

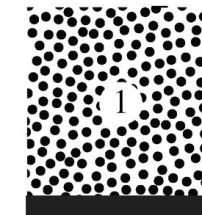
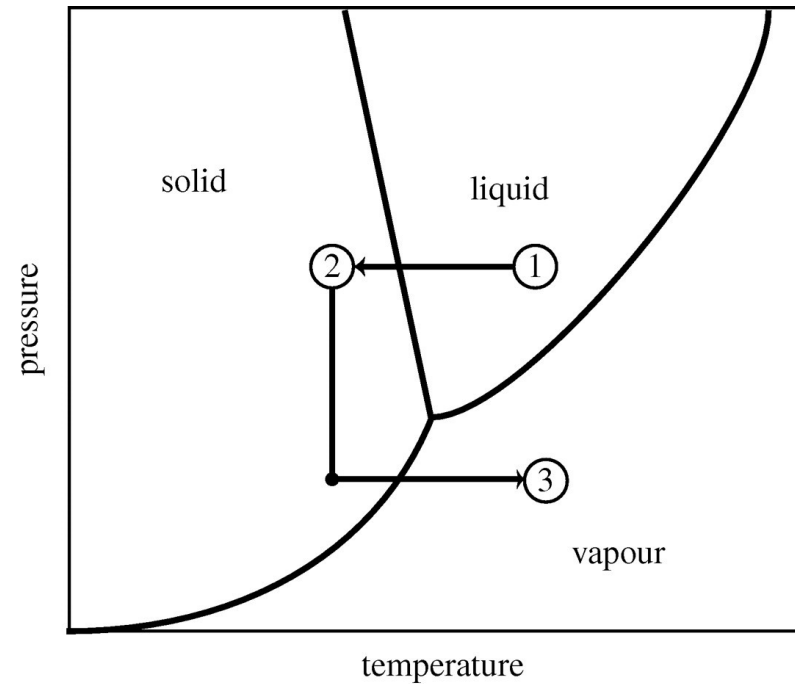
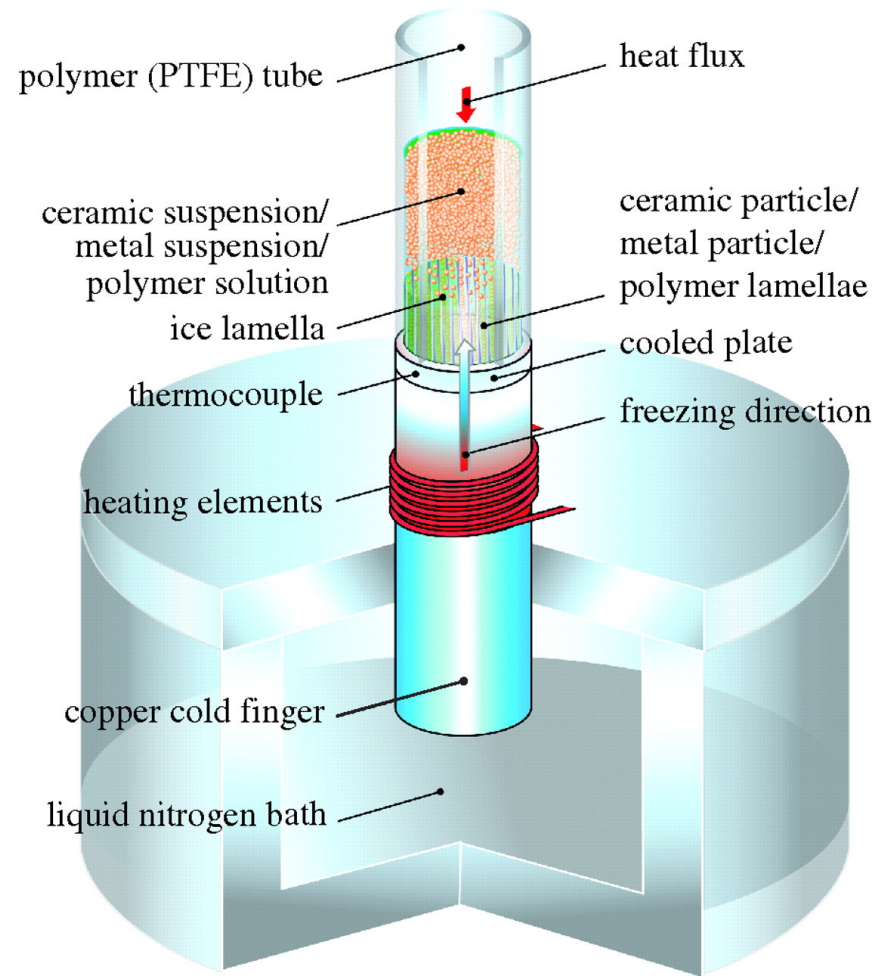
Experimental Observations of Mechanisms of Pattern Formation during Freeze Casting

Kaiyang Yin¹, ***Kaihua Ji***¹,
Louise Strutzenberg², ***Rohit Trivedi***³,
Alain Karma¹, ***Ulrike G.K. Wegst***¹

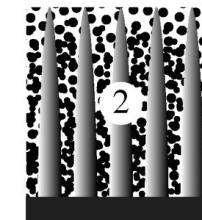
1. Northeastern University, MA, USA
2. NASA Marshall Space Flight Center
3. Iowa State University



Freeze Casting: Directional Solidification of Water-based Systems



polymer solution or ceramic slurry is poured into mould at room temperature

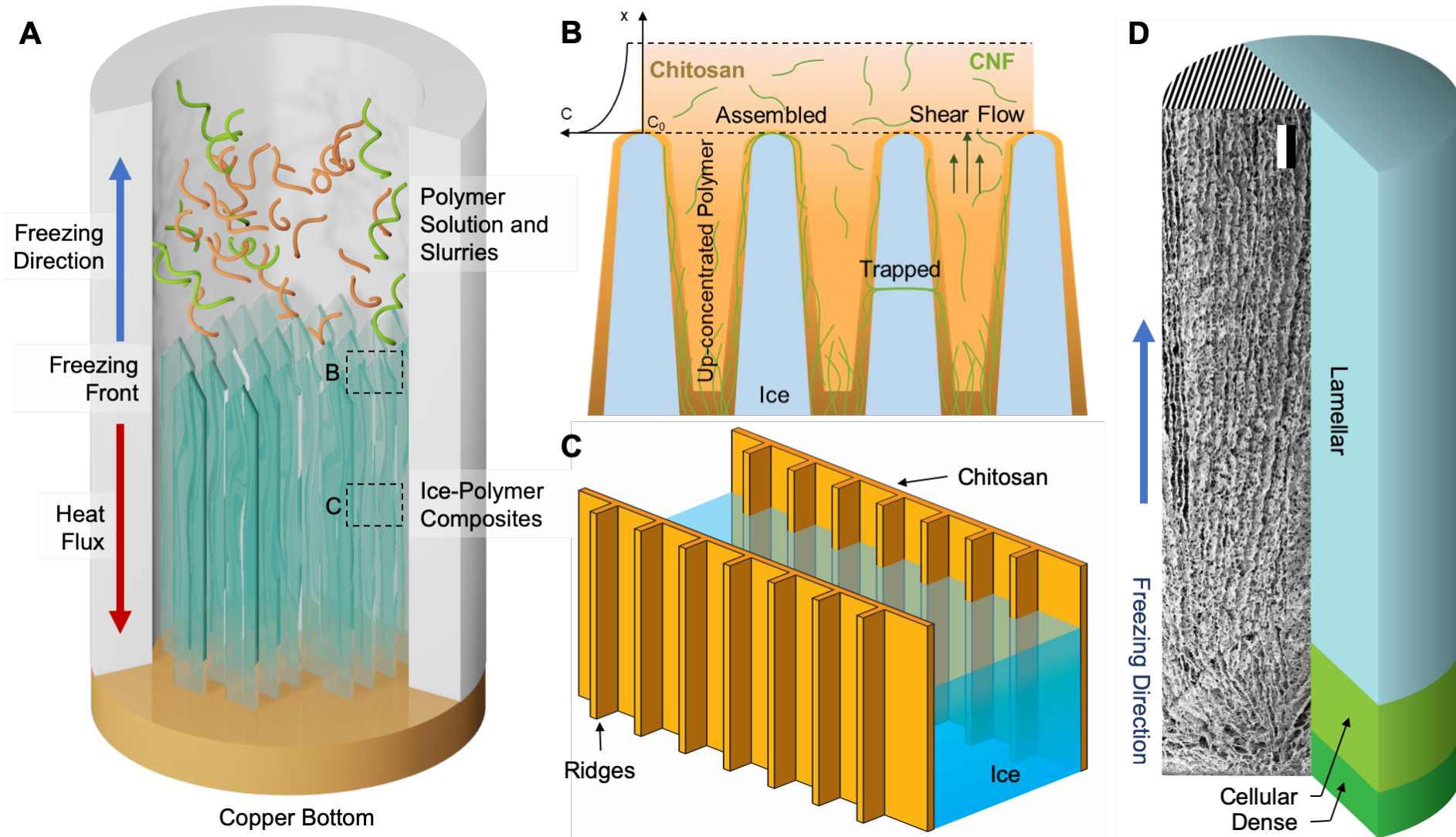


as ice lamellae grow, they force polymer molecules and suspended particles into voids



