Strain-induced uniaxial alignment of cellulose nanocrystals in polymer nanocomposites

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

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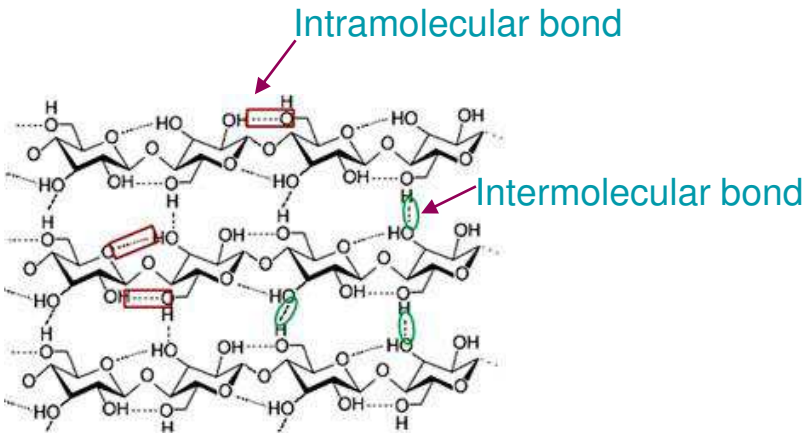
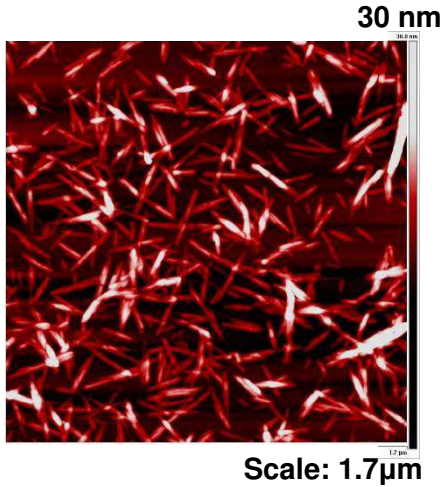
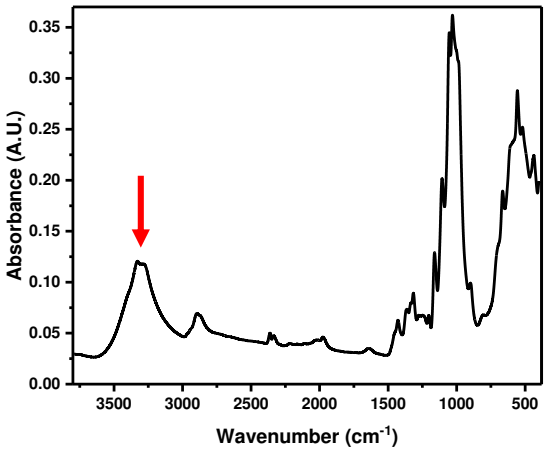
Cellulose Nanocrystals (CNCs)







- **Intermolecular and intramolecular hydrogen bonding**
- **Opportunities for various surface functionalization**
- **Crystalline structure→ 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)

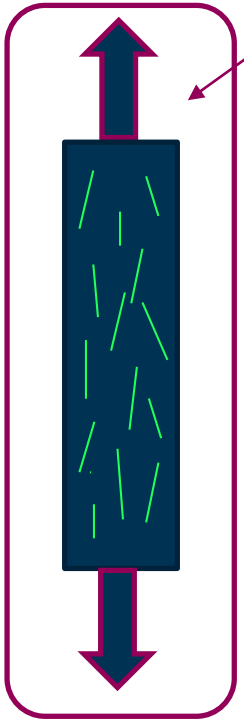
Why strain-induced technique?

