Structured cellulose nanocrystal – lysozyme composite films

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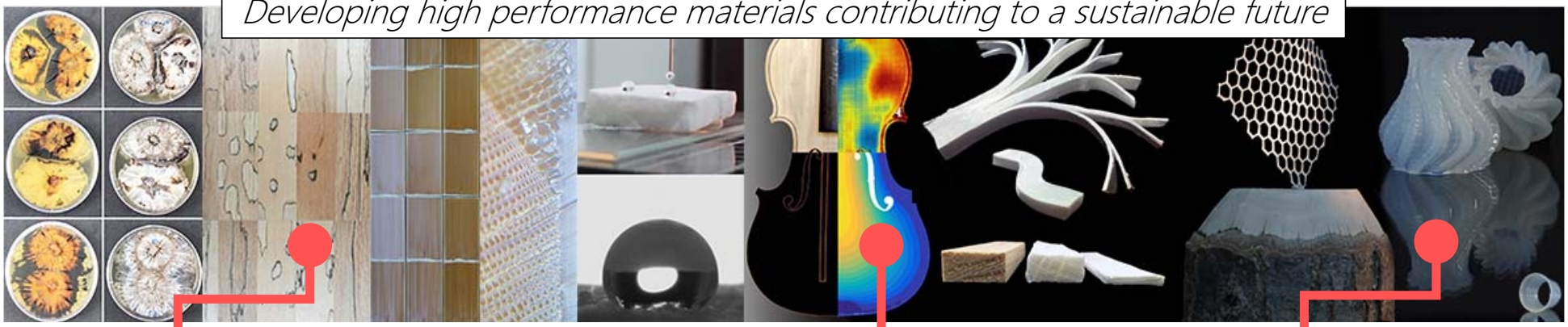
Developing high performance materials contributing to a sustainable future



Fungal & Enzymatic Bioengineering

- Biological Control
- Fungal engineering of wood
- Fungal composites

Wood & Native Wood Components

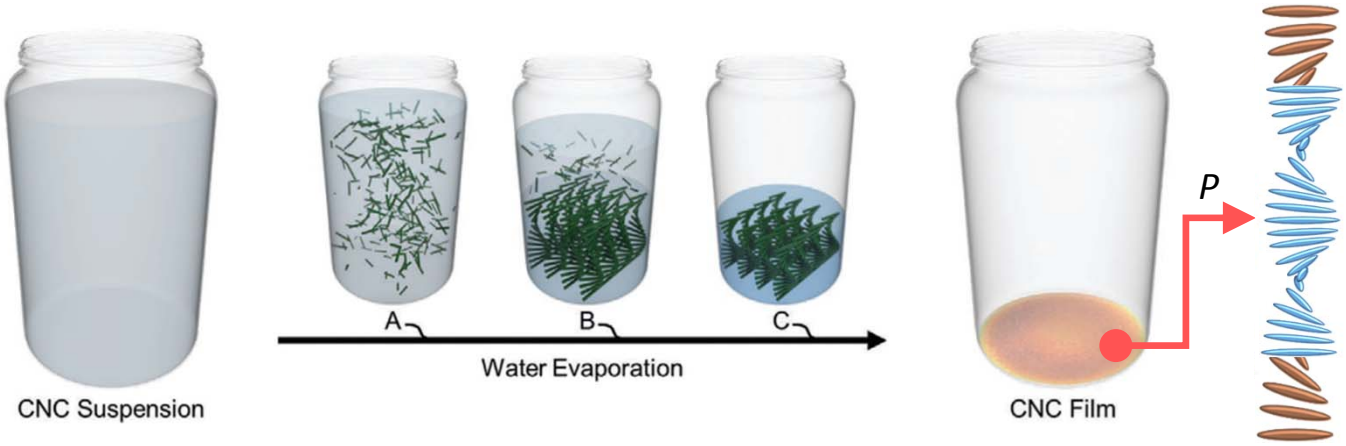
- Wood coatings & bio-modifications
- Machine Learning in the wood industry
- Novel applications for wood

Nanocellulose & Biopolymer Hybrids

- 3D Printing (inks & devices)
- Nanocellulose self-assembly
- Nanocellulose – protein biohybrids

CNC Self-Assembly

- Concentration-dependent self-assembly into chiral nematic phase
  → photonic/iridescent films
- Incorporation of polymers/particles is of high interest

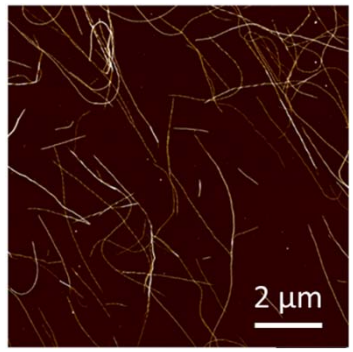


- Adsorbing (non-ionic) polymers ↑
- Non-adsorbing (anionic) polymers ↓
- Cationic polymers X

