

NRC Publications Archive Archives des publications du CNRC

Strain-induced uniaxial alignment of cellulose nanocrystals in polymer nanocomposites

Gumfekar, Sarang P.; Wadood, Mohamed; Cho, Jae-Young; Elias, Anastasia L.; Harris, Kenneth D.

NRC Publications Archive Record / Notice des Archives des publications du CNRC :

<https://nrc-publications.canada.ca/eng/view/object/?id=2dbc1838-cb71-47c3-8648-3d125ea1d84b>

<https://publications-cnrc.canada.ca/fra/voir/objet/?id=2dbc1838-cb71-47c3-8648-3d125ea1d84b>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at

<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site

<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

Questions? Contact the NRC Publications Archive team at

PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

Vous avez des questions? Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.

Strain-induced Uniaxial Alignment of Cellulose Nanocrystals (CNCs) in Polymer Nanocomposites

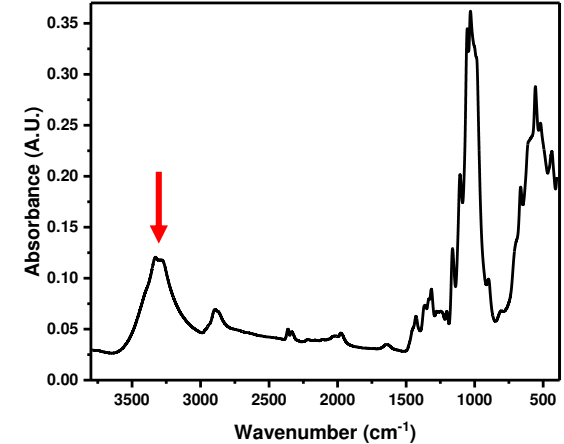
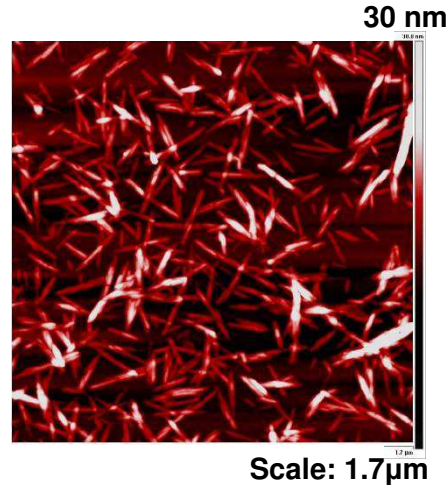
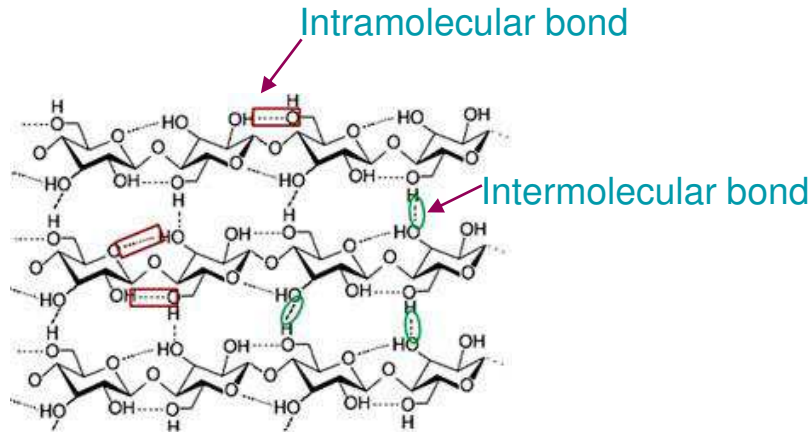
Sarang Gumfekar

National Research Council of Canada –
Nanotechnology Research Center
Edmonton, Canada

Department of Mechanical Engineering
University of Alberta, Edmonton, Canada



Cellulose Nanocrystals (CNCs)



- Intermolecular and intramolecular hydrogen bonding
- Opportunities for various surface functionalization
- Crystalline structure \rightarrow suitable as reinforcement material
- Our CNC source: *Innotech Alberta*

Alignment: Benefits and Methods

Benefits

- Manipulation of optical properties (birefringence)
- Unidirectional amplification of mechanical and rheological properties
- Anisotropic electrical properties (in case of conductive fillers)

Methods reported in literature

- Using electric field (applicable for only electrically conducting fillers)
- Using magnetic field (applicable for only magnetic fillers)
- Dry spinning process (applying force in various directions)

Why strain-induced technique?