- 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

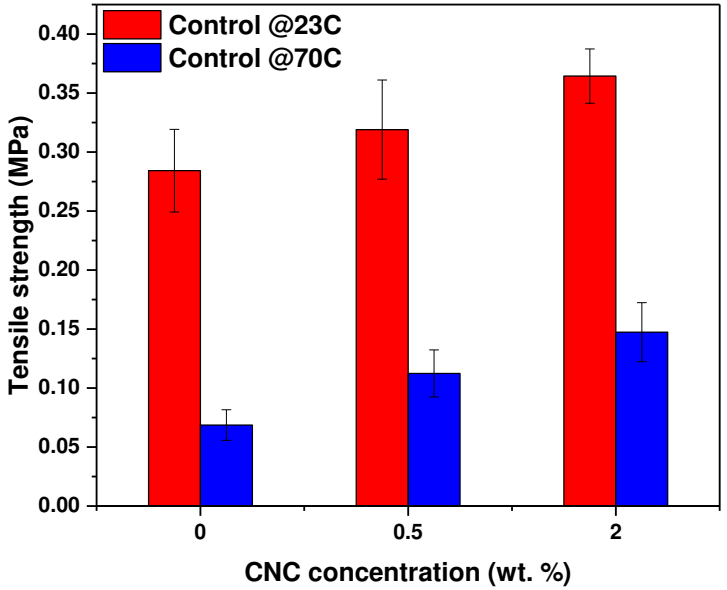


23 °C or 70 °C

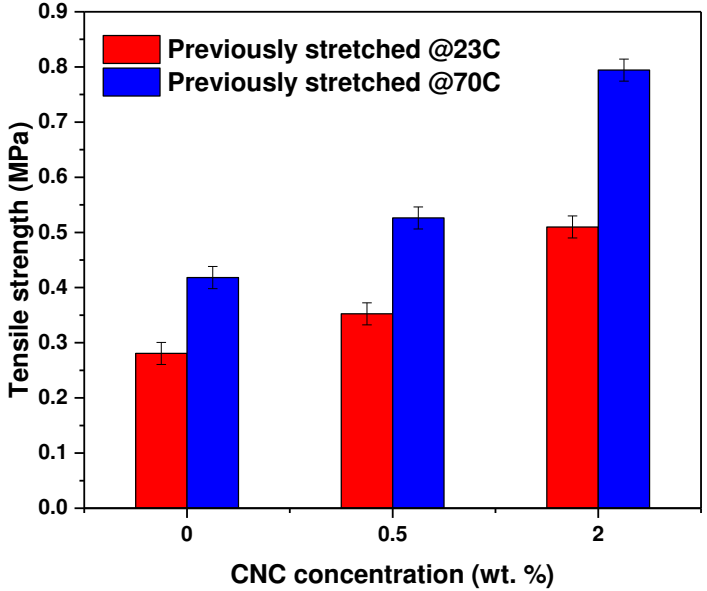
Polyvinyl alcohol (PVA)-CNC
Film: 90mm × 20mm × 300μm
Film formation: mold casting