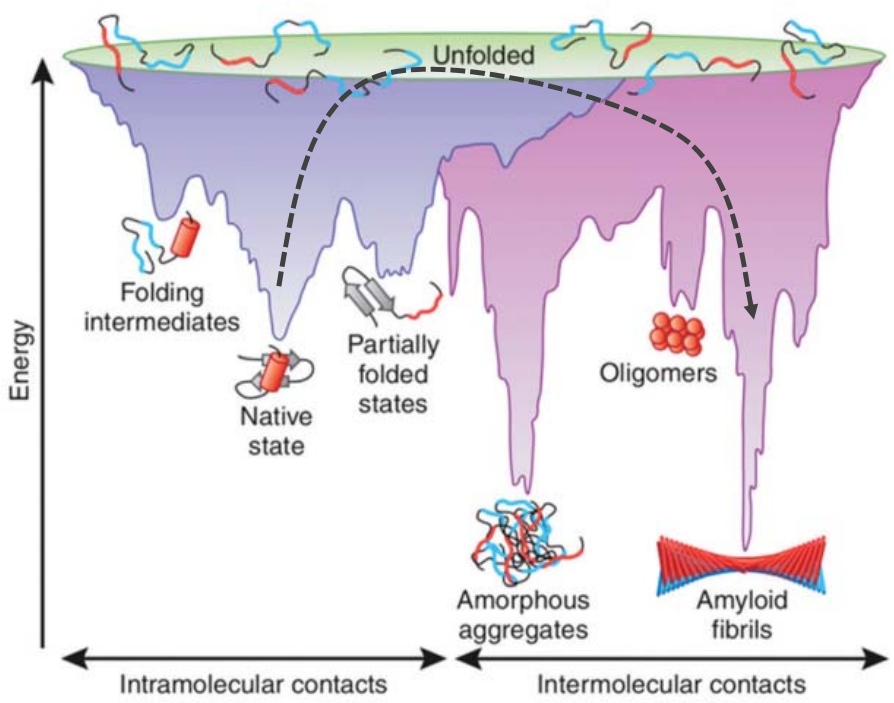
Jin et al. *Journal of Colloid & Interface Science* **2021**, *599*, 207-218

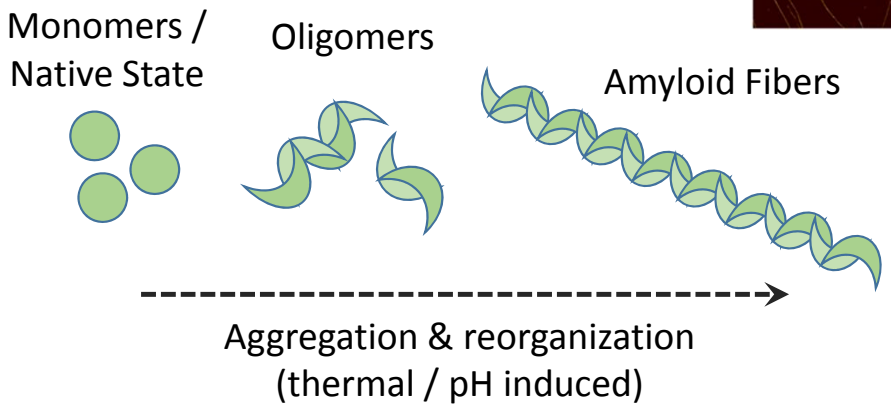
Incorporation of (+ve) Lysozyme in various conformations