- Simple and robust technique
- Involves stretching the film at controlled strain and temperature
- Can be used for non-conducting and non-magnetic materials

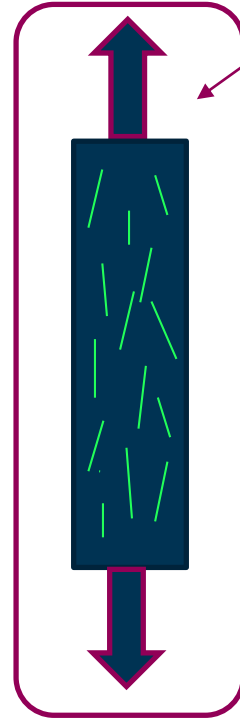
Strain-induced Alignment

Initial composition

2 mg CNC
5 mg PVA
93 mg Water

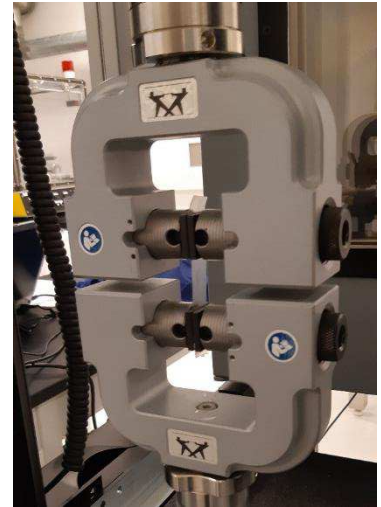


Stretching
5 mm/min



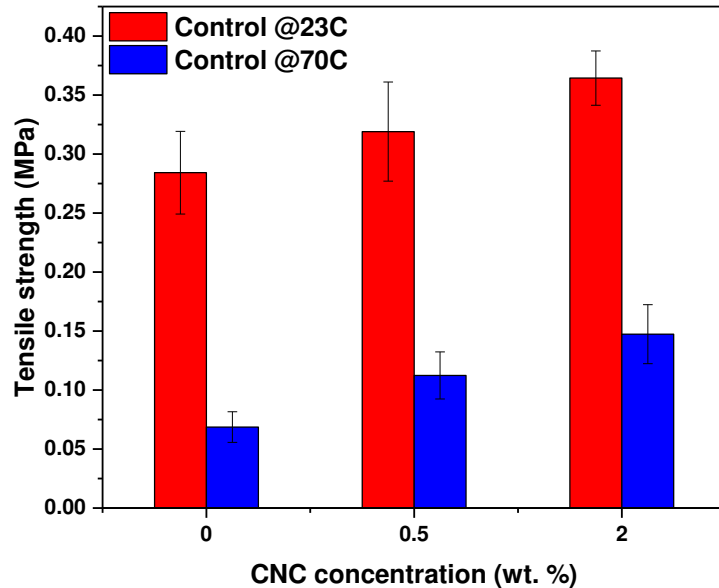
23 °C or 70 °C

Polyvinyl alcohol (PVA)-CNC
Film: 90mm × 20mm × 300μm
Film formation: mold casting

