SO_4 → CNFs

Han, J., Zhou, C., Wu, Y., Liu, F., & Wu, Q. (2013). Self-assembling behavior of cellulose nanoparticles during freeze-drying: Effect of suspension concentration, particle size, crystal structure, and surface charge. Biomacromolecules, 14(5), 1529-1540.

TGA: Surface Modified Cellulose

Silylated Cellulose

Best Experimental Duration: 4 Hours
Thermal Decomposition Temperature (°C): 341.36 ± 7.18
Rate of Decomposition (%/°C): 0.83 ± 0.26
Residue (%): 16.00± 0.29

Sample	Max Decomposition Temperature (°C)	Rate of Decomposition (°C)	Residue (%)
Commercial	333.37 ± 0.60	1.75 ± 0.07	4.81 ± 0.54
Albright-Goldman	339.26 ± 6.61	1.00 ± 0.90	8.71 ± 0.90
Jones	242.22 ± 13.37	0.43 ± 0.04	29.70 ± 2.77
Silanization	341.36 ± 7.18	0.83 ± 0.26	16.00 ± 0.29