Lysozyme Protein Amyloid Fibers



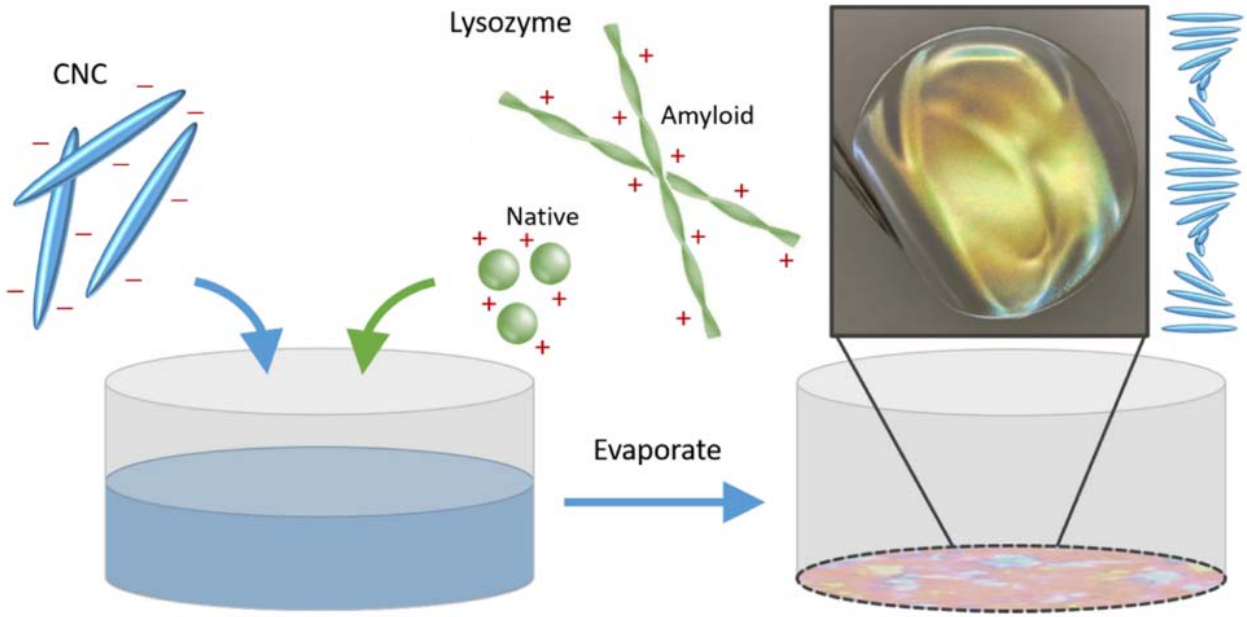
- High-aspect ratio nanoparticles from aggregated lysozyme

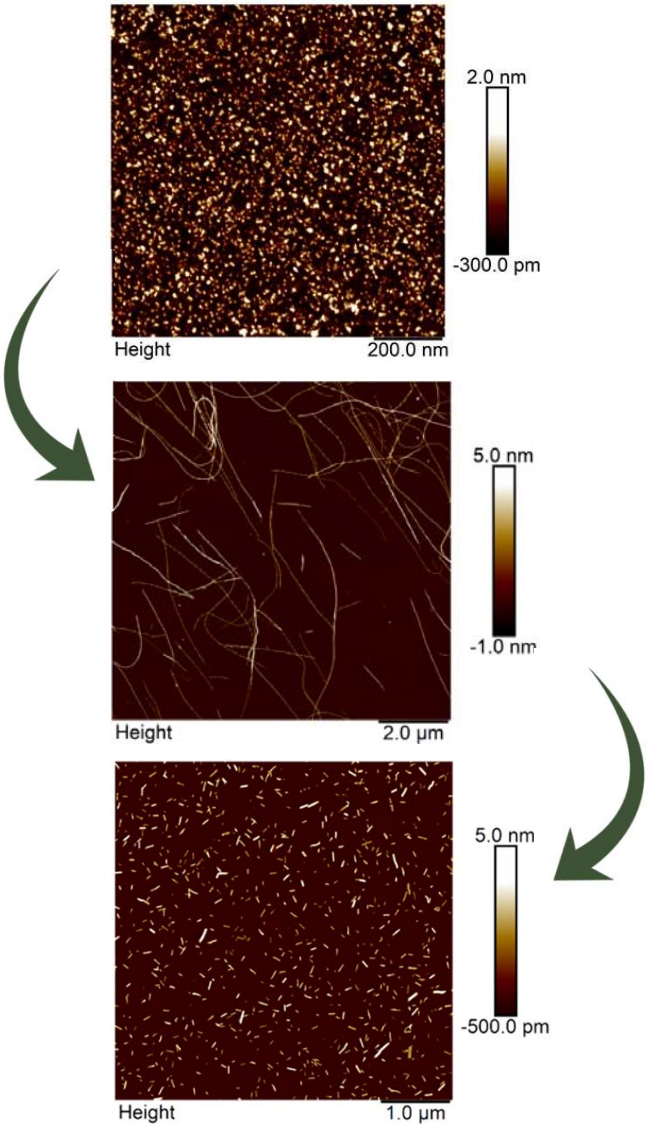




- Simple preparation (self-assembly)
- High strength
- High surface charge density
- Broad-spectrum antibacterial activity