frozen structure is lyophilized, sublimating ice and generating porosity

Hierarchical Structure Formation during Freeze Casting

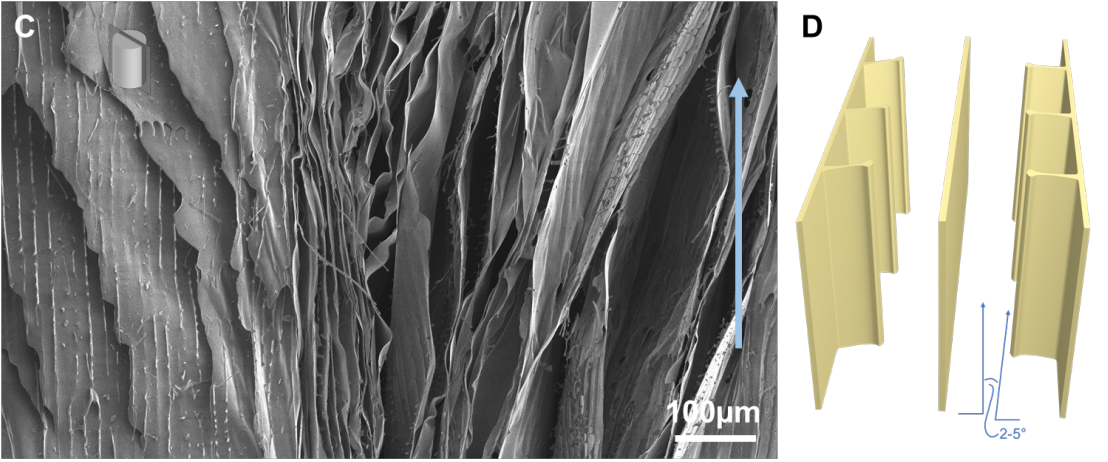
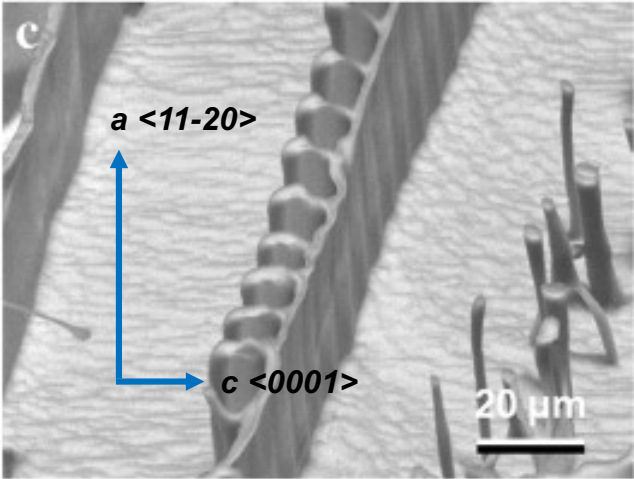
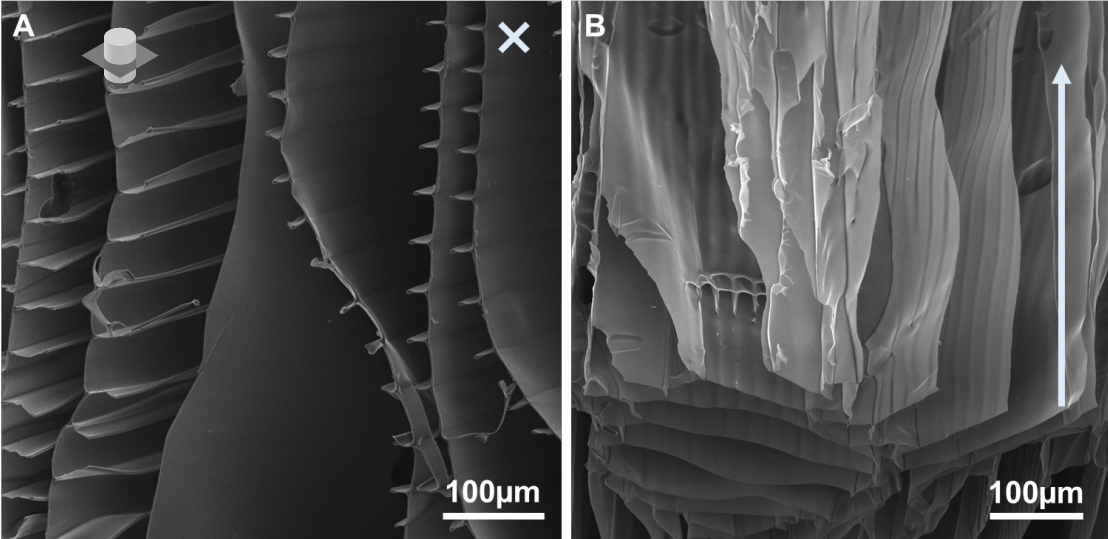
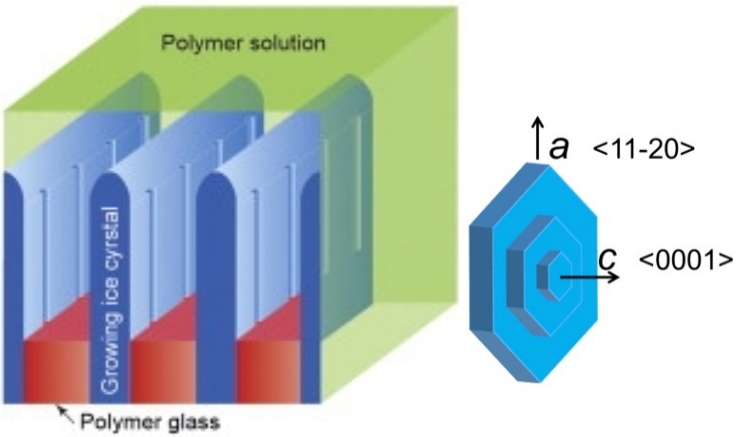


Yin, K., Divakar, P., Wegst, U.G.K., *Biomacromolecules*, 2019



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Instability Formation in Ice Crystal Growth



Donius et al., *Mater. Charact.*, 2014

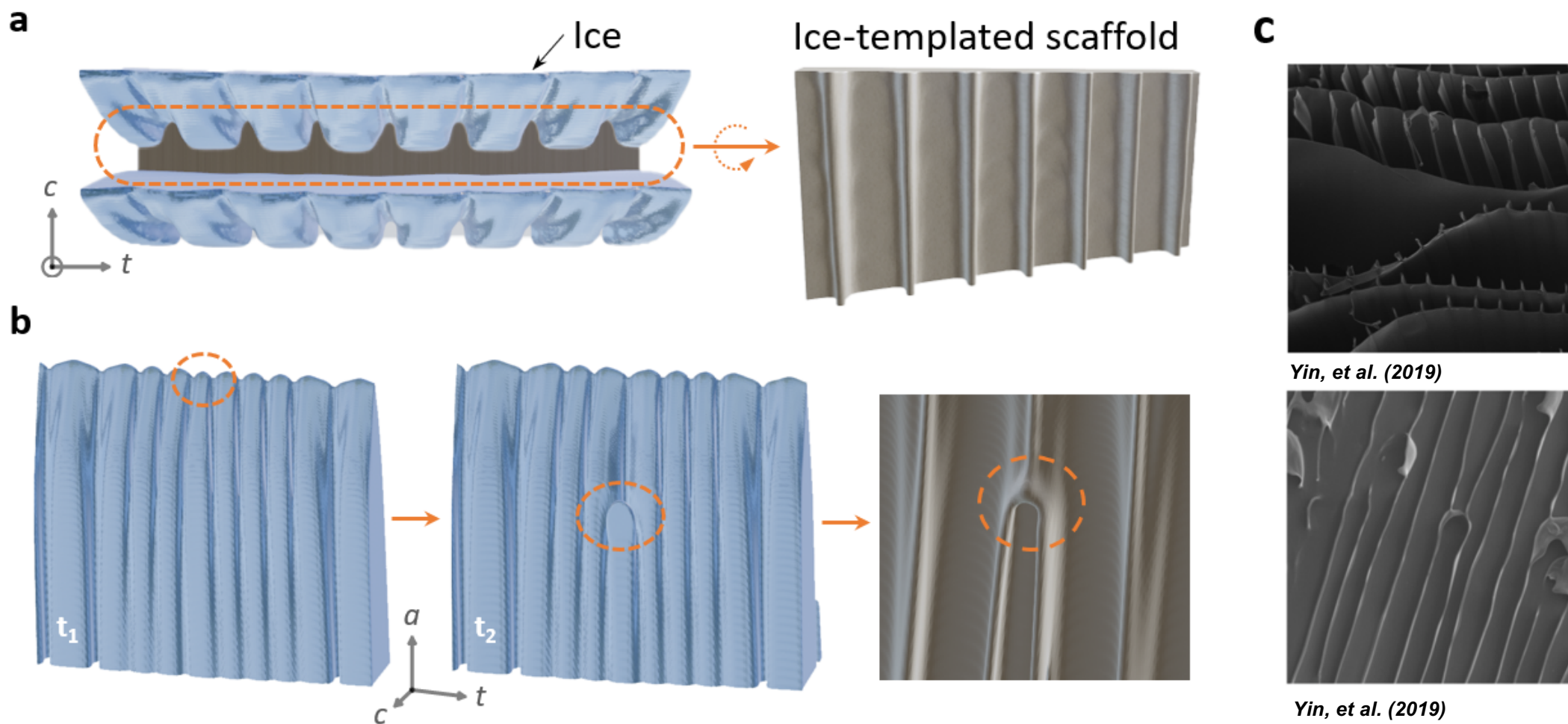
Yin, K., Ji, K., Strutzenberg, L., Trivedi, R., Karma, A., Wegst, U.G.K., in prep



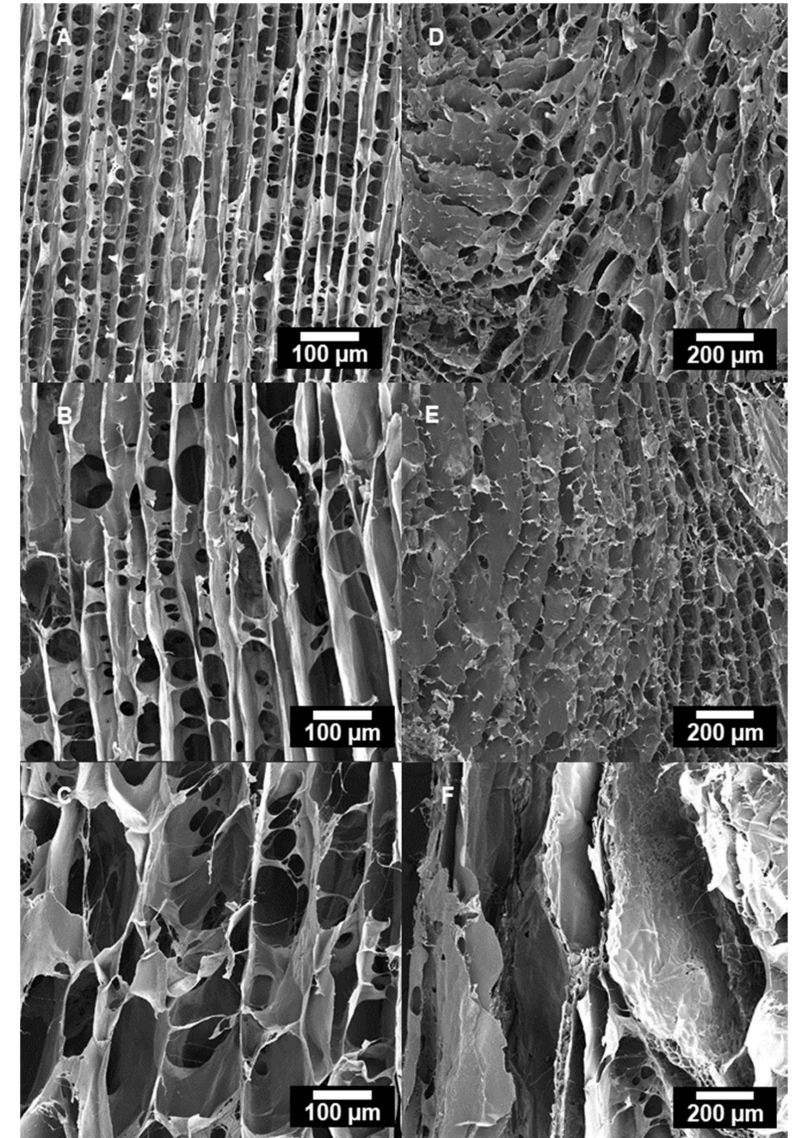
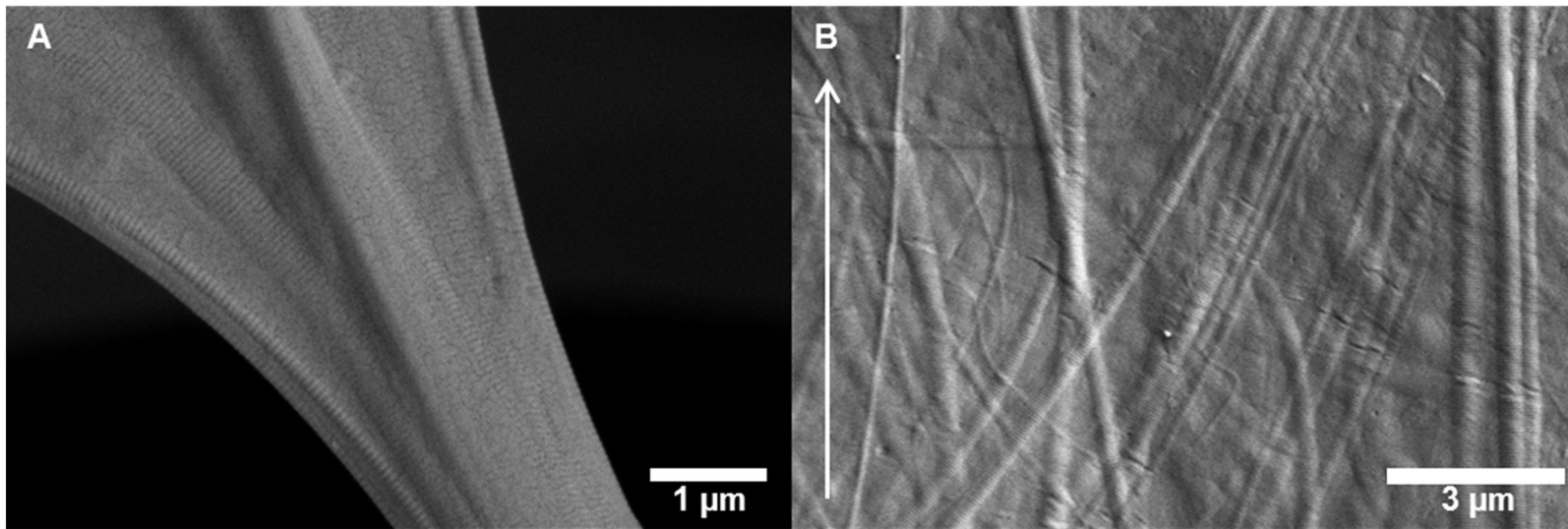
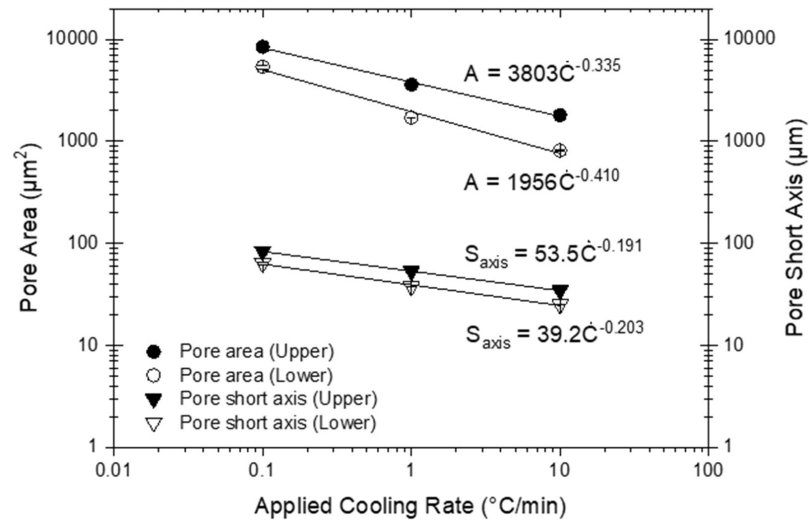
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Hierarchical pattern formation

