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Structure-property relations of highly ordered bio-nanocomposites

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Structure-property relations of Highly ordered Bio-nanocomposites

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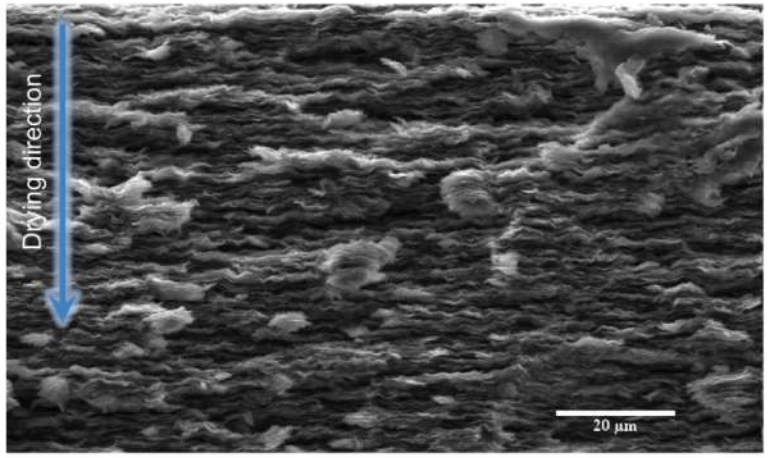
Conference: Nature-Inspired Engineering

TU Delft

Outline

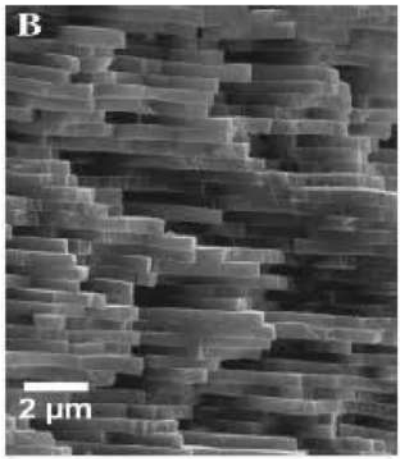
- Highly ordered bio-nanocomposites
- Ordering by affine deformation
- Experiments with thermo-reversible gels
- Film casting
- Morphology and mechanical analysis
- Discussion
- Conclusions



Introduction

Nature-inspired advanced materials

- Nacre: brick-and-mortar



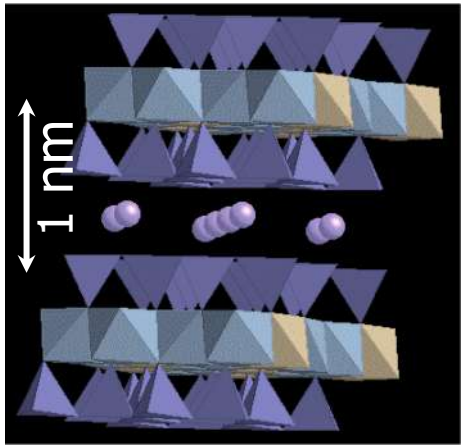
Start-of-the-art bio-nanocomposites

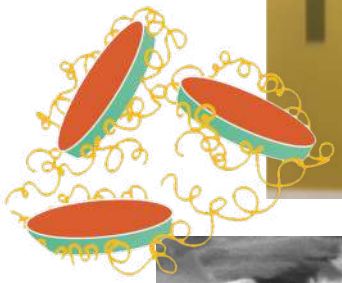
- High strength and toughness, lightweight

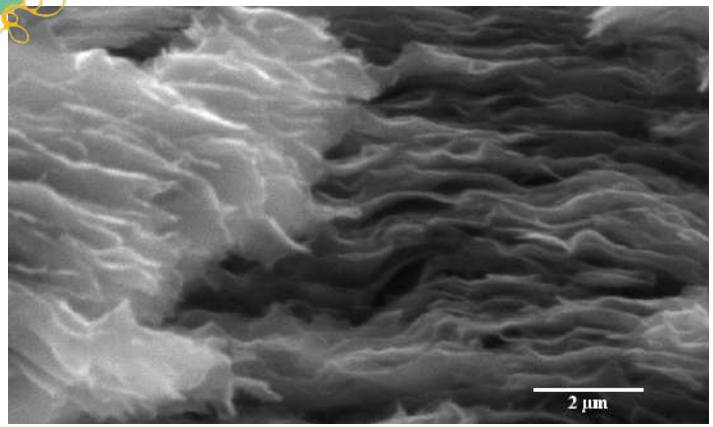
Montmorillonite bio-nanocomposites

- High clay content
- Enhanced properties
  - Mechanical
  - Transport
  - Flame-retardant