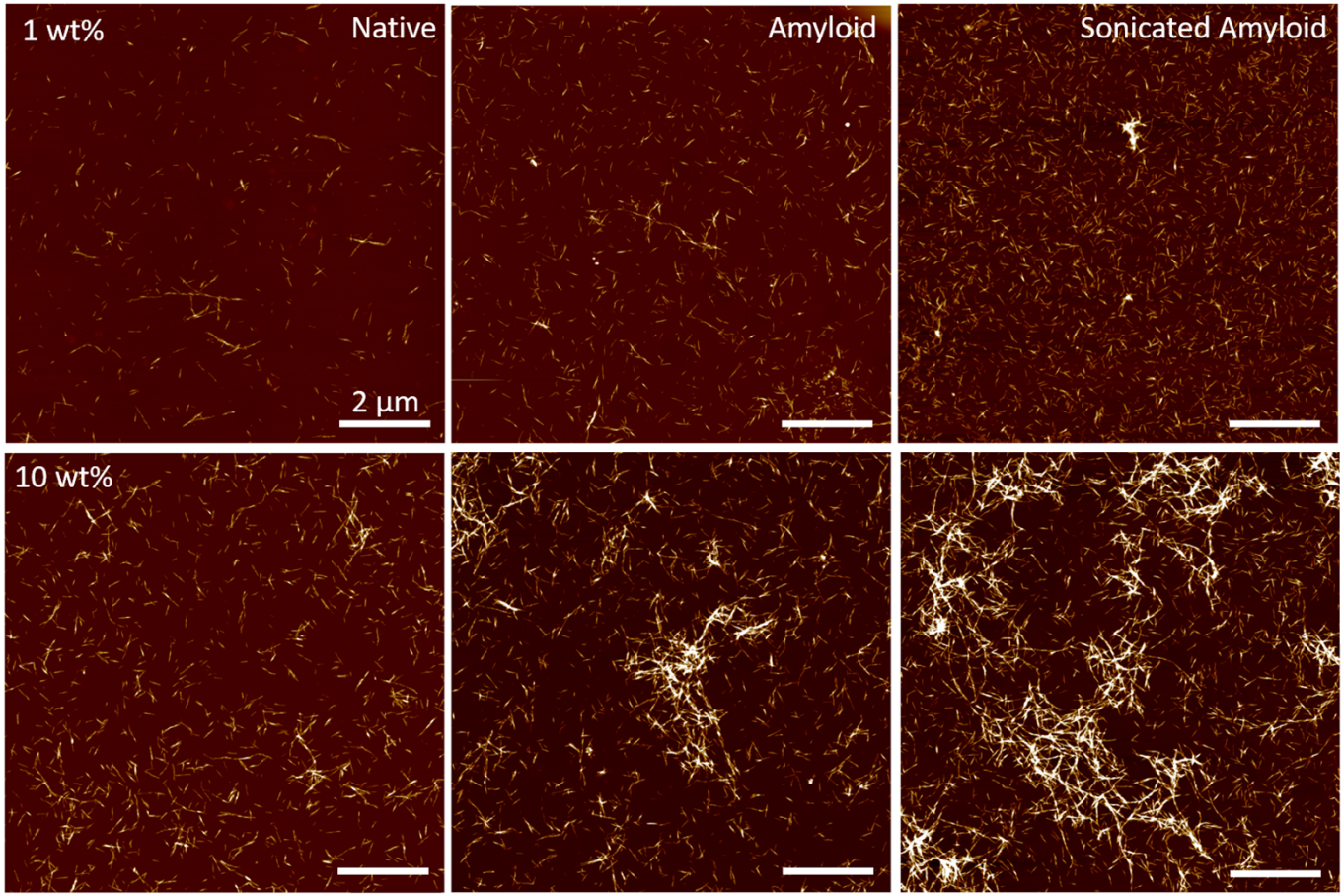
Project Goals

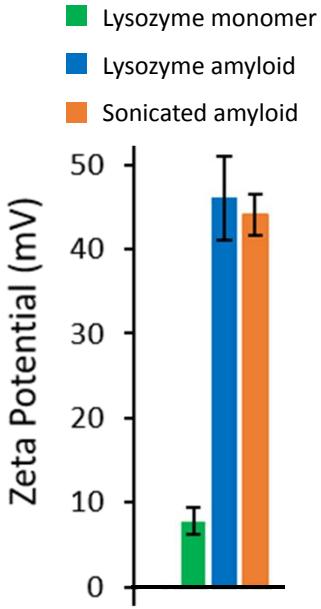




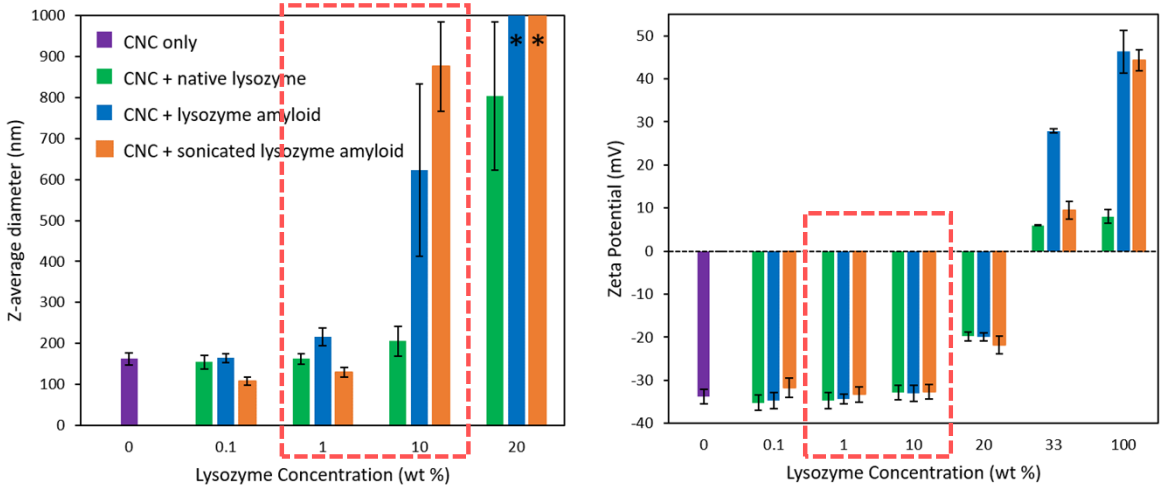
- ✓ Structural morphology
- ✓ Optical properties
- ✓ Mechanical strength
- ✓ Antibacterial activity