3D phase-field simulations explain the formation of ridges and the single jellyfish



Structure-Processing Correlation in Freeze Cast Collagen Scaffolds

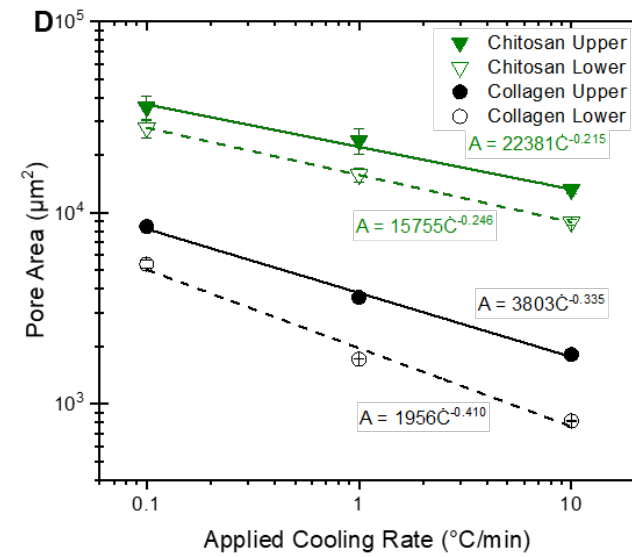
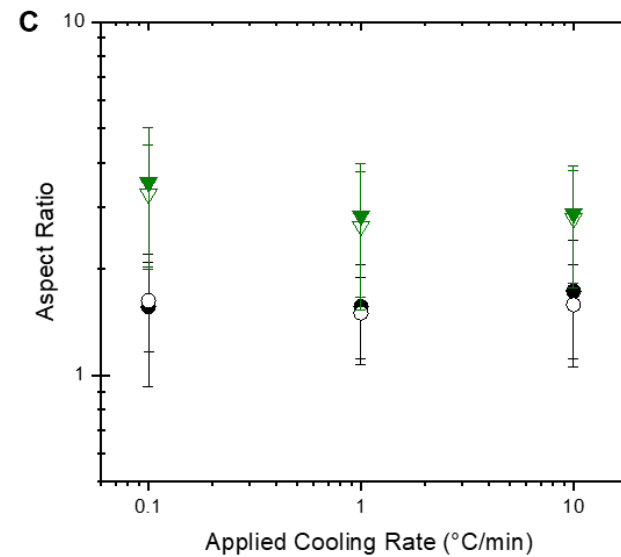
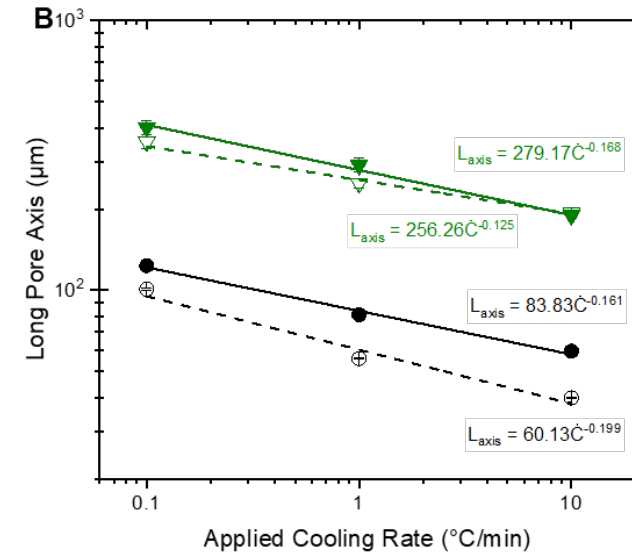
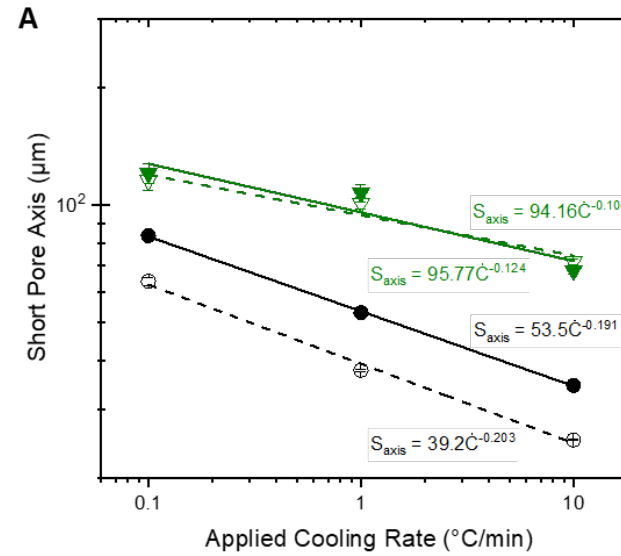
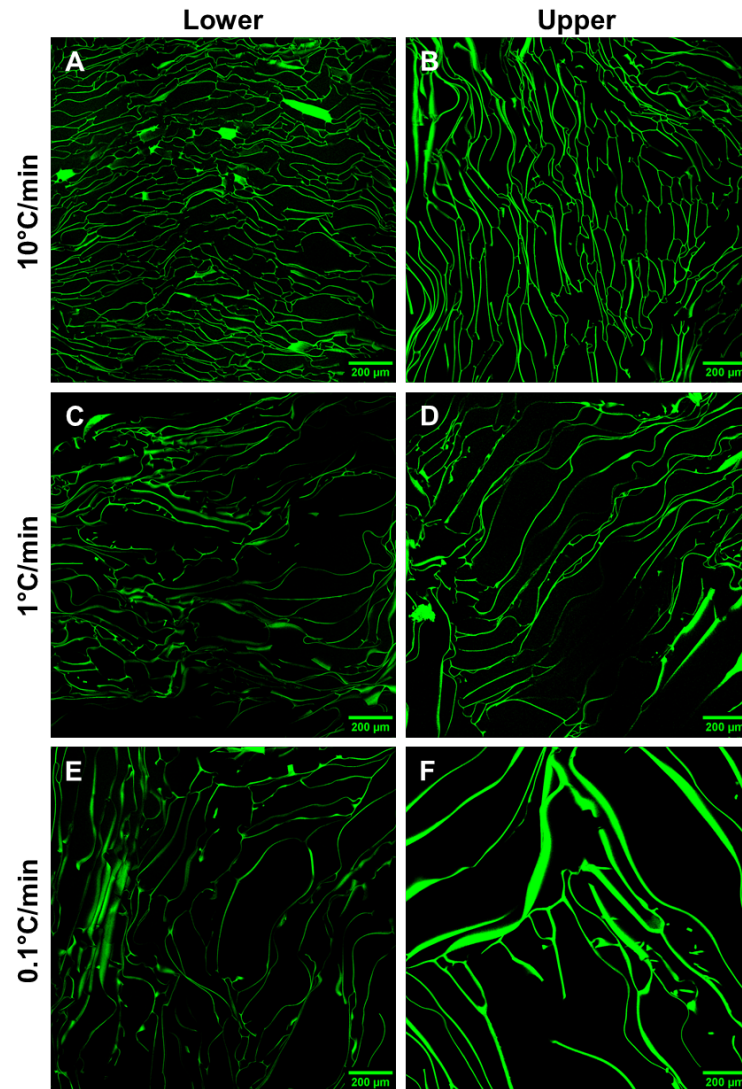


Divakar, P., Yin, K., Wegst, U.G.K. *JMBBM*, 2019



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Structure-Processing Correlation in Freeze Cast Chitosan Scaffolds