Alginate-MMT



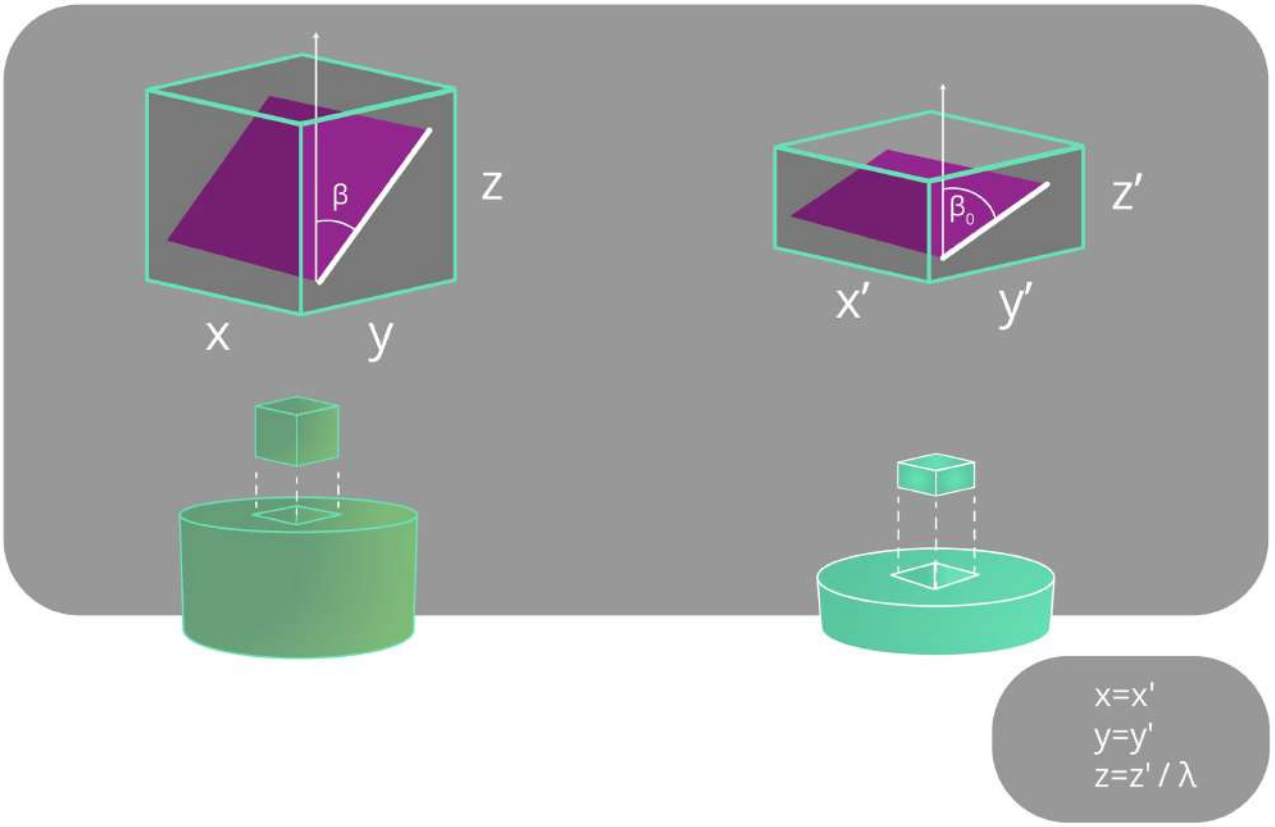




Affine deformation

Concentration of “immobilization” due to yield stress

Local deformation = global deformation



Orientation of nanoparticles

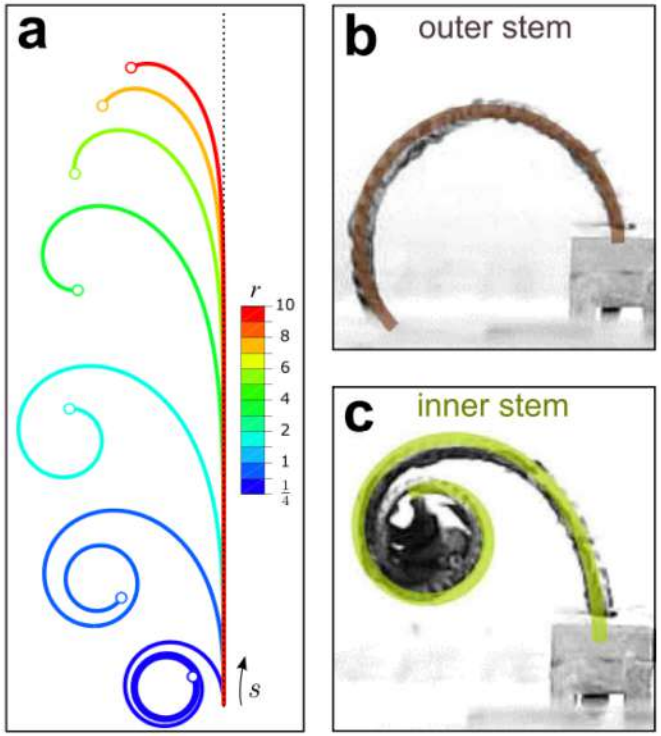
- Assume affine deformation

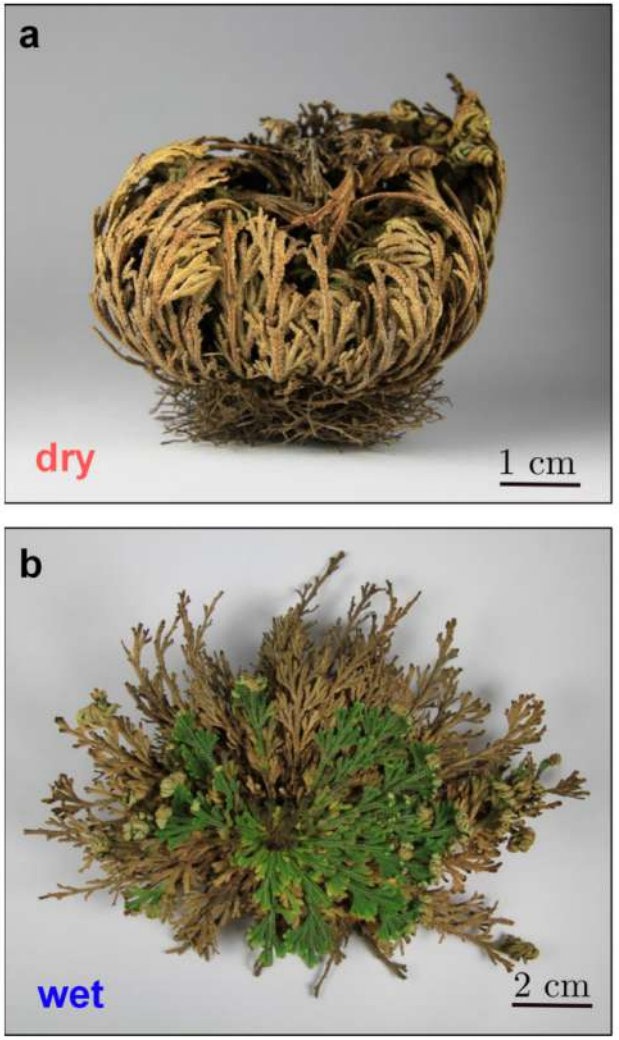