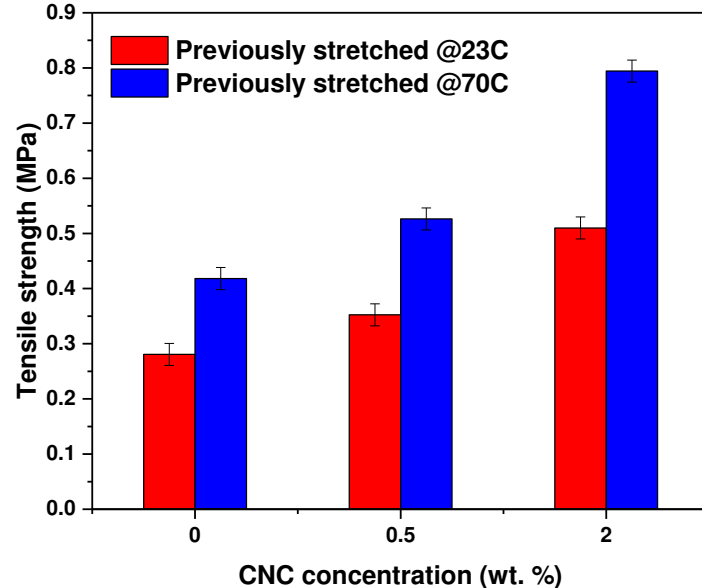


Heating inside the chamber

Mechanical Properties-Tensile Strength

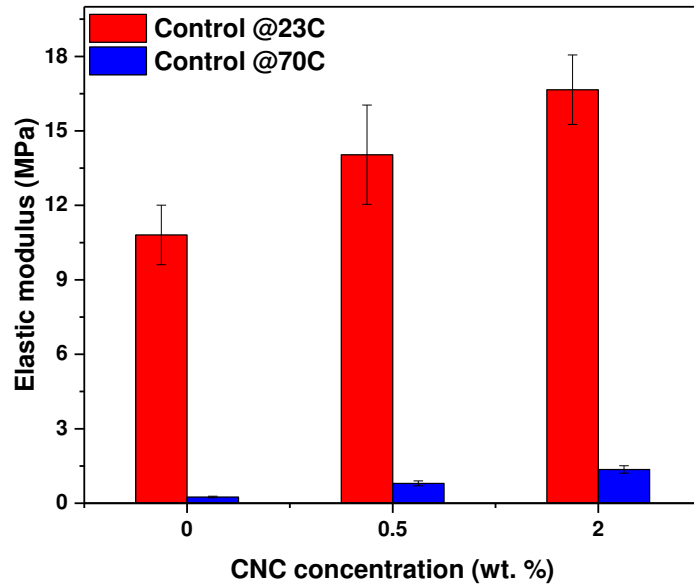


Tests performed at 23 °C and 70 °C

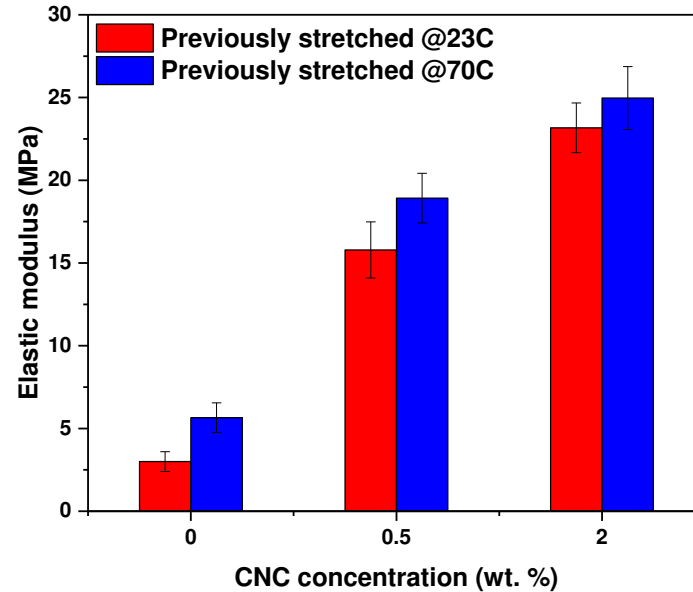


Tests performed at 23 °C

Mechanical Properties-Elastic Modulus