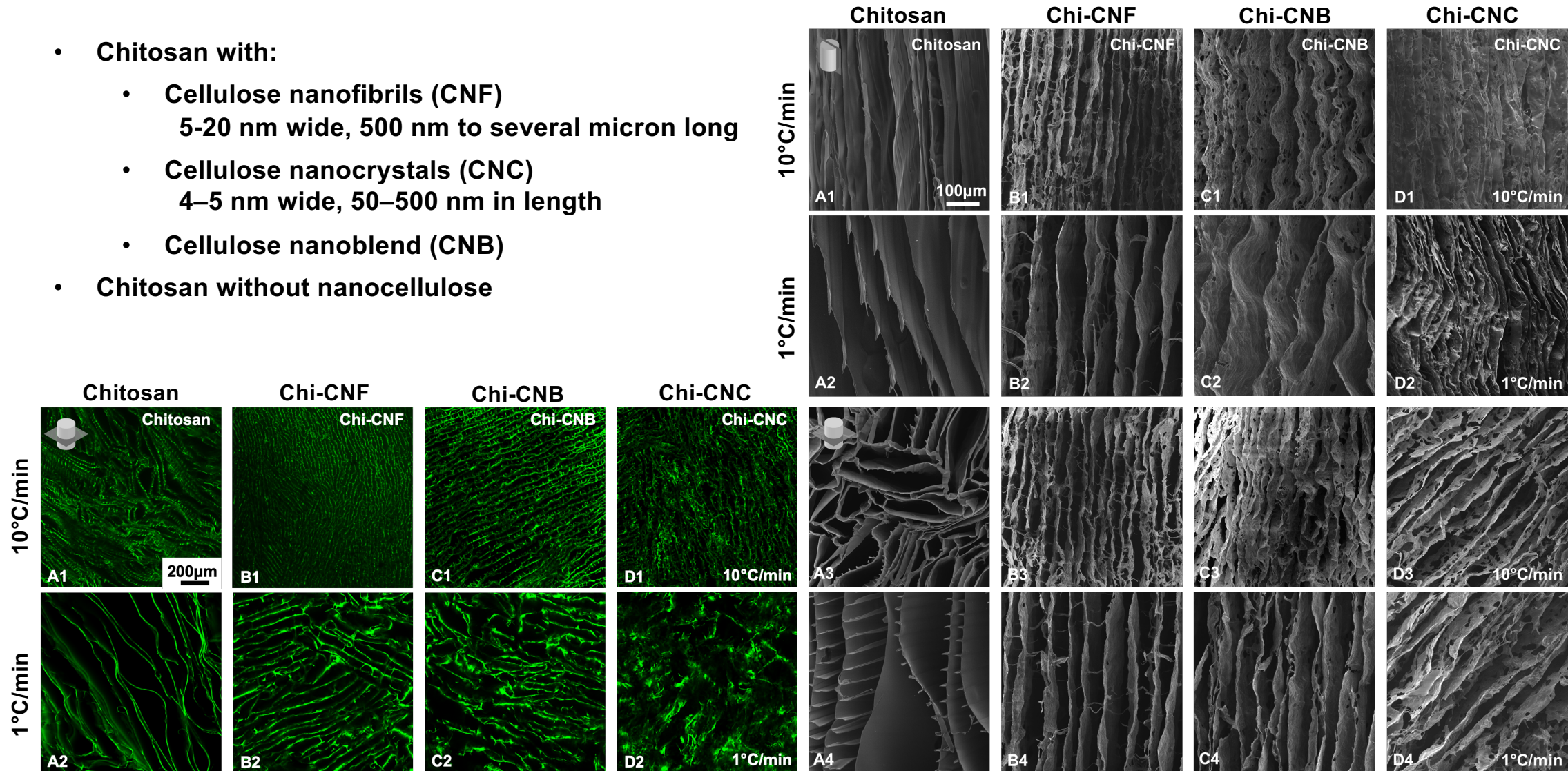
Yin, K., Divakar, P., Wegst, U.G.K. *in prep*



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Effects on the Mechanical Performance of Chitosan-Nanocellulose Composites

- Chitosan with:
 - Cellulose nanofibrils (CNF)
5-20 nm wide, 500 nm to several micron long
 - Cellulose nanocrystals (CNC)
4-5 nm wide, 50-500 nm in length
 - Cellulose nanoblend (CNB)
- Chitosan without nanocellulose

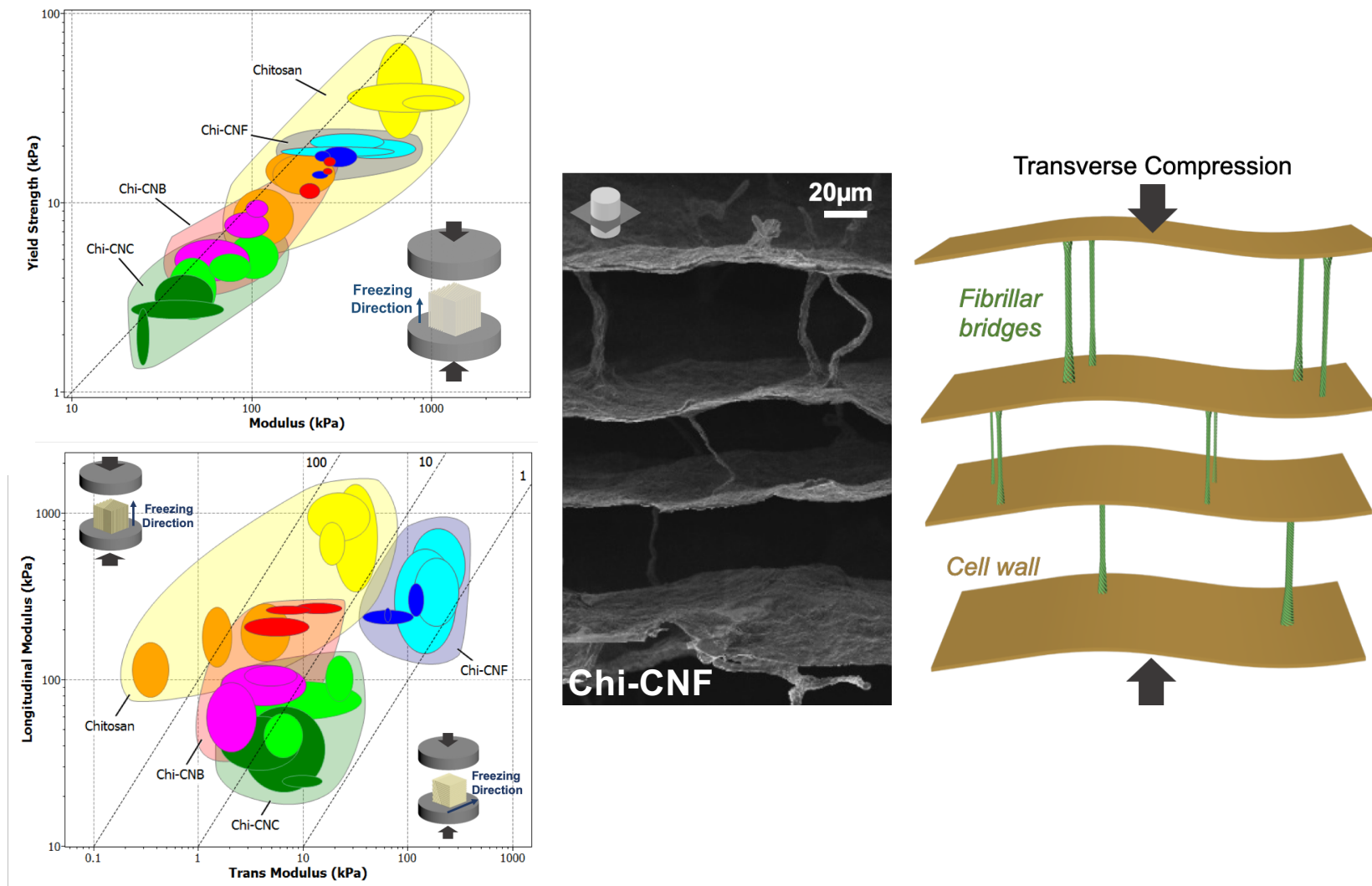


Yin, K., Divakar, P., Wegst, U.G.K. *Biomacromolecules*, 2019



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Effects on the Mechanical Performance of Chitosan-Nanocellulose Composites



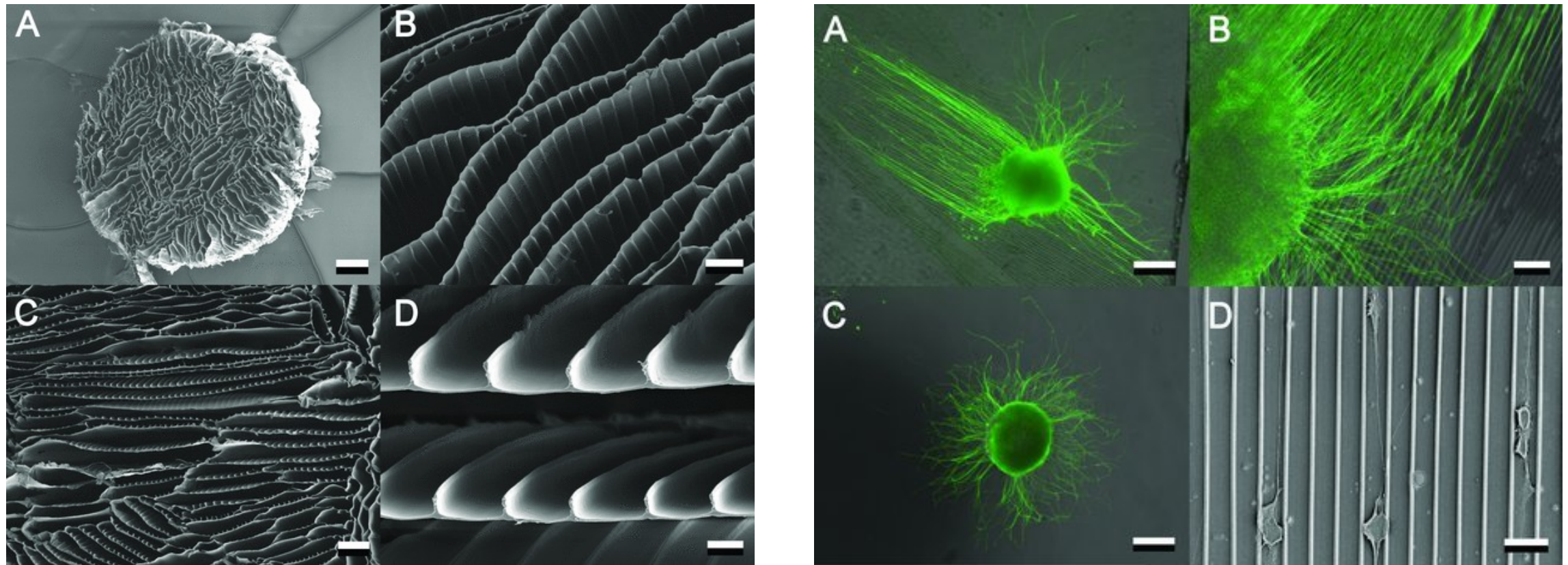
Yin, K., Divakar, P., Wegst, U.G.K. *Biomacromolecules*, 2019



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Structural Features in Freeze Cast Polymer Scaffolds