Heating inside the chamber

Mechanical Properties-Tensile Strength

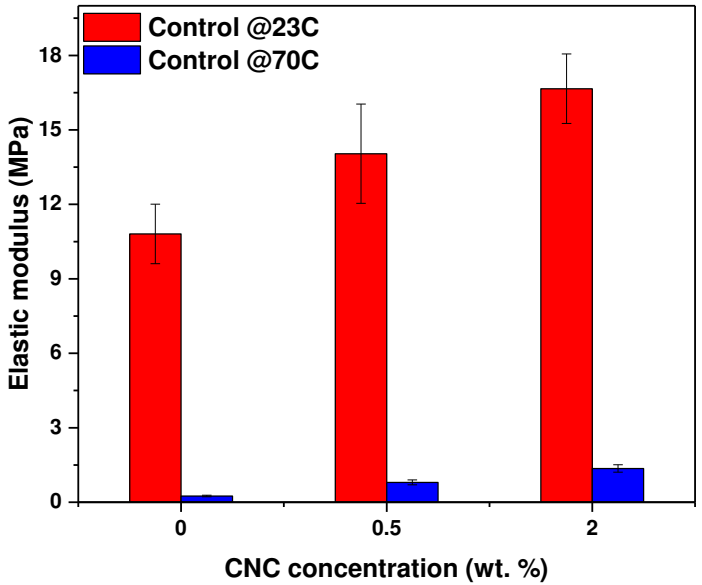


Tests performed at 23 °C and 70 °C

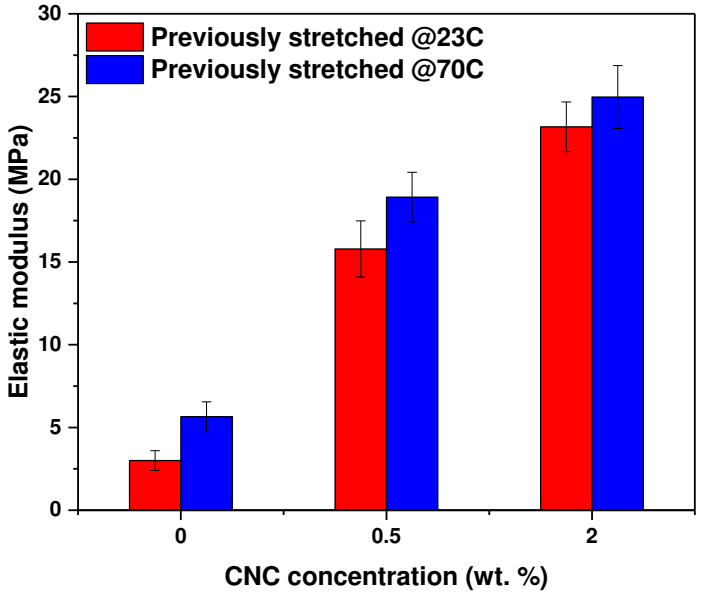


Tests performed at 23 °C

Mechanical Properties-Elastic Modulus

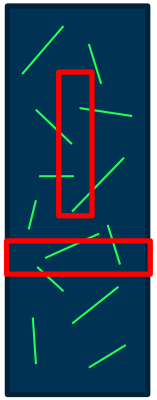


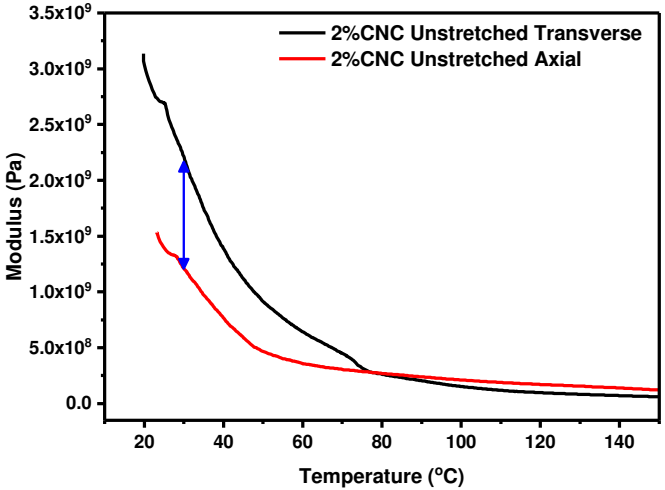
Tests performed at 23 °C and 70 °C

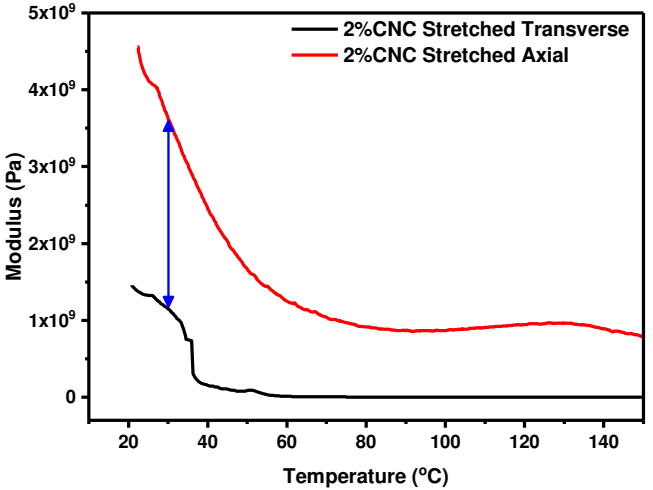