Structural Morphology



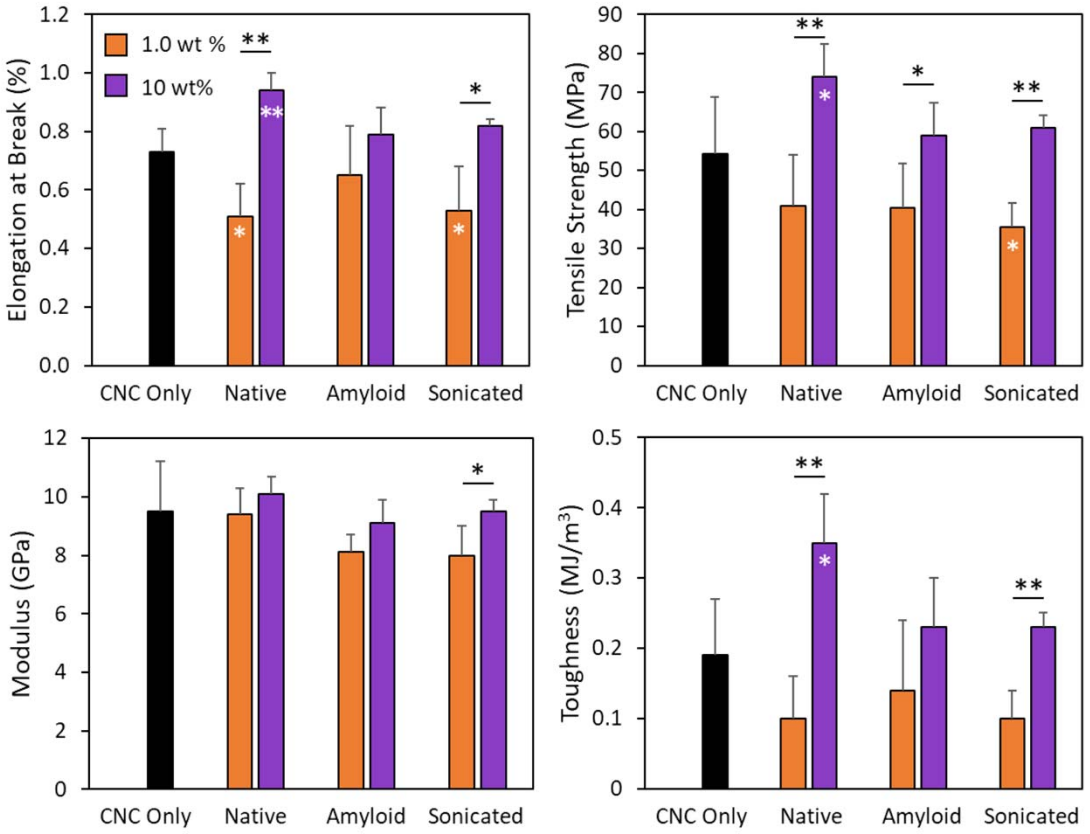


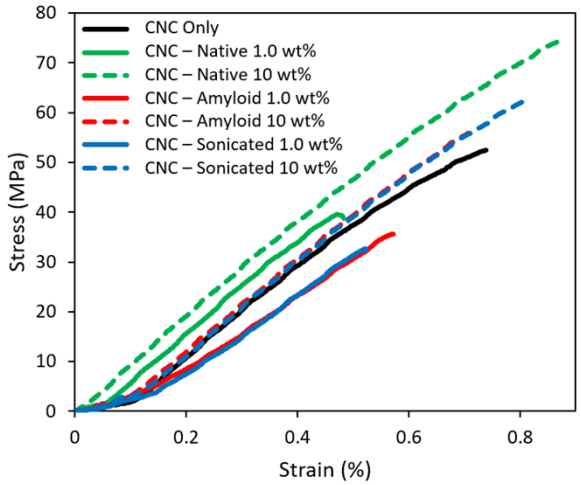
Optical Properties



- Increased charge screening, & formation of local (-ve charged) aggregates → follows trend for anionic polymer addition
- Enhanced steric and surface charge effects of amyloids
  → larger aggregates, and quicker loss of chiral nematic structure