Effect on Performance of Freeze Cast Scaffolds for Peripheral Nerve Repair

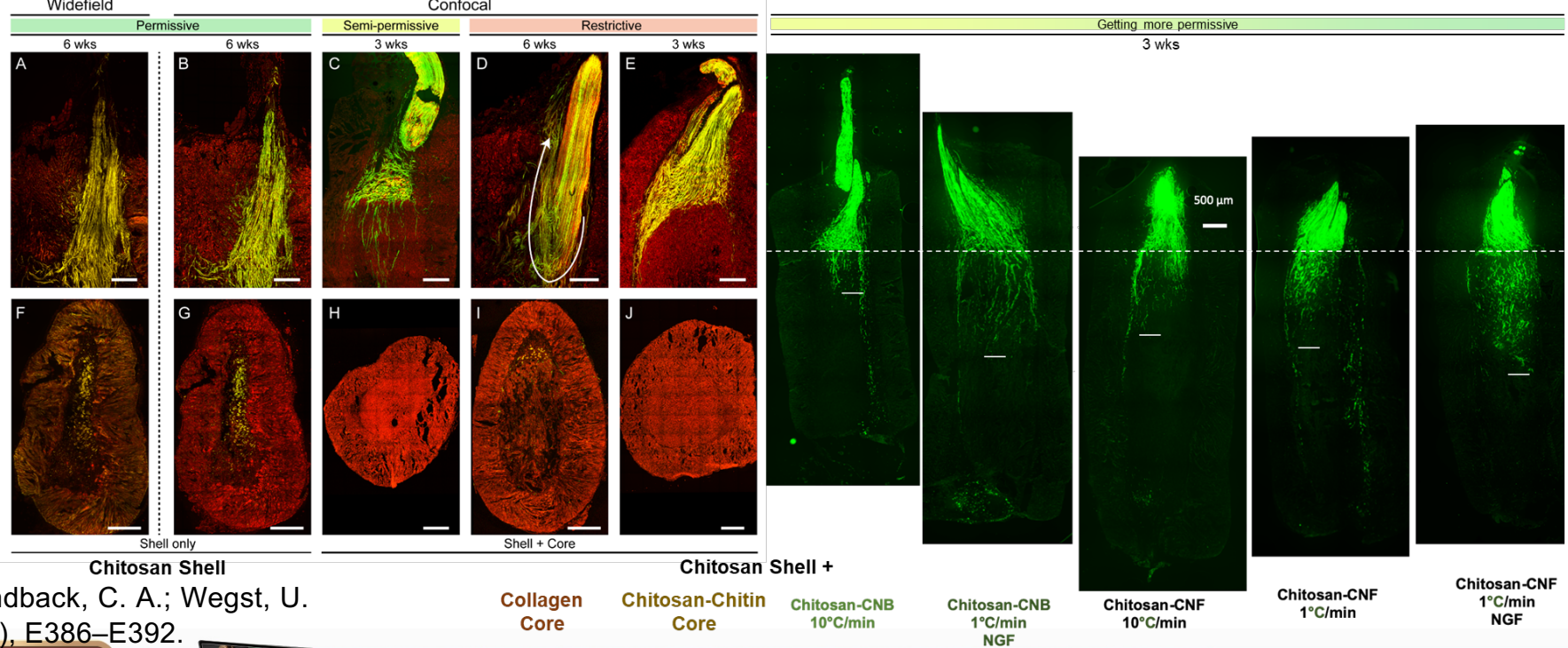
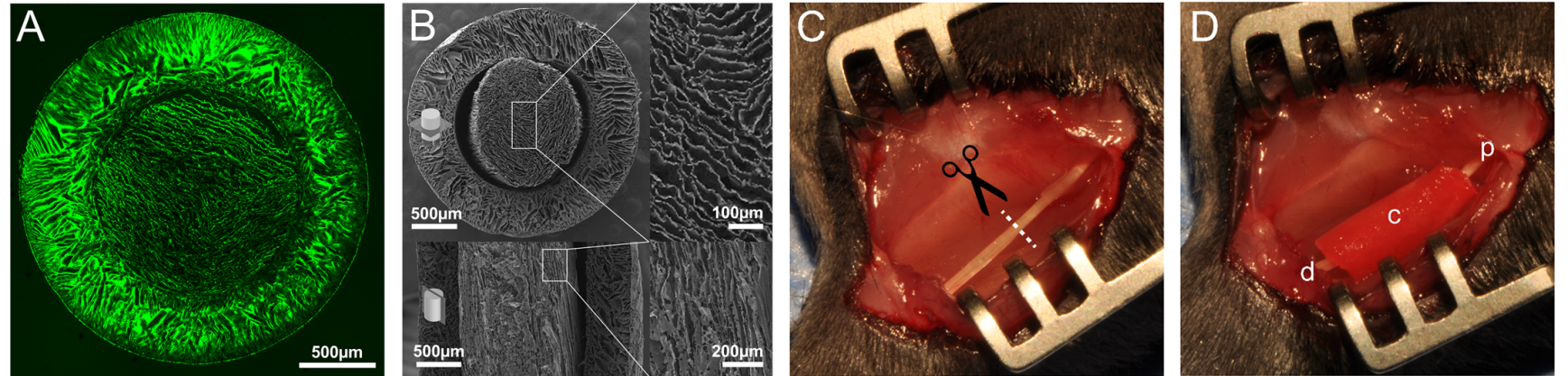
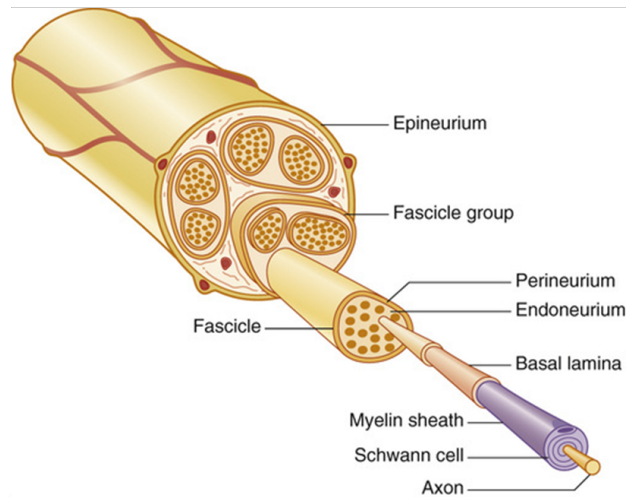


Riblett, B.W., Francis, N.L., Wheatley, M.A. and Wegst, U.G.K. (2012), *Adv. Funct. Mater.*, 22: 4920-4923.



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Effect on Performance of Freeze Cast Scaffolds for Peripheral Nerve Repair



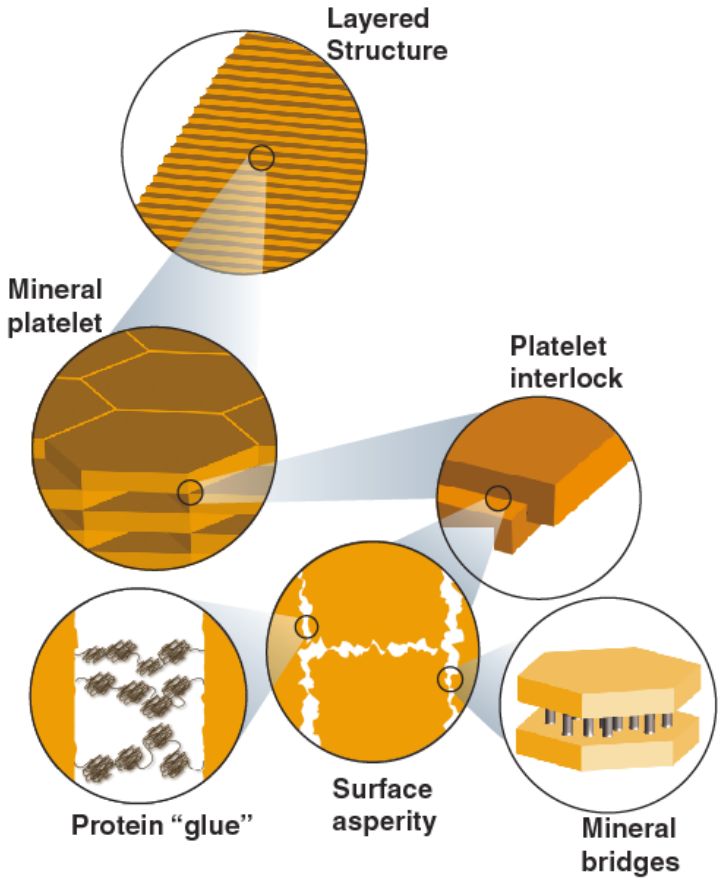
Mohan, S.; Hernández, I. C.; Wang, W.; Yin, K.; Sundback, C. A.; Wegst, U. G. K.; Jowett, N. (2018). *The Laryngoscope*, 128 (11), E386–E392.



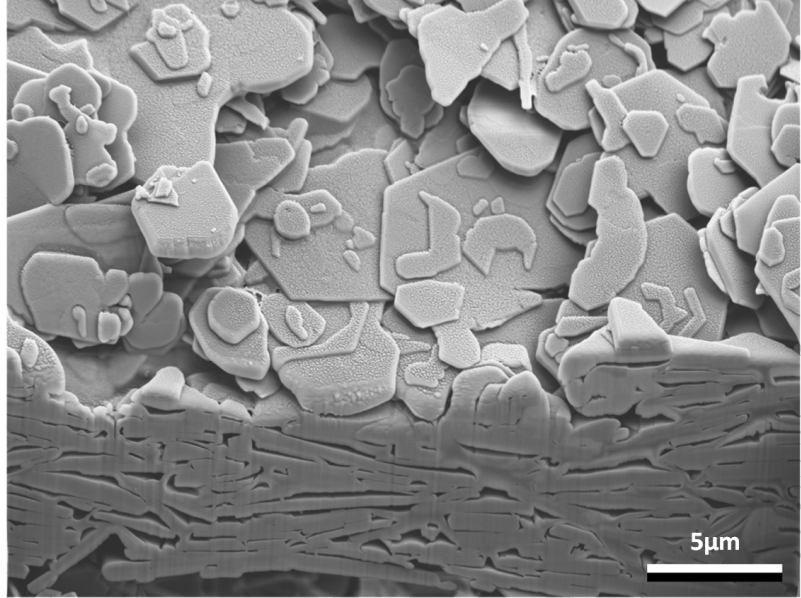
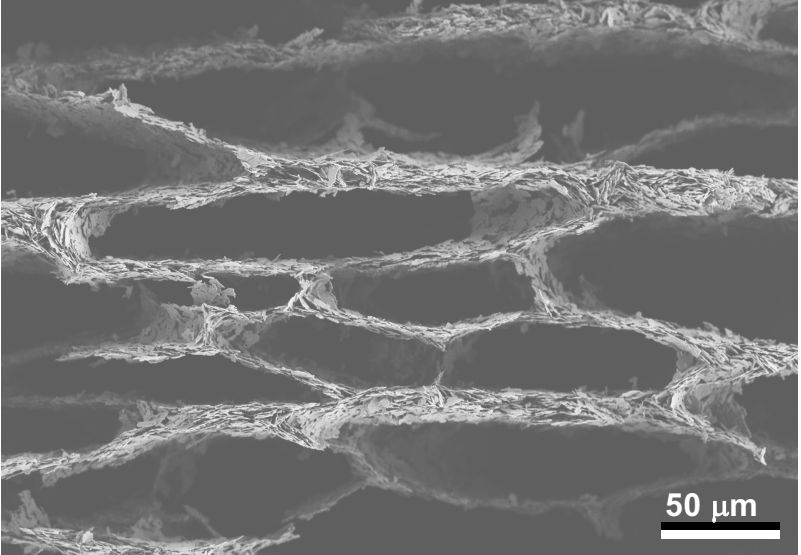
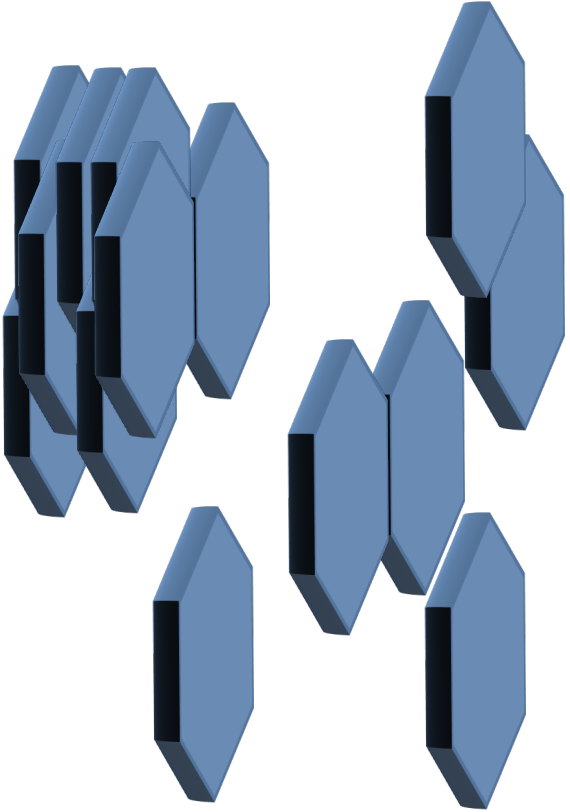
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Alignment of Al₂O₃ Platelets