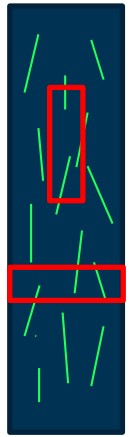
Tests performed at 23 °C

Rheological Properties: Dynamic Mechanical Analysis (DMA)



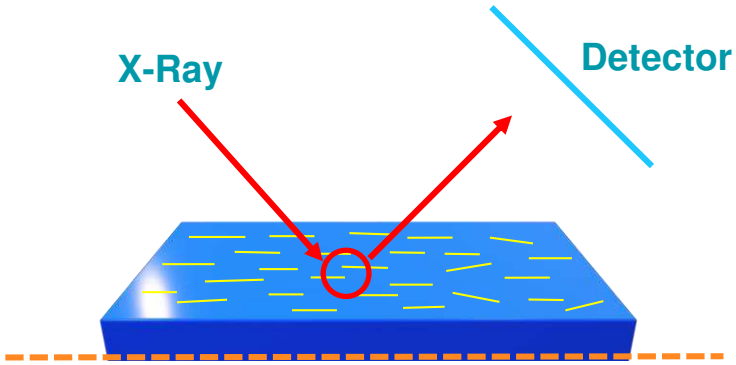


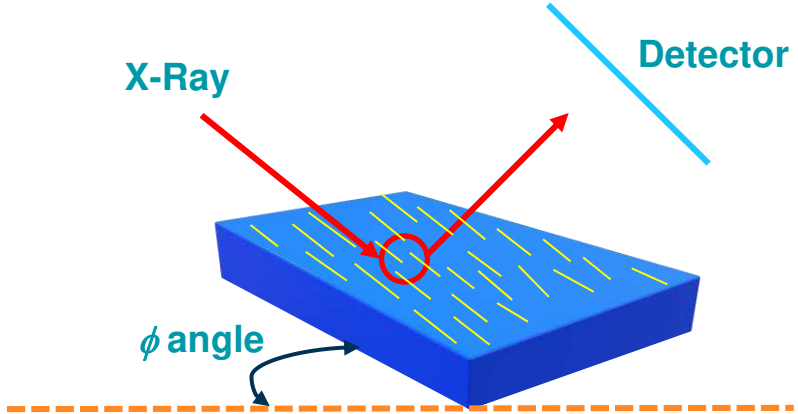




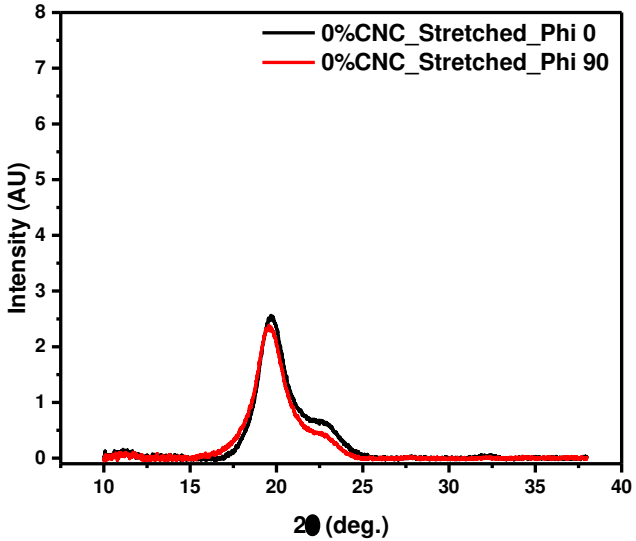
- Non-aligned CNCs: Axial modulus = **0.55 x** Transverse modulus
- Aligned CNCs: Axial modulus = **3.10 x** Transverse modulus