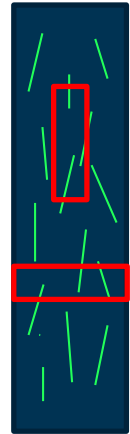
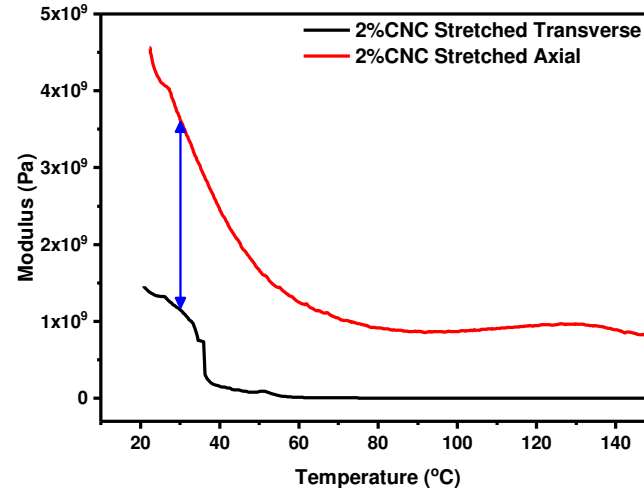
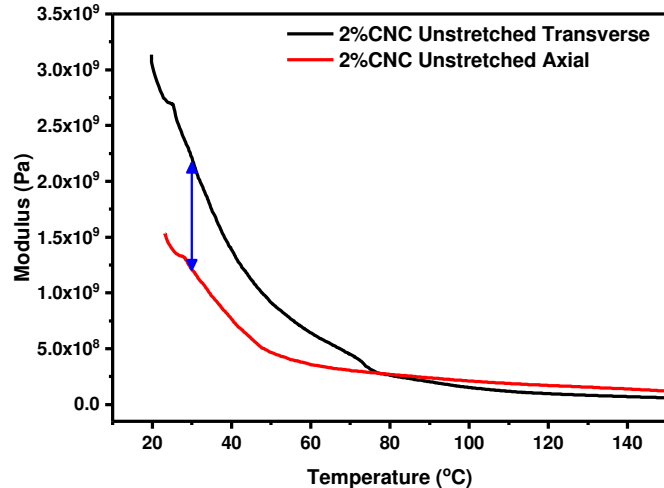
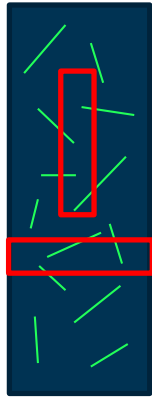


Tests performed at 23 °C and 70 °C



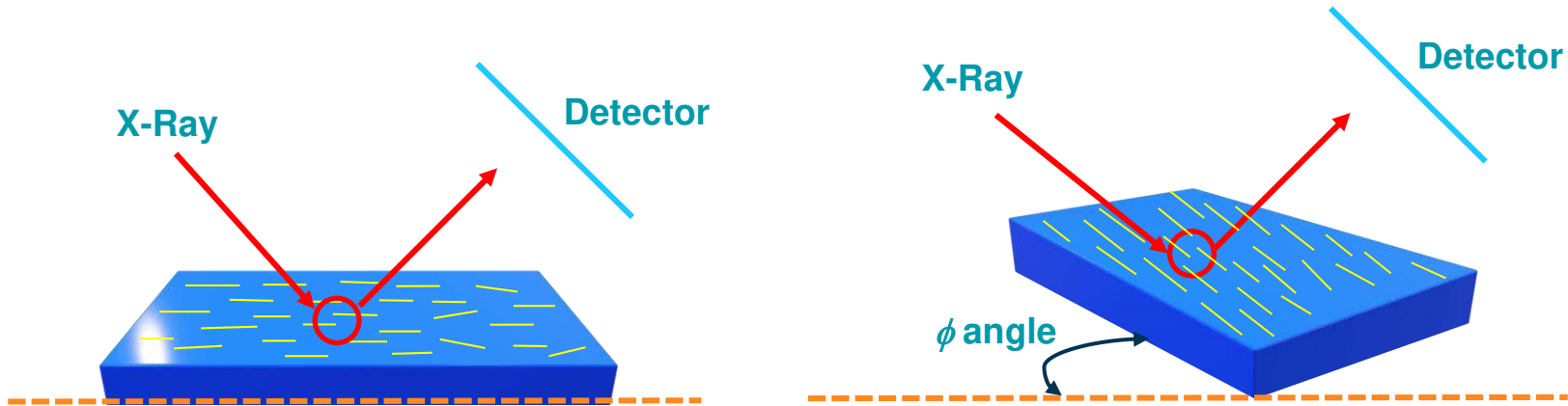
Tests performed at 23 °C

Rheological Properties: Dynamic Mechanical Analysis (DMA)