- Higher ordering by better immobilizing nanoparticles (MMT)?
  - Gelled matrix: less stacking = higher aspect ratio

exfoliated

(De)hydration of plants

- Plasticization (water)
- **Orientation**
- Shape change

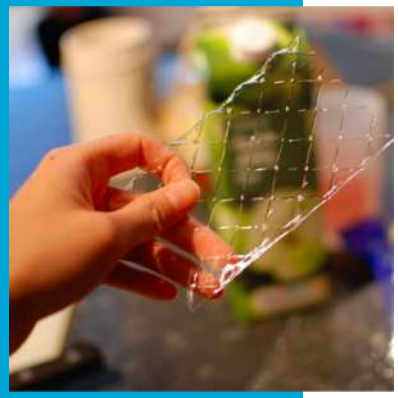


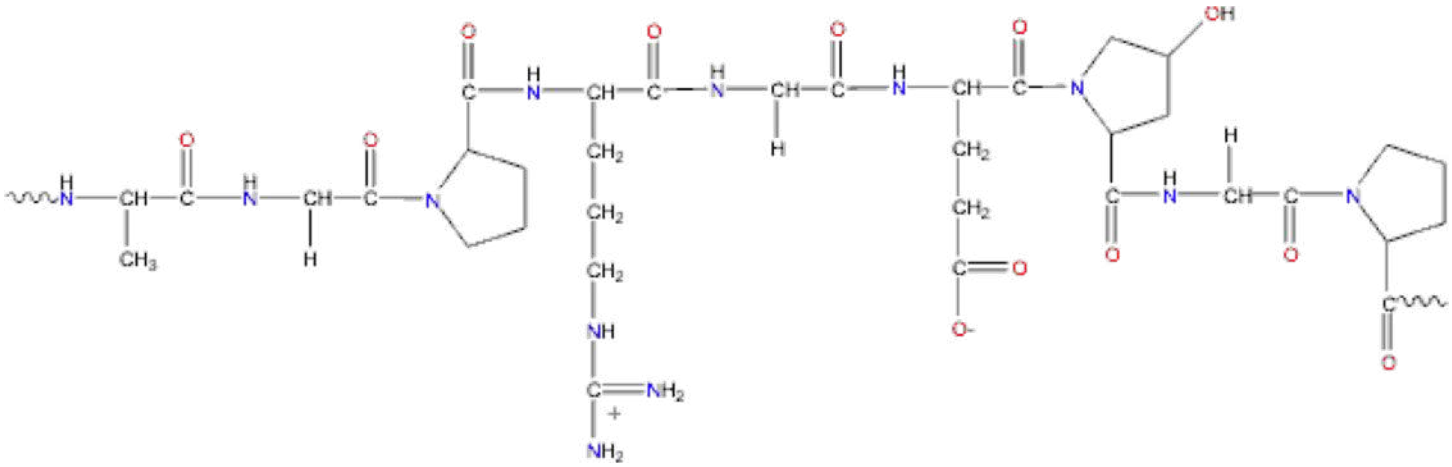


Rafsanjani, A. et al. (2005)