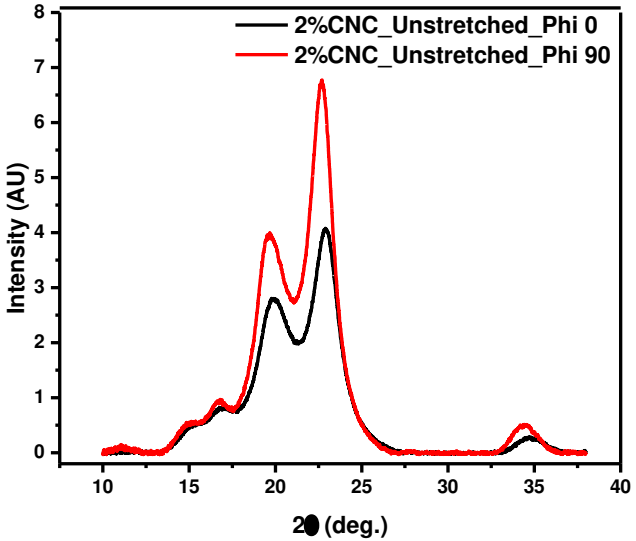
Structural Properties: X-Ray Diffraction





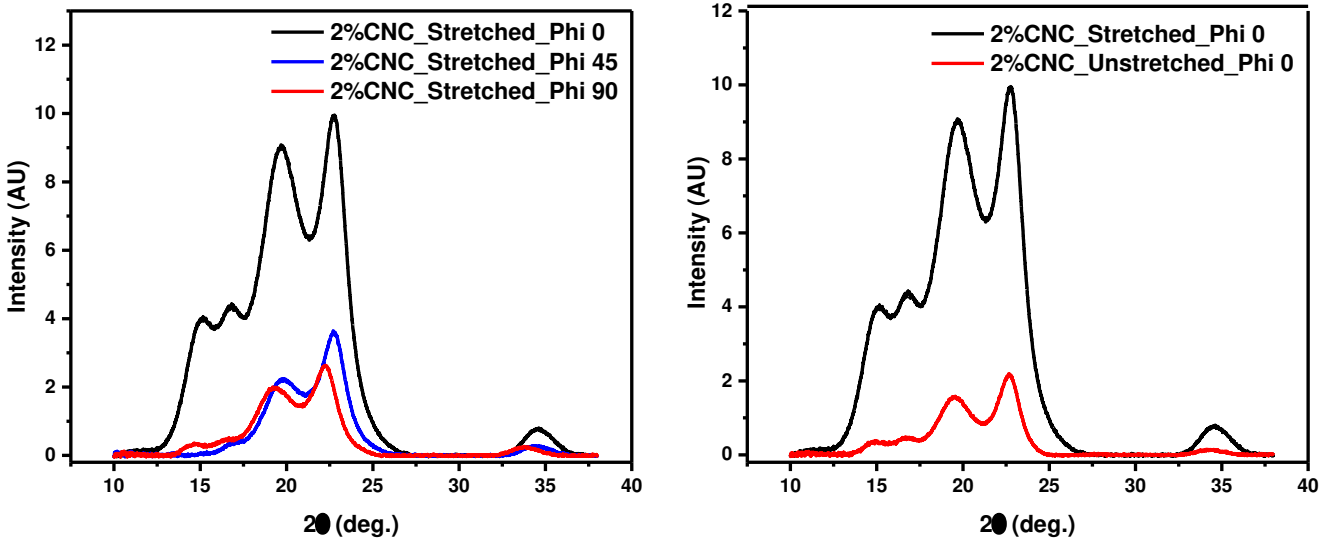
Structural Properties: X-Ray Diffraction