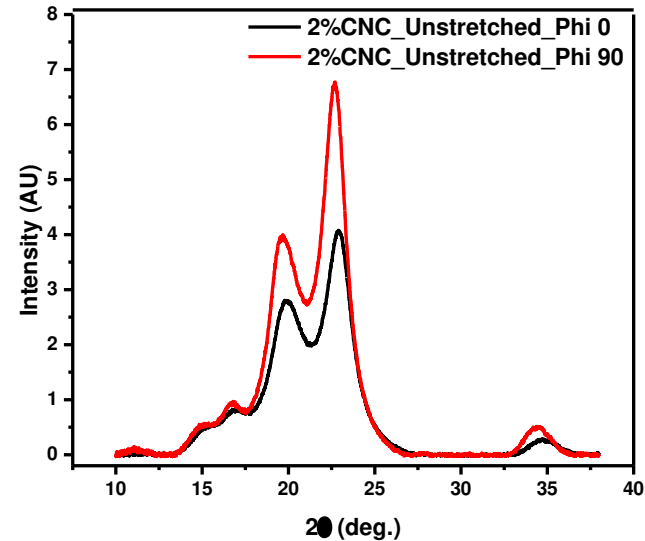
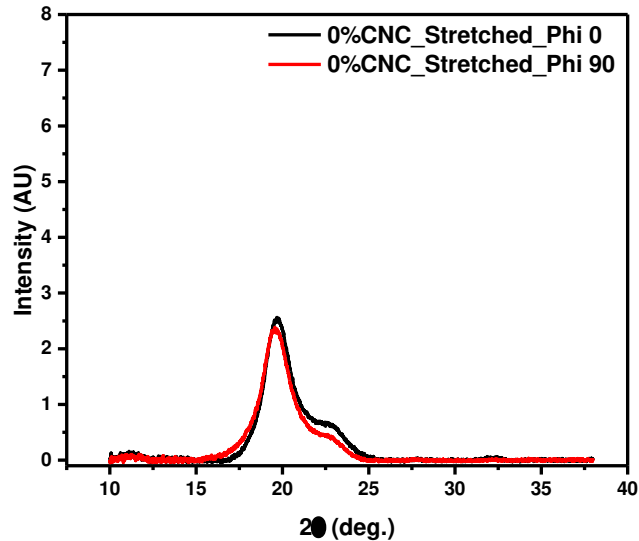


- Non-aligned CNCs: Axial modulus = **0.55 x** Transverse modulus
- Aligned CNCs: Axial modulus = **3.10 x** Transverse modulus

Structural Properties: X-Ray Diffraction

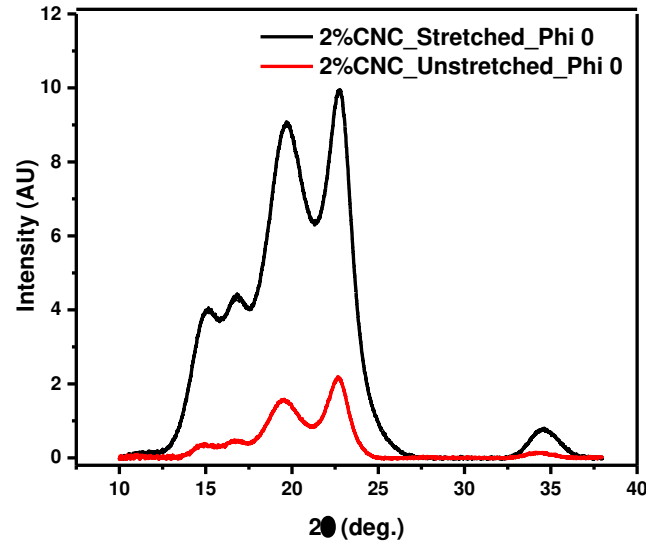
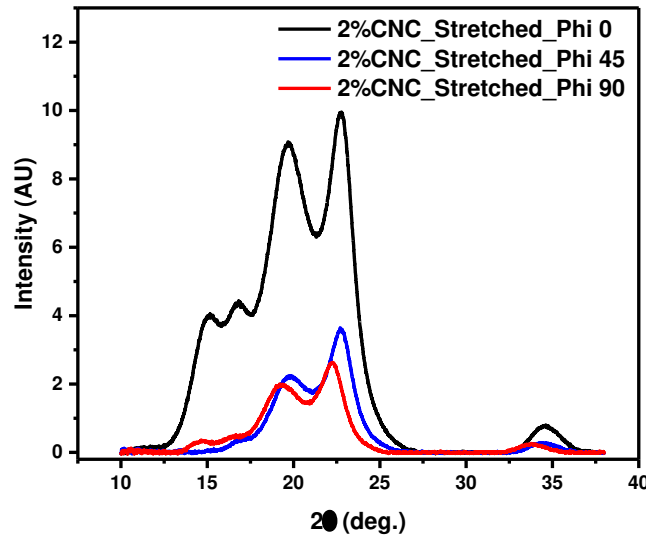