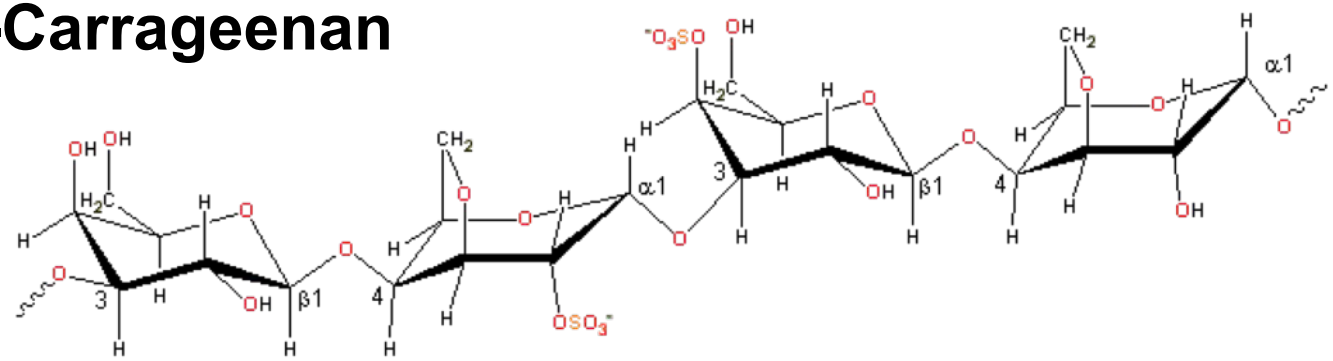
Thermo-reversible gels

Gelatin



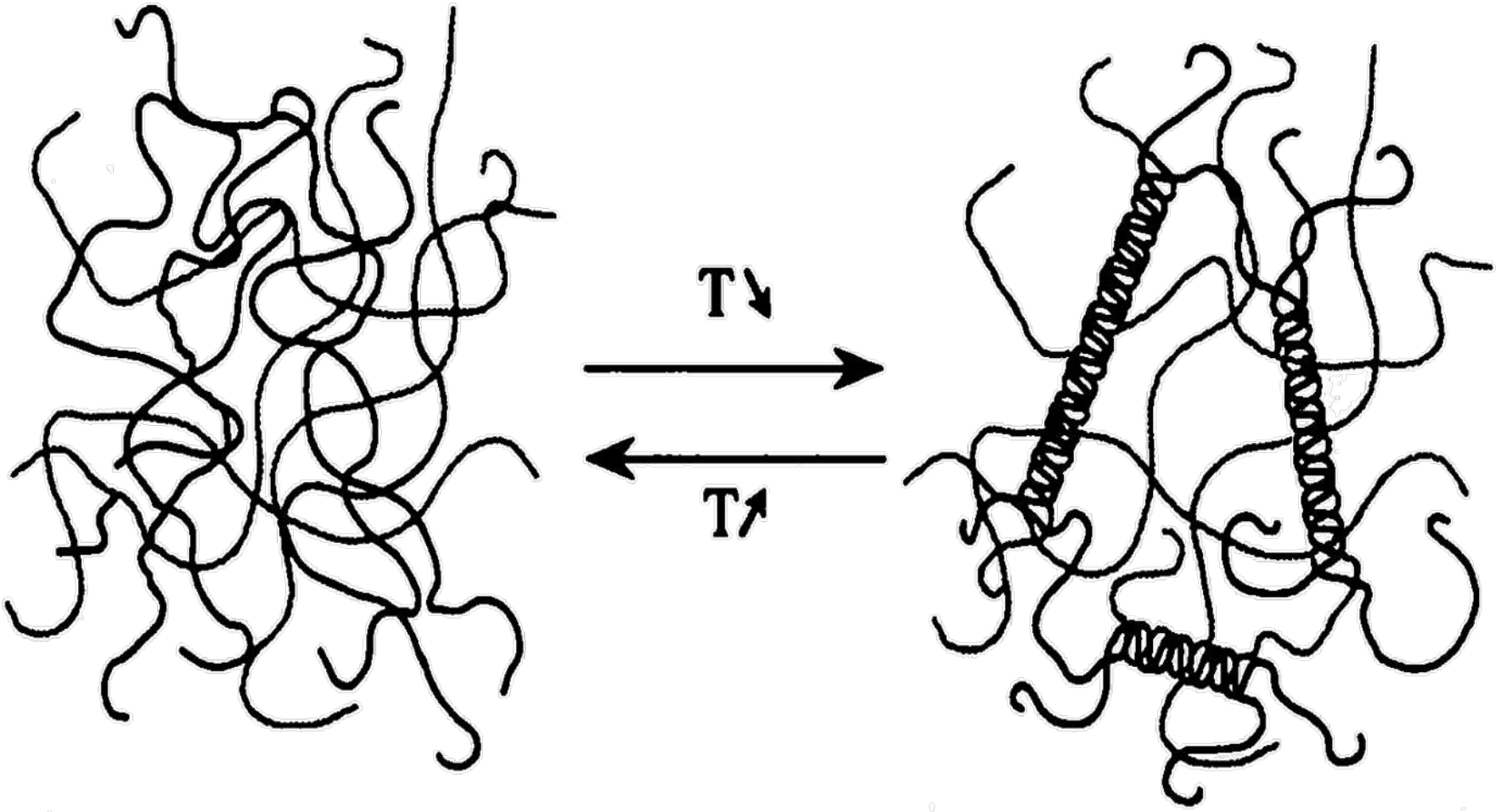


κ-Carrageenan



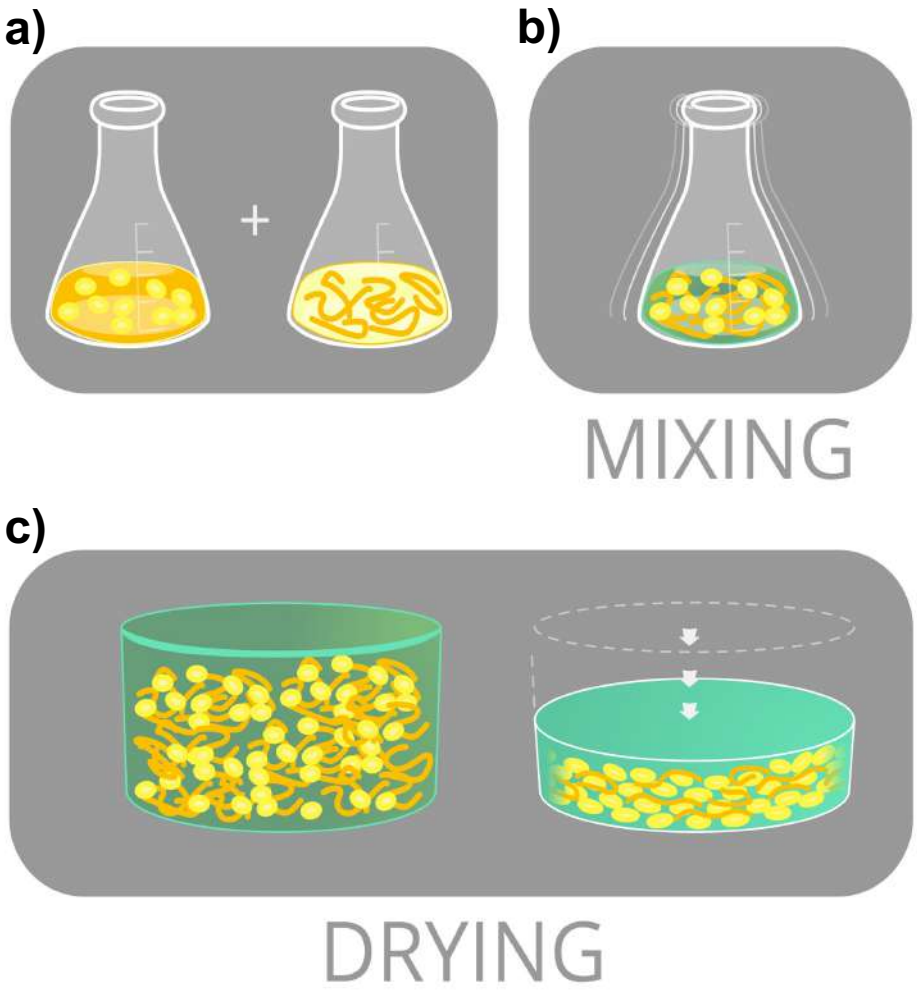
Early gelation!

Thermo-reversible gels



Early gelation!

Materials and methods



a) Solutions

Gelatin (Type A)

κ-Carrageenan

MMT (⇧ shear, 24h)