Nacre



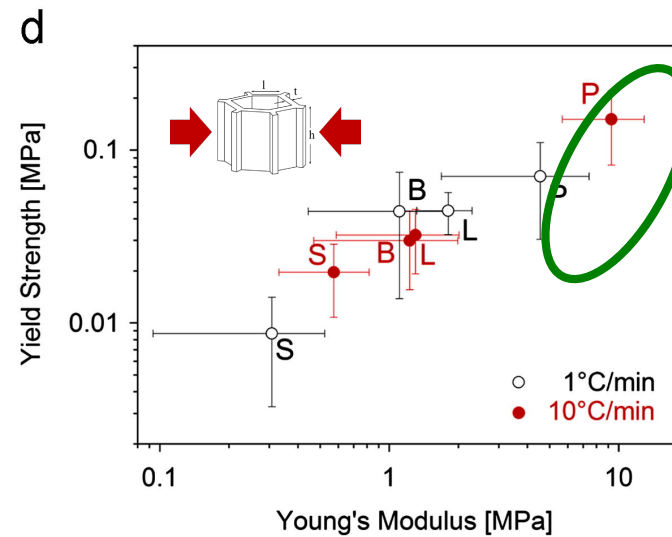
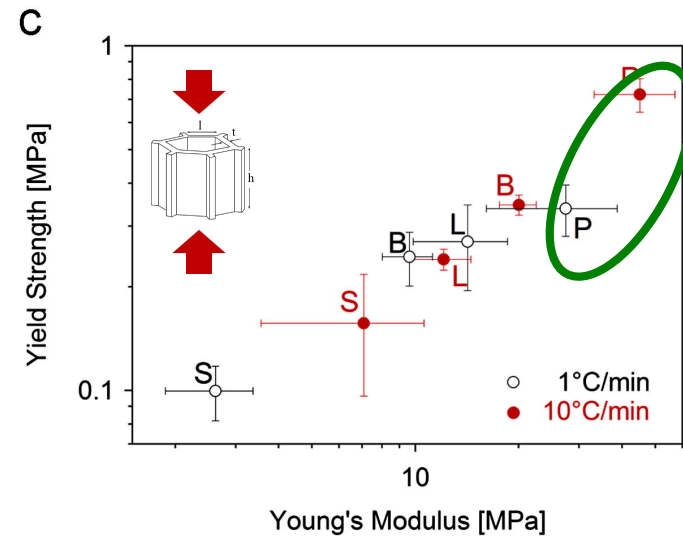
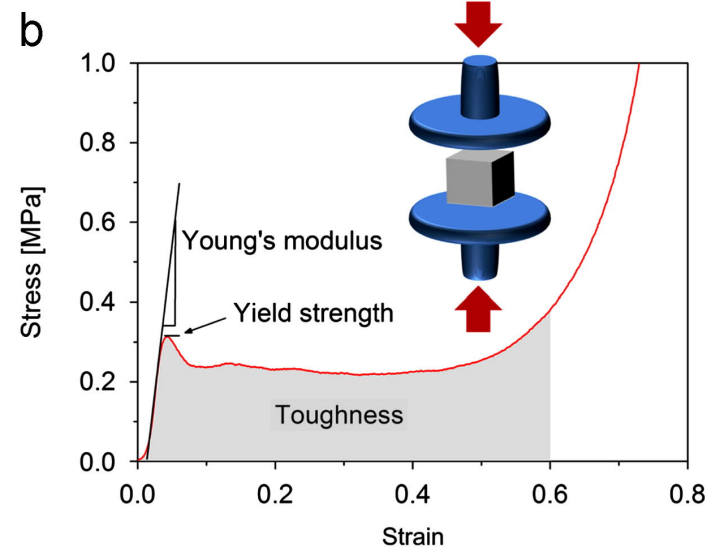
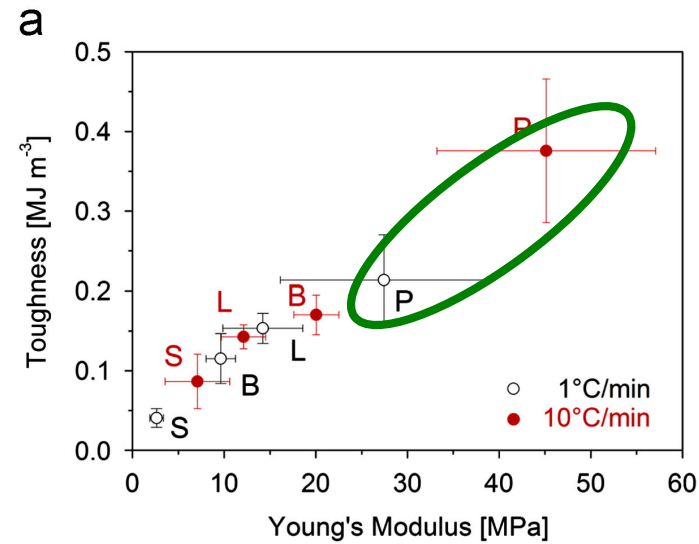
Freeze Cast Nacre from Al₂O₃ Platelets?



Hunger, Donius, Wegst (2013), *J Mech Behav Biomed Mater*, 10.1016/j.bbr.2011.03.031.
 Hunger, Donius, Wegst (2013), *Acta Biomat.*, 10.1016/j.actbio.2013.01.012



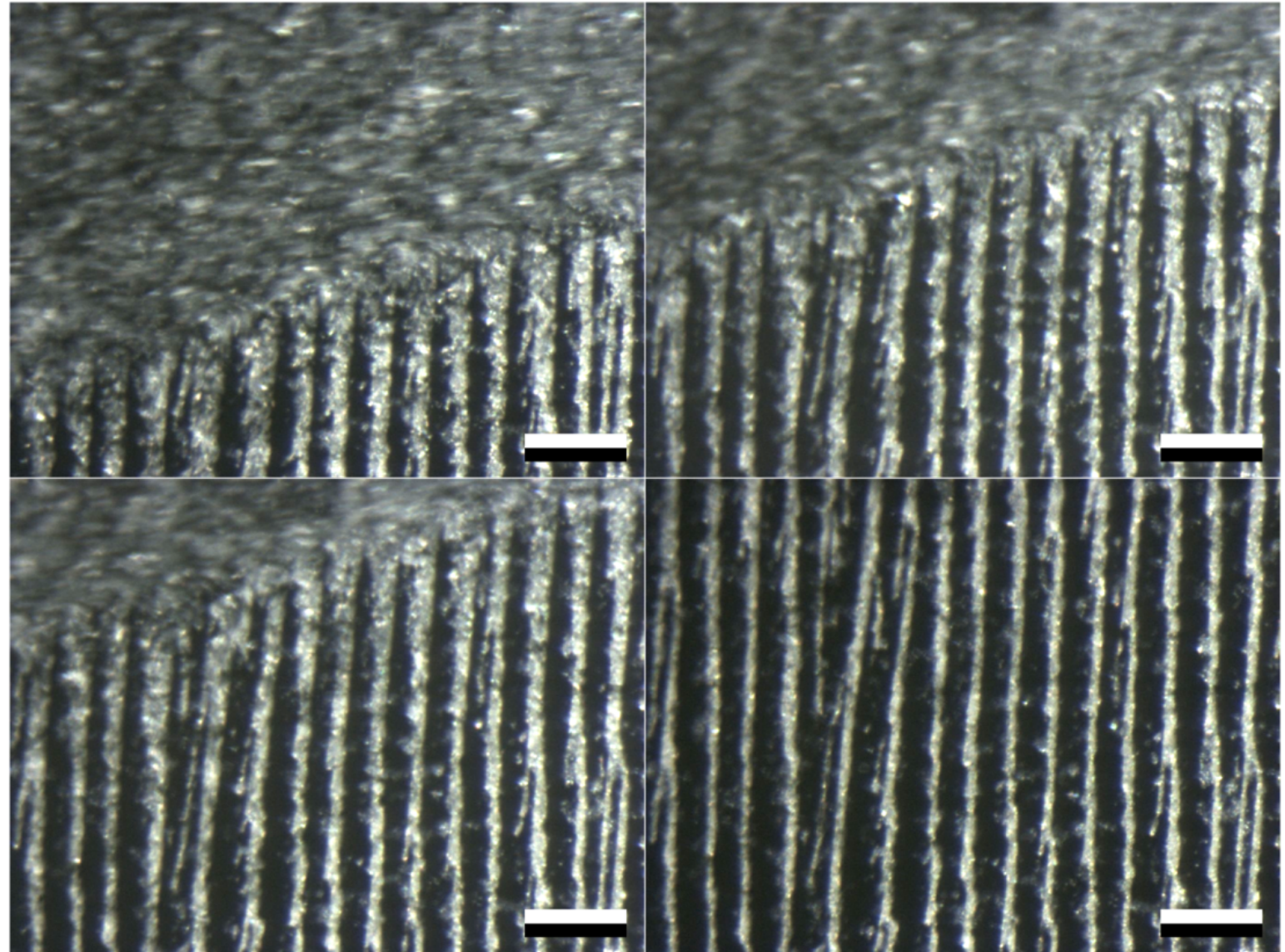
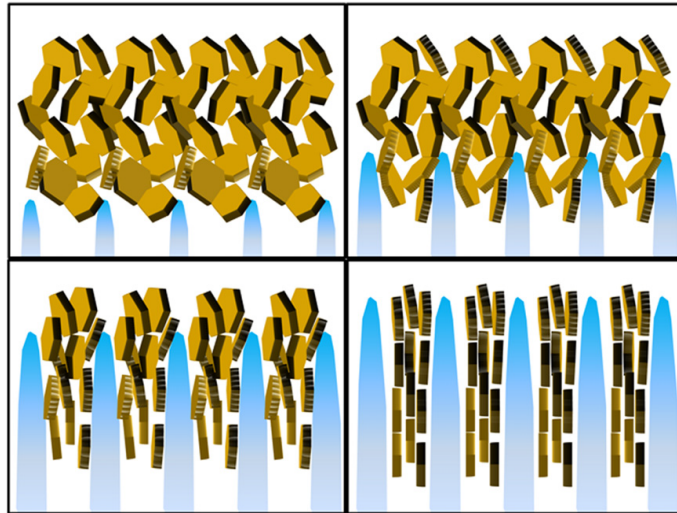
Enhanced Mechanical Properties: Platelets outperform Particles



Hunger, Donius, Wegst (2013), *J Mech Behav Biomed Mater*, 10.1016/j.bbr.2011.03.031.