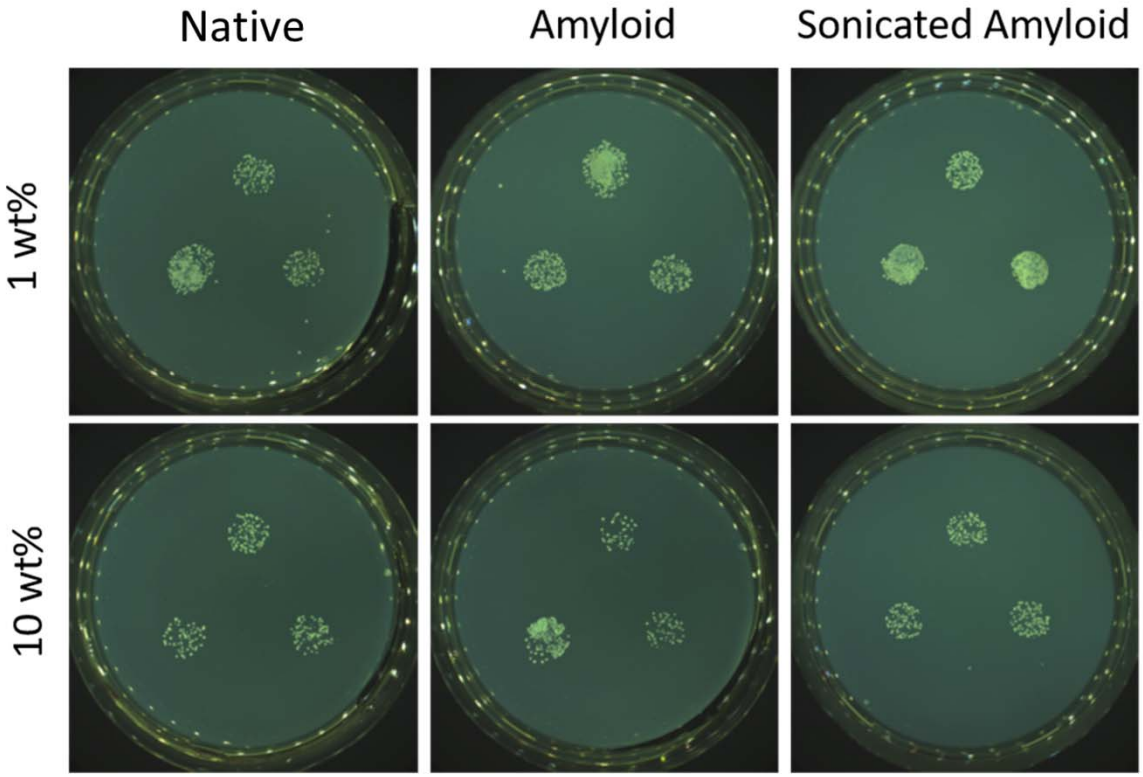
Mechanical Strength





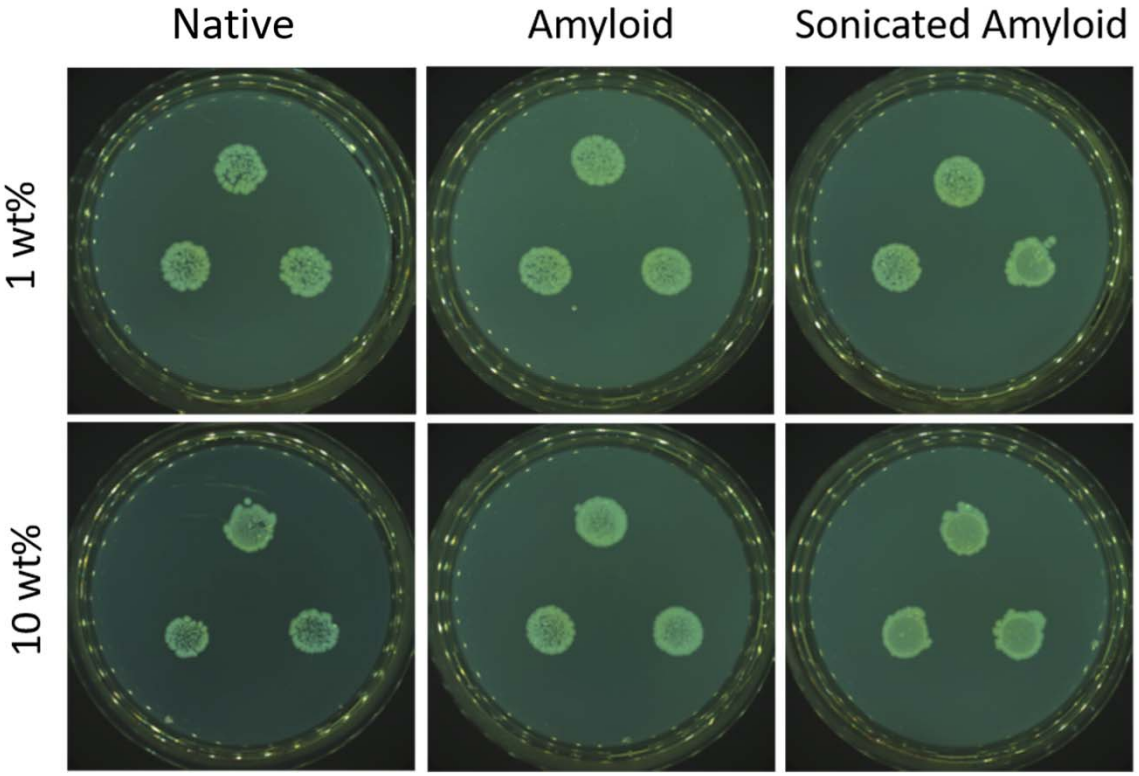
- Linear stress-strain response (no inelastic deformation → brittle
- 1 wt% → some aggregation, disrupting chiral nematic structure
- 10 wt% → complete loss of CN structure, decreased 'defects'

Antibacterial Activity: *S. aureus* (Gram +)

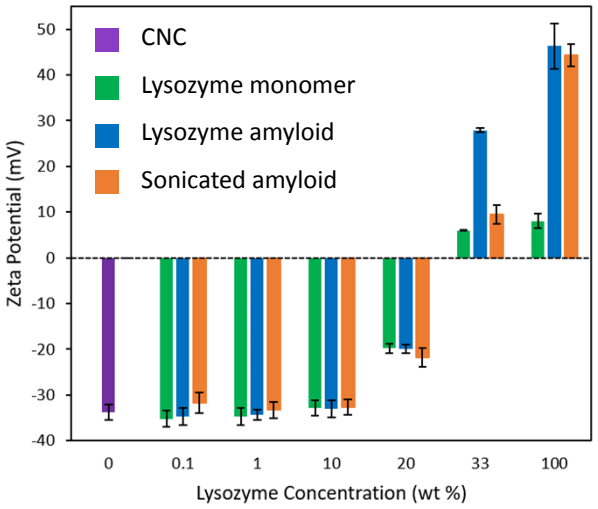


- Native lysozyme has enzymatic activity against Gram +ve bacteria
- Lysozyme amyloids are not enzymatically active
- Concentration-dependent antibacterial activity in all cases

Antibacterial Activity: *E. coli* (Gram -)



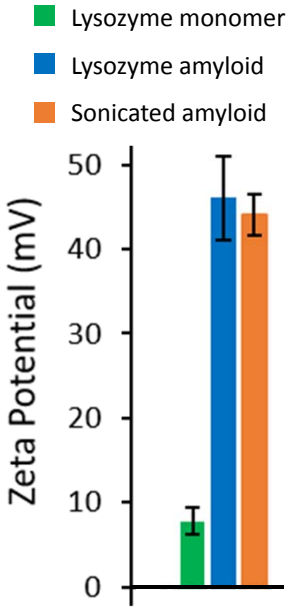
- No significant antibacterial activity
- Amyloid antibacterial activity thought to be contact mediated (+ve surface charge)