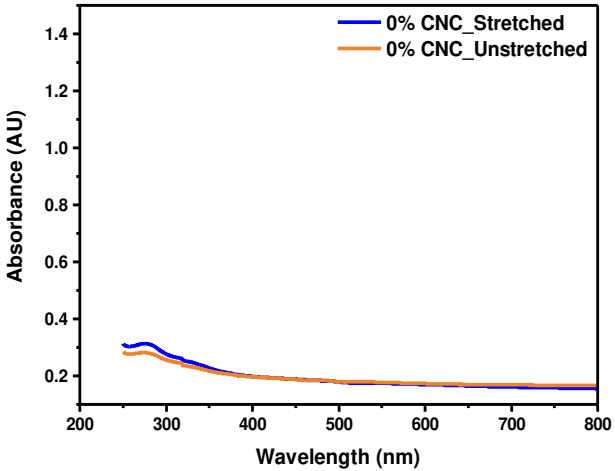
- No change in crystallinity of polymer after stretching
- There is limited natural alignment of CNC in polymer without stretching

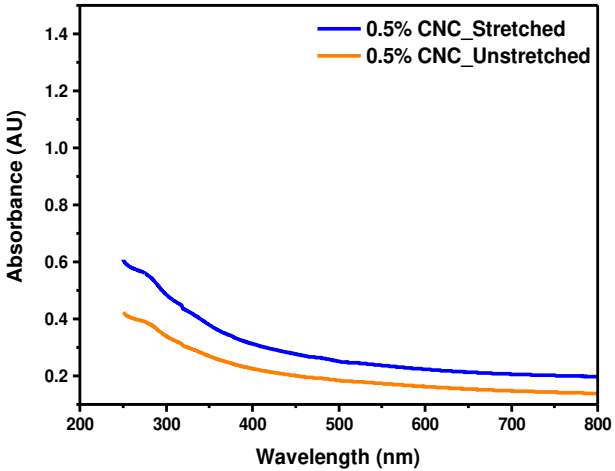
Structural Properties: X-Ray Diffraction

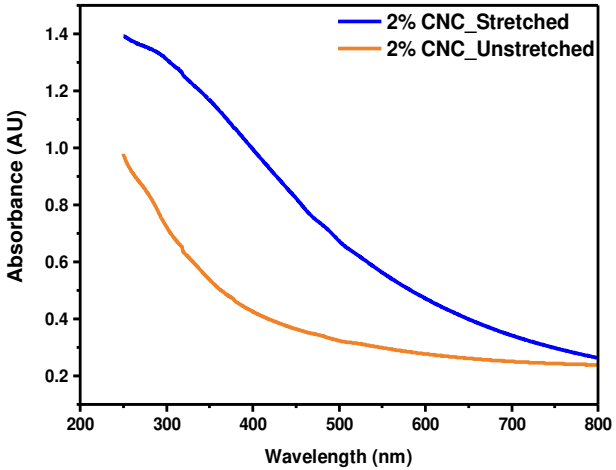


- As film orientation changes, crystallinity ‘seen’ by X-Rays changes
- Evidence of anisotropic crystallinity in the film