Hunger, Donius, Wegst (2013), *Acta Biomater.*, 10.1016/j.actbio.2013.01.012

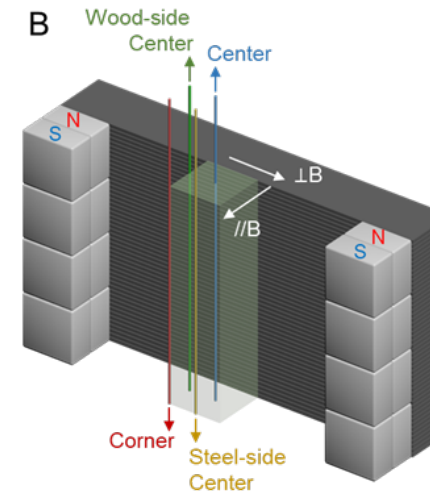
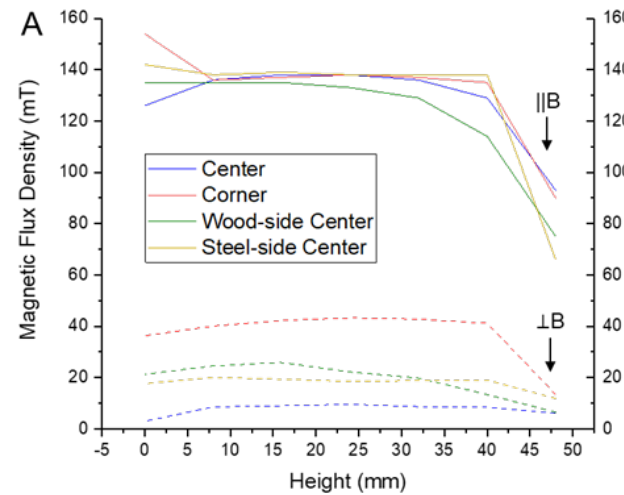
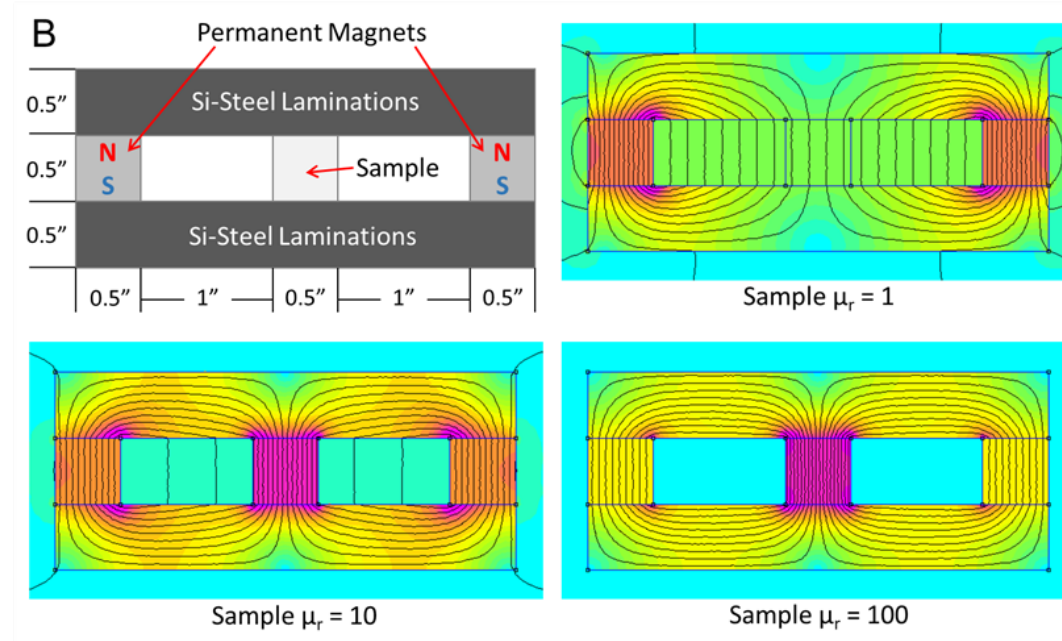
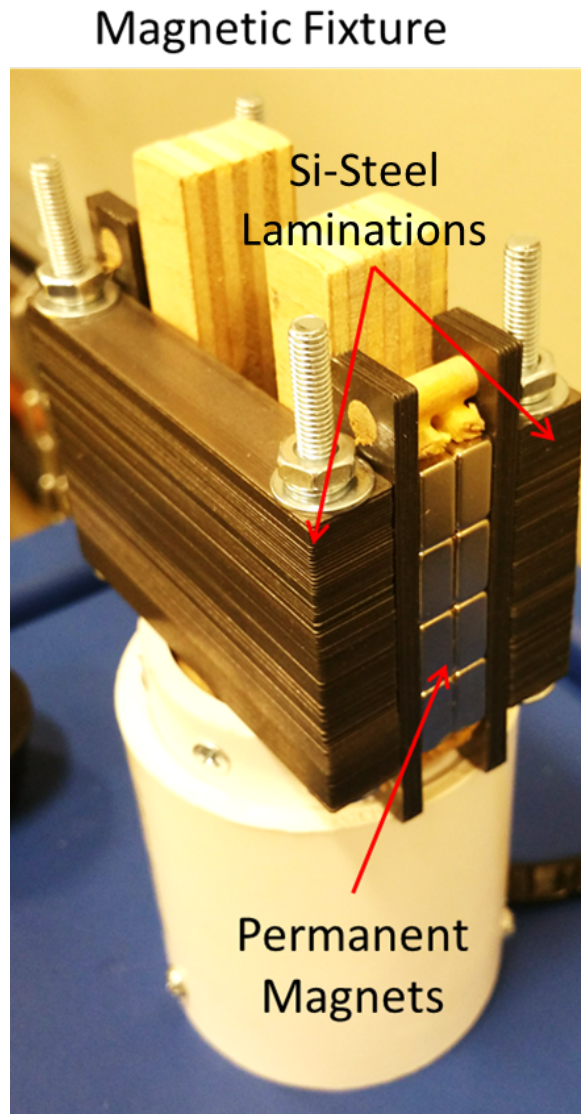
Mechanism of Alignment: Shear Flow During Freezing



Hunger, Donius, Wegst (2013), *J Mech Behav Biomed Mater*, 10.1016/j.bbr.2011.03.031.