b) Suspensions

0 - 80 wt.% MMT

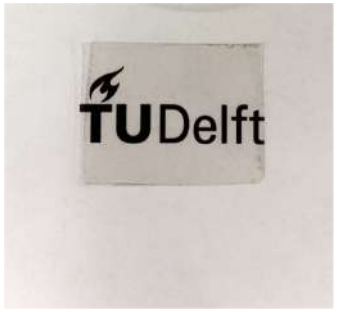
High shear for ≥4h

c) Solvent casting

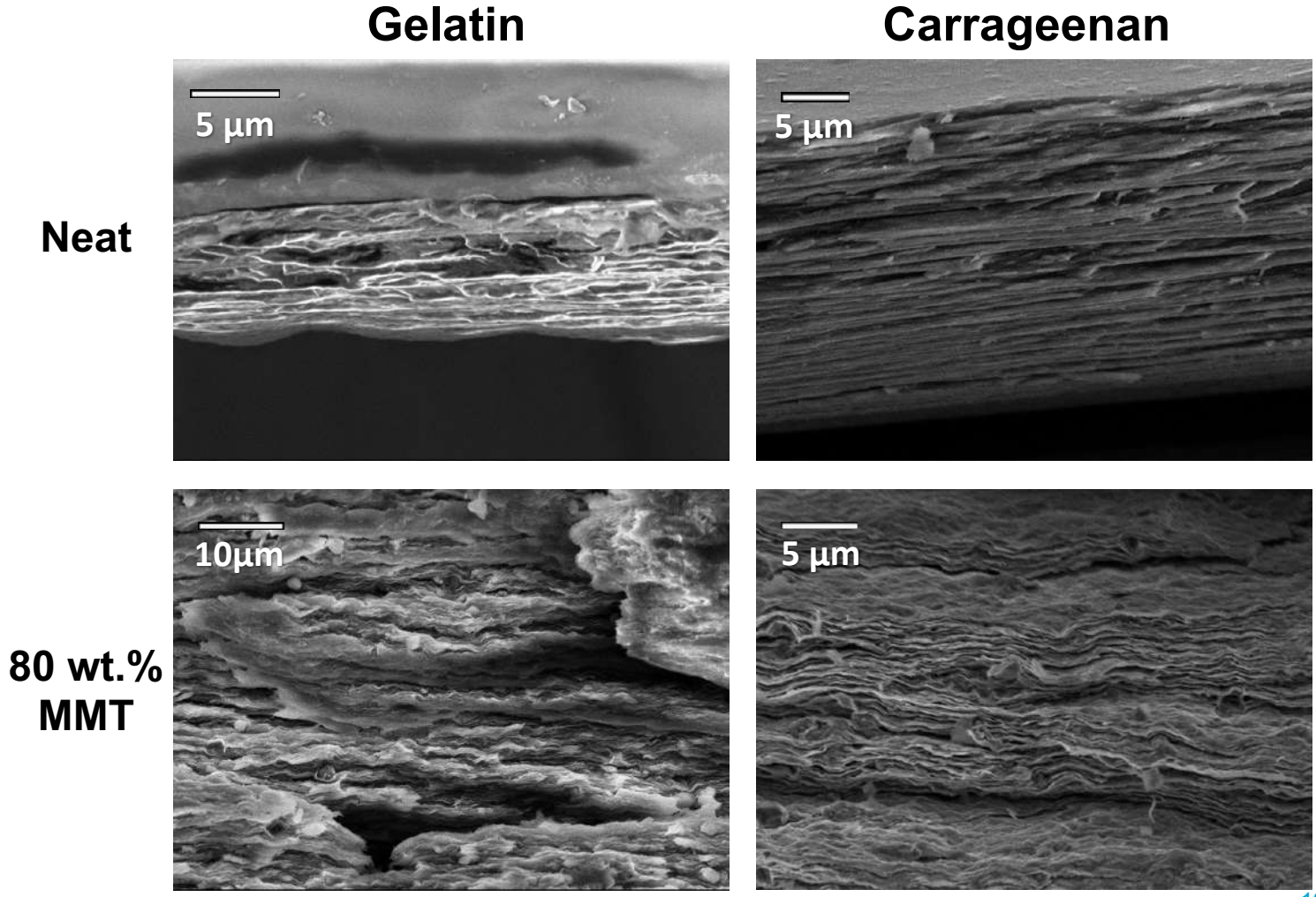
Ambient drying

4 days

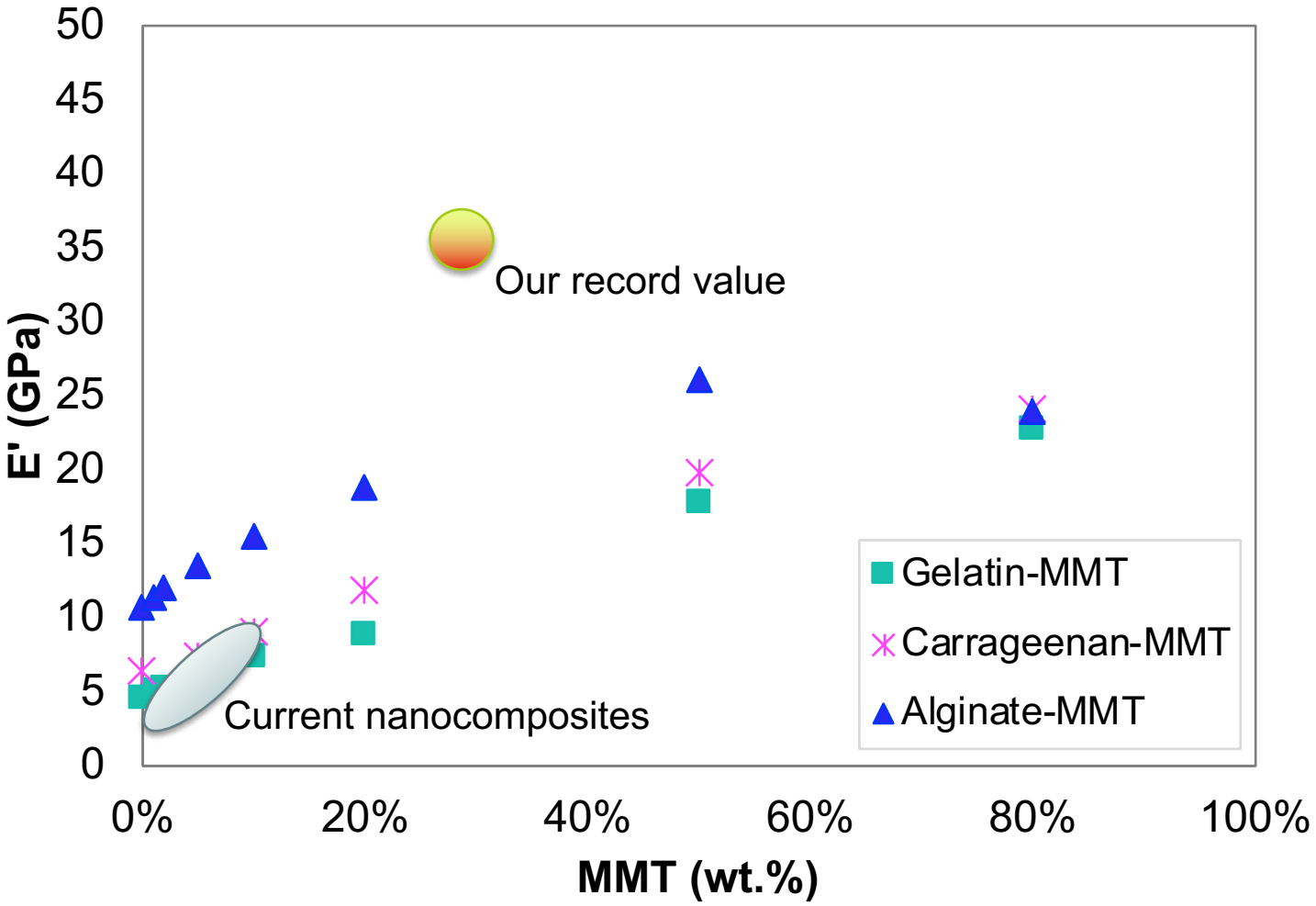