Structural Properties: X-Ray Diffraction



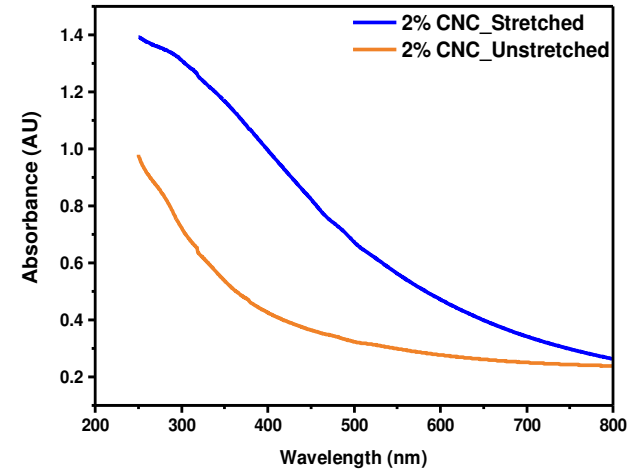
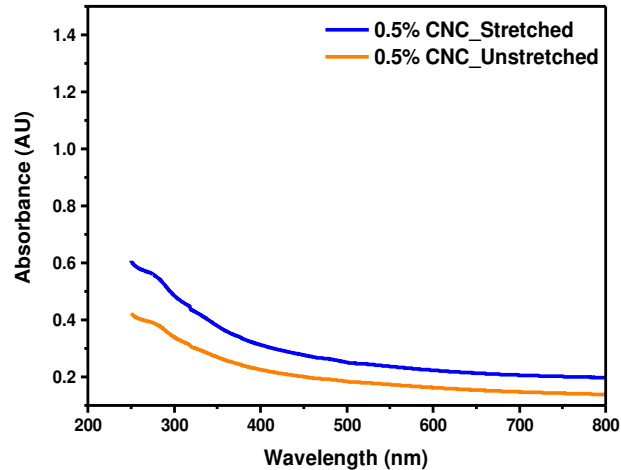
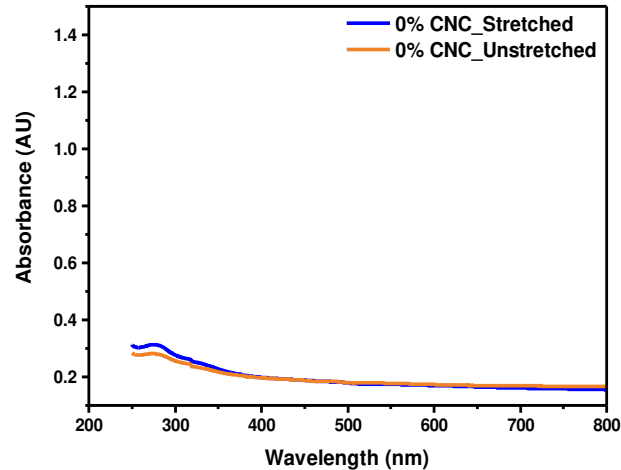
- No change in crystallinity of polymer after stretching
- There is limited natural alignment of CNC in polymer without stretching

Structural Properties: X-Ray Diffraction



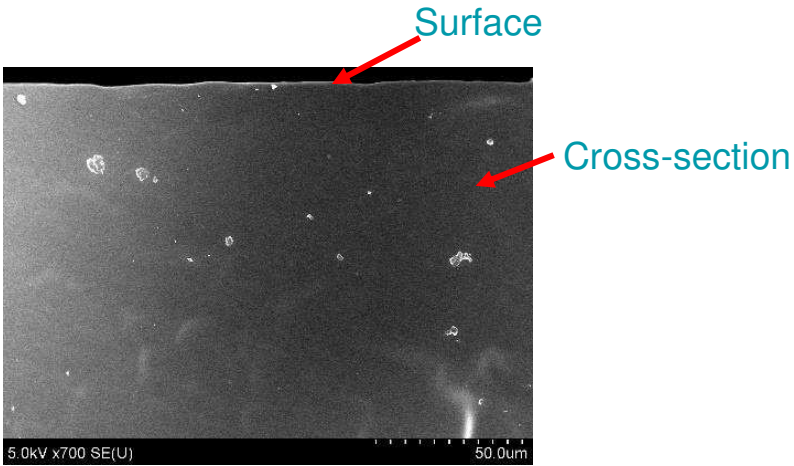
- As film orientation changes, crystallinity 'seen' by X-Rays changes
- Evidence of anisotropic crystallinity in the film