Optical properties: Absorbance

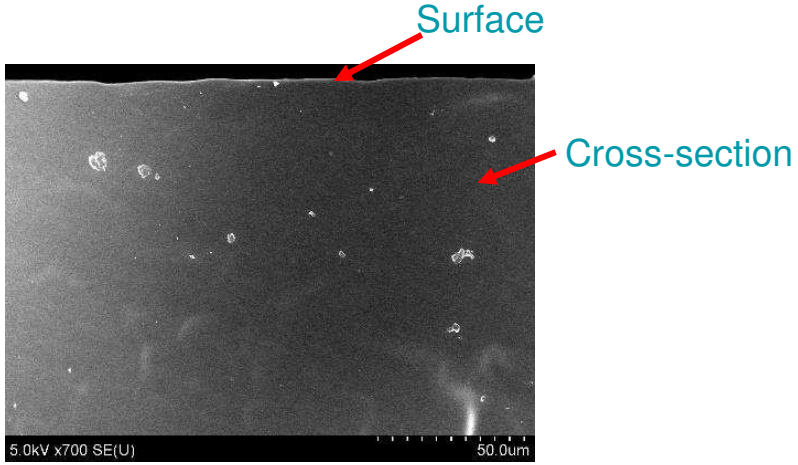




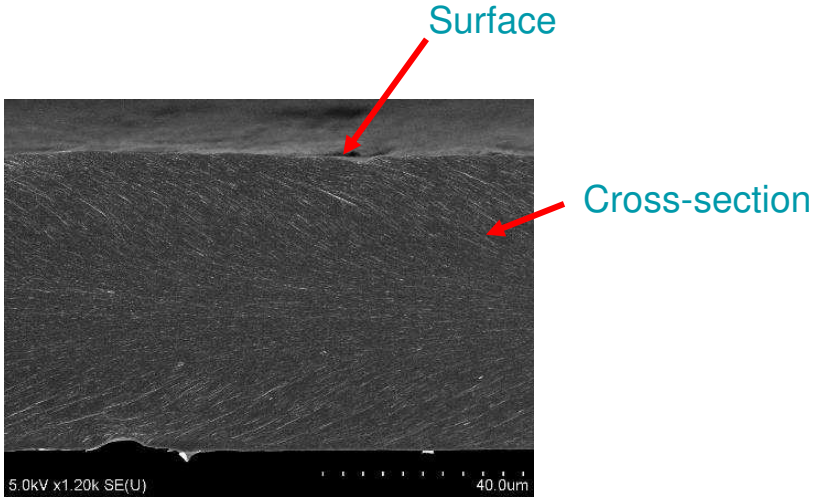


- Enhanced scattering after CNC alignment
- Overall increase in scattering with increase in CNC content of the composite

Alignment Morphology- CNC 0%



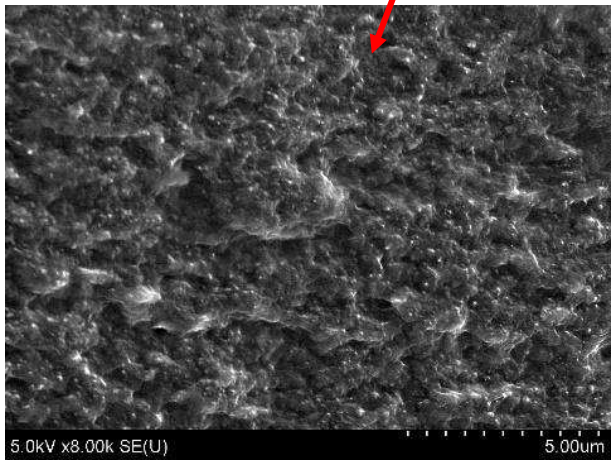
Before stretching



After stretching

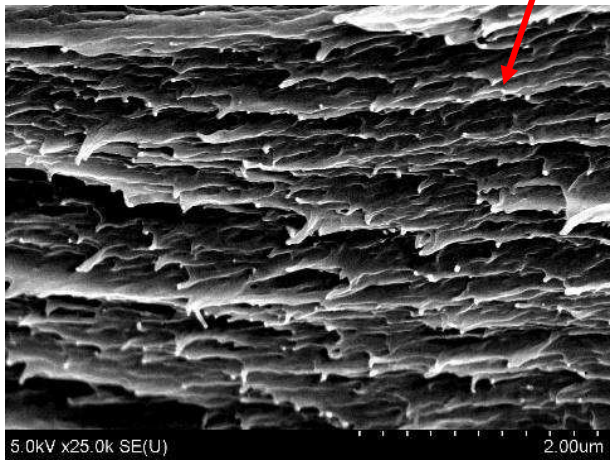
Alignment Morphology 2% CNC

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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