Films

	0% MMT	20% MMT	80% MMT
Gelatin			
Carrageenan			
Alginate			

Scanning Electron Microscopy



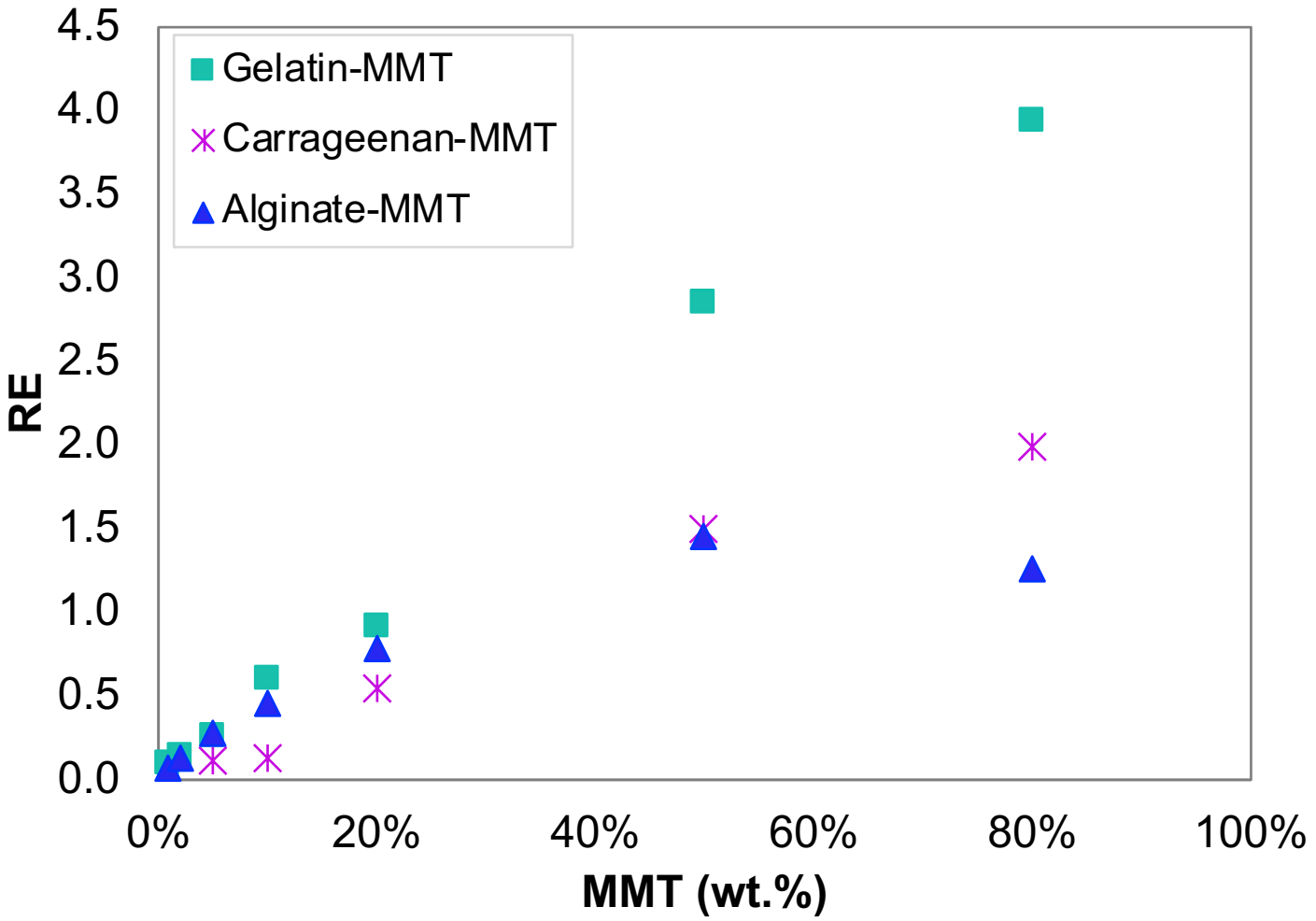
Dynamic Mechanical Analysis



Alginate-MMT: Zlopaša, J. (2017)