Hunger, Donius, Wegst (2013), *Acta Biomater.*, 10.1016/j.actbio.2013.01.012

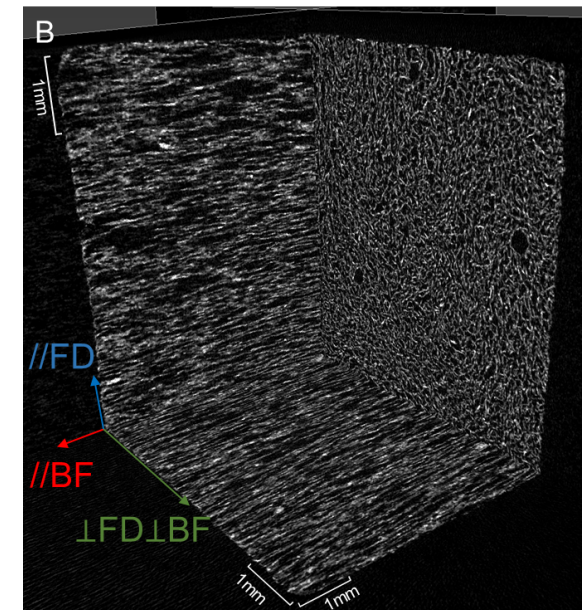
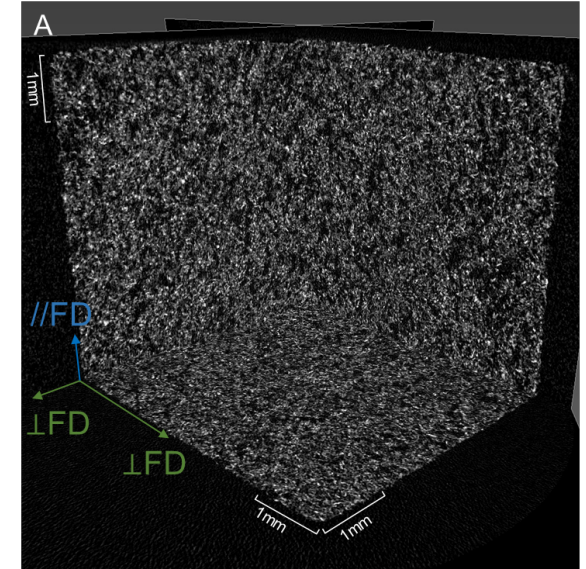
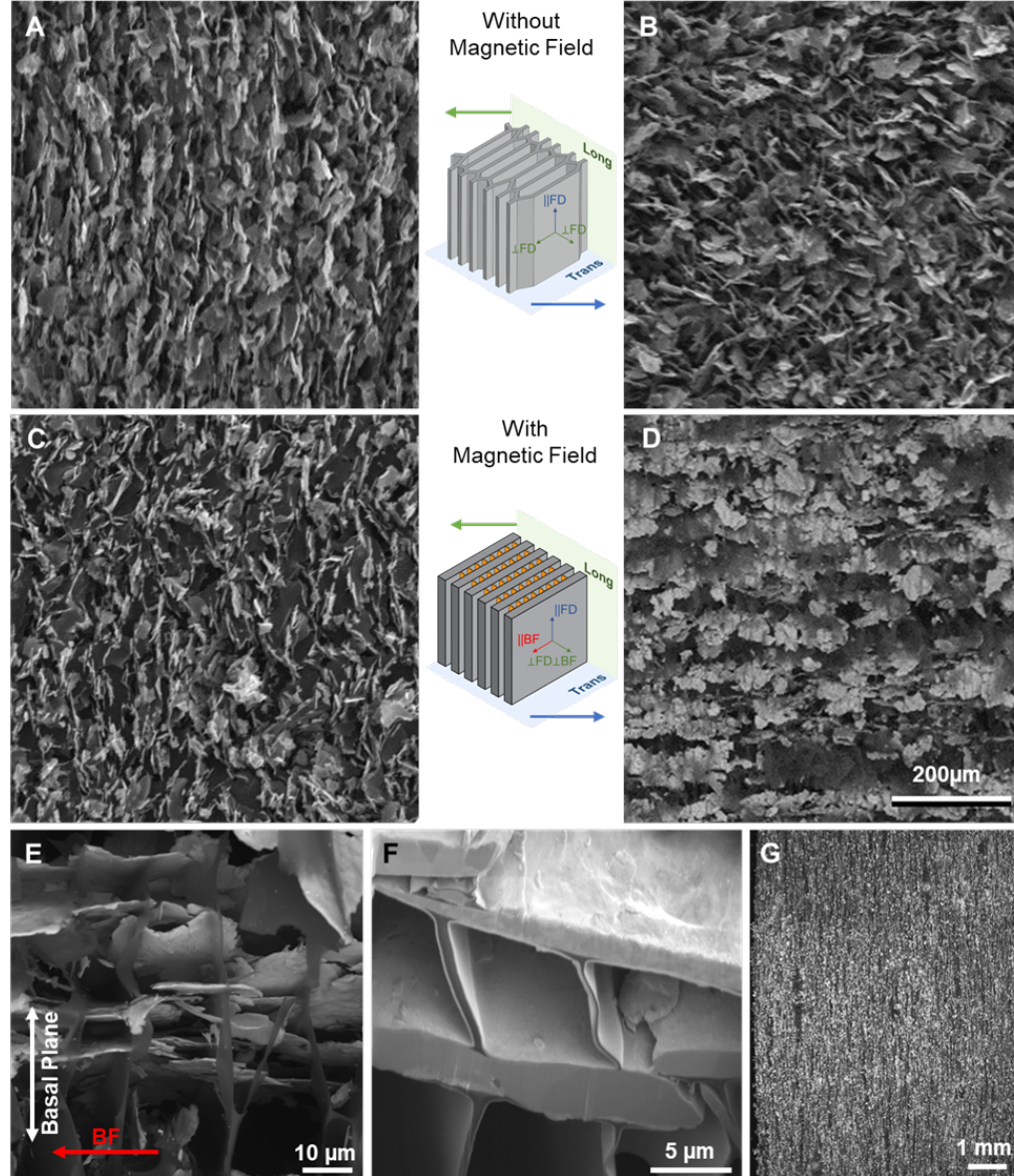
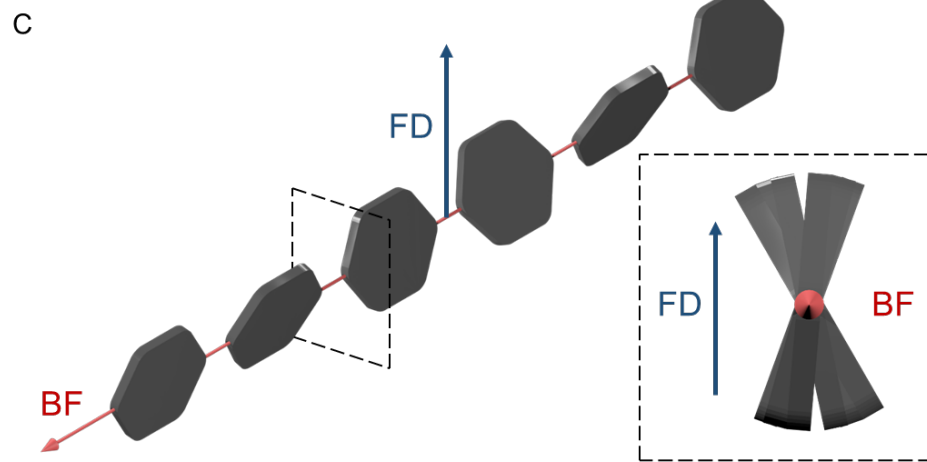
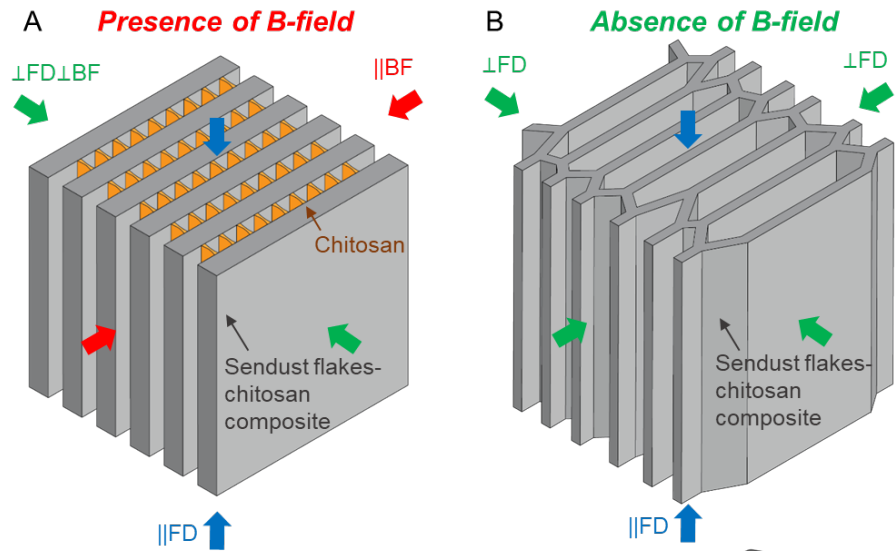
Freeze Casting in Uniform Magnetic Flux



Yin, Reese, Sullivan, Wegst (2020), Adv. Funct. Mater. 31, 2007743.

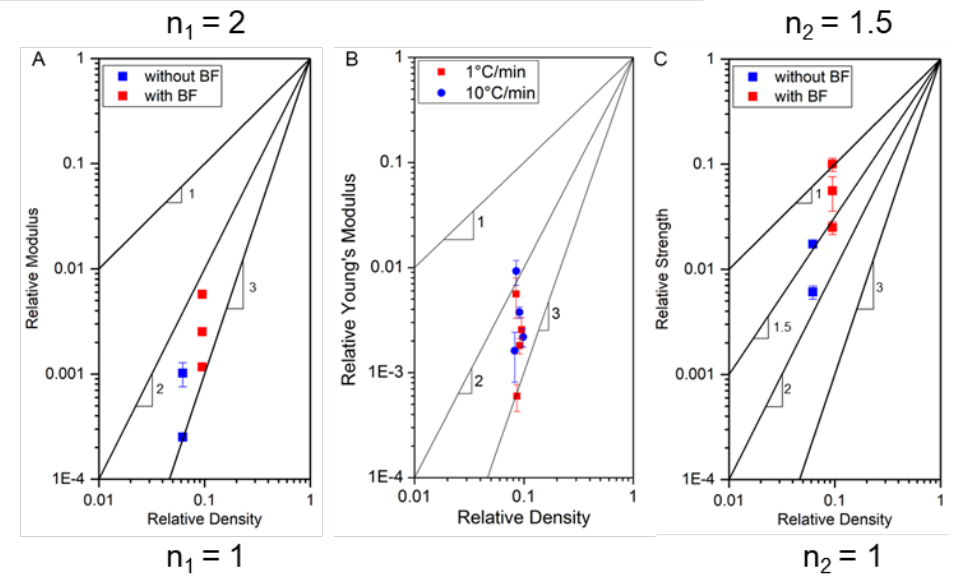
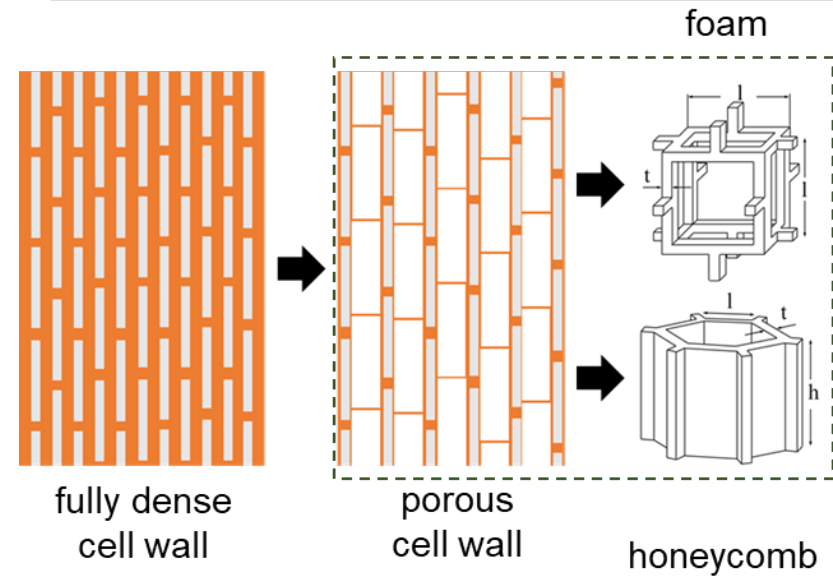
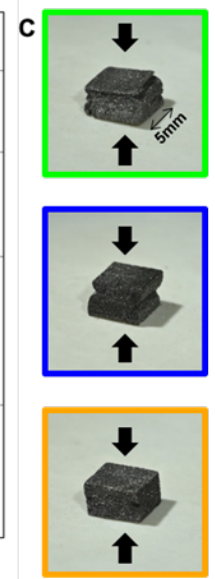
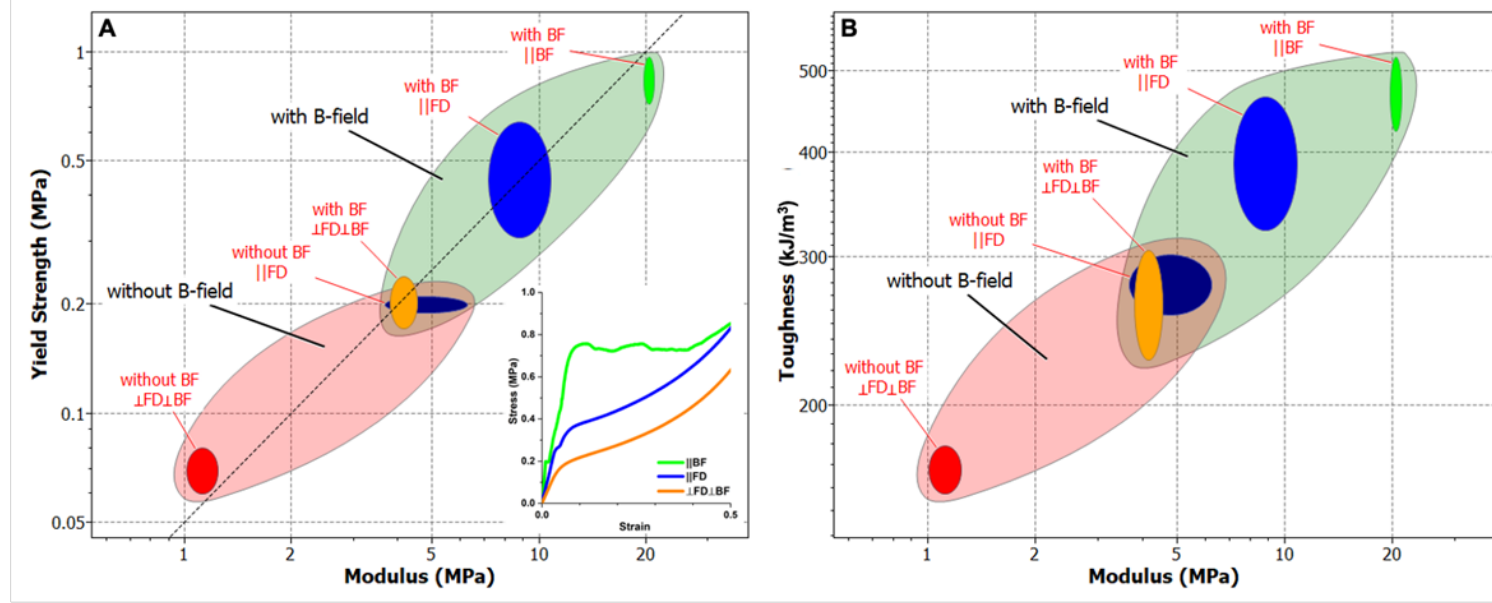