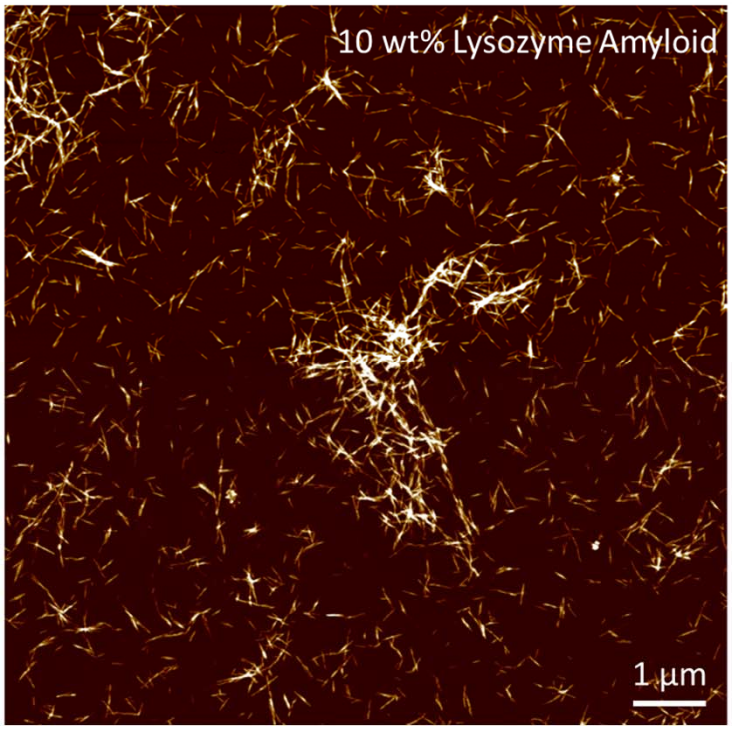


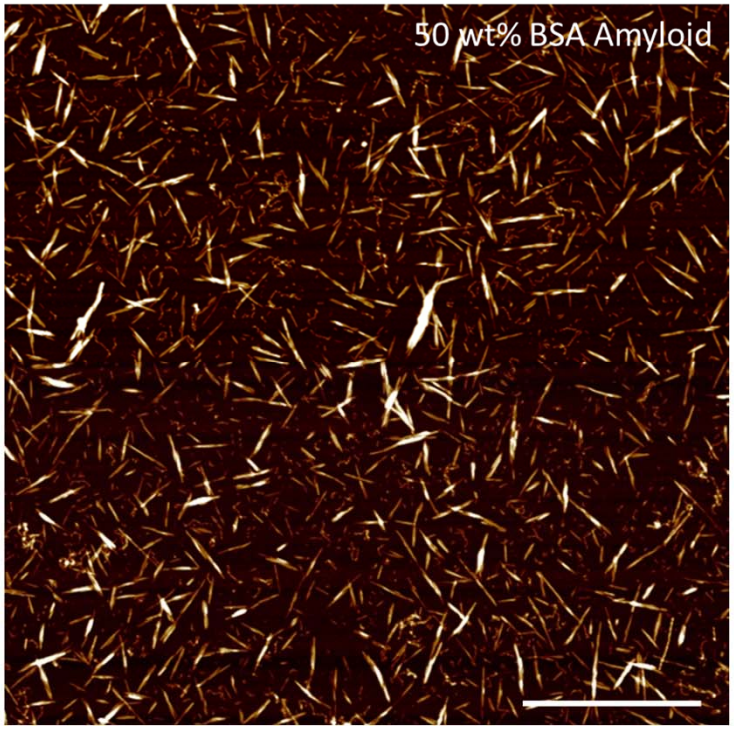
Conclusions & Outlook

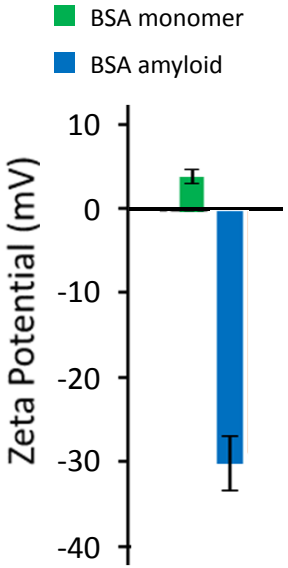
- Chiral nematic structure maintained at low lysozyme loadings
- Charge screening and local aggregation leads to blue shifting
- Increased size & surface charge density of amyloids …
  - → increased aggregation
  - → increased disruption of chiral nematic ordering
- Improvement in film mechanics at high (10 wt%) lysozyme loading
- Concentration-dependent antibacterial activity against *S. aureus*
- Investigate the incorporation of BSA amyloids into CNC films

Lysozyme vs BSA Amyloids









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