Reinforcement efficiency

$$RE = \frac{Ec - Em}{Em}$$



Alginate-MMT: Zlopaša, J. (2017)

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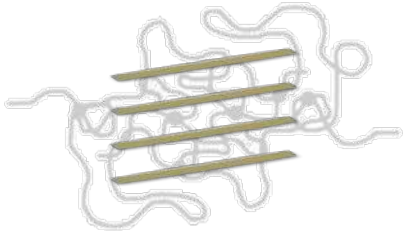
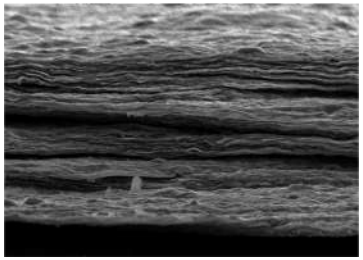
Conclusions

Highly ordered composites of gelatin- and carrageenan-MMT:

- Easily fabricated
- **Remarkably high inorganic fractions, up to 80 wt.%**
- Thermo-reversible gels:

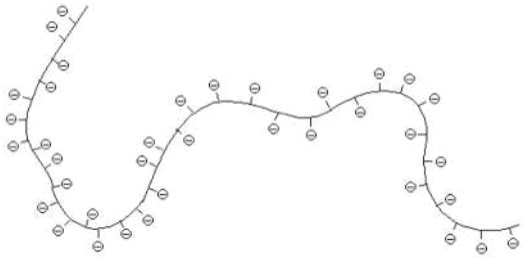
  high clay orientation through affine deformation!
- **High storage modulus**, up to 24 GPa
- Continued **reinforcement efficiency at ⇧high clay** content





Nature-inspired bio-nanocomposites with ultimate properties

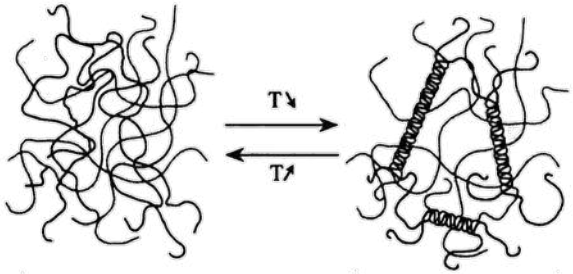
1) **Charged biopolymers**: higher stiffness than man-made polymers



and...

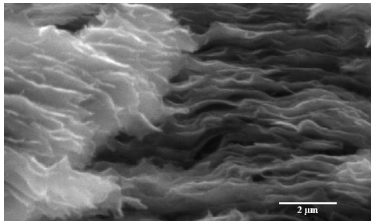
2) Orientation/anisotropy:

higher due to **earlier immobilisation!**



Gelation: Reduce stacking =

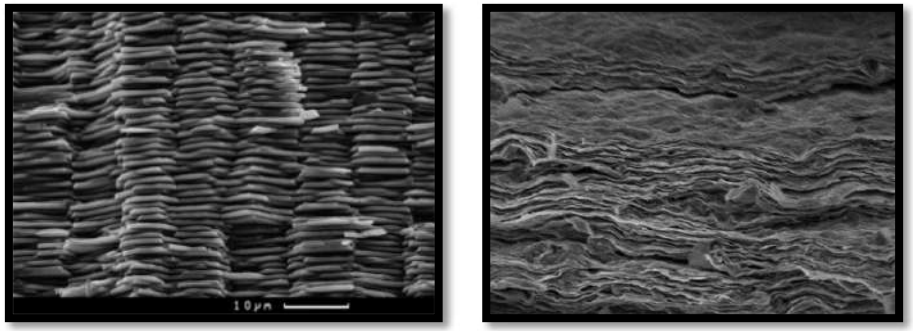
Increase effective aspect ratio



Recipe could lead to **ultimate properties**:

Modulus as high as **35 to 40 GPa** could be achieved

QUESTIONS?



Thank you!

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APPLIED SCIENCES

Chemical Engineering
Advanced Soft Matter

Biotechnology
Environmental Biotechnology

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[1] Fornes, T. D., & Paul, D. R. (2003). *Polymer*, *44*(17), 4993–5013. DOI: 10.1016/S0032-3861(03)00471-3

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[5] Rafsanjani, A., Brulé, V., Western, T. L. & Pasini (2015), *Sci. Rep.* **5**, 8064.