Optical properties: Absorbance

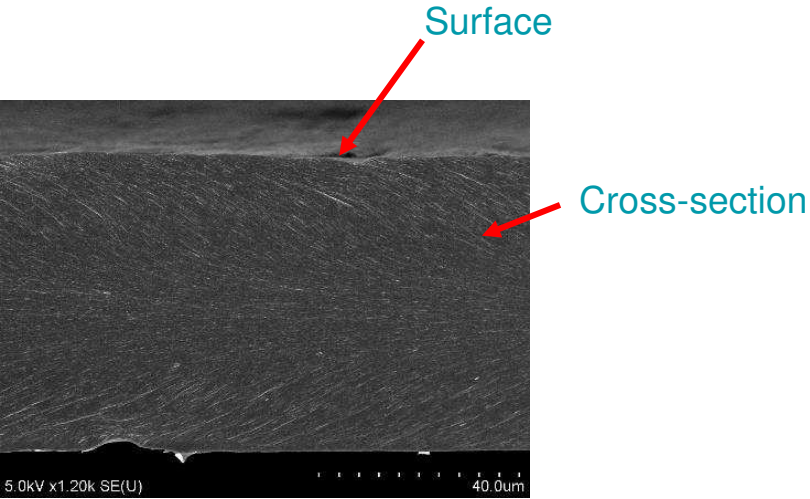


- Enhanced scattering after CNC alignment
- Overall increase in scattering with increase in CNC content of the composite

Alignment Morphology- CNC 0%



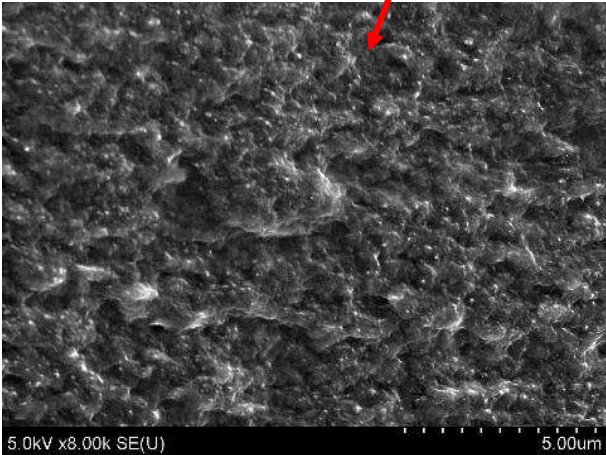
Before stretching



After stretching

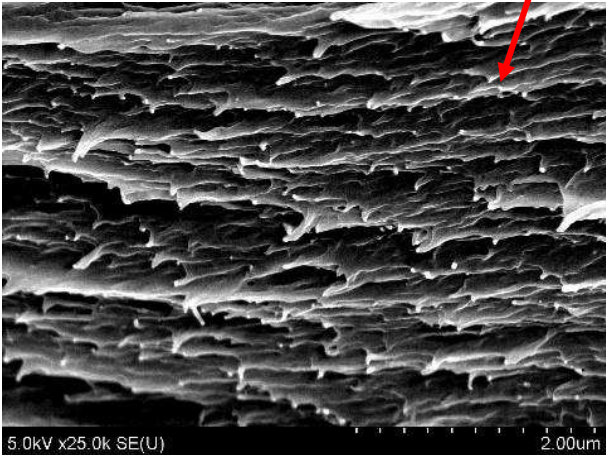
Alignment Morphology 2% CNC

Cross-section



CNCs not aligned

Cross-section



Aligned CNCs

Conclusions

- **Strain-induced alignment is an effective, easy, and robust technique to align CNCs**
- **Alignment of CNCs is facilitated above the glass transition temperature of the film**
- **Mechanical, rheological, and structural properties become anisotropic after alignment of CNCs in the film**

THANK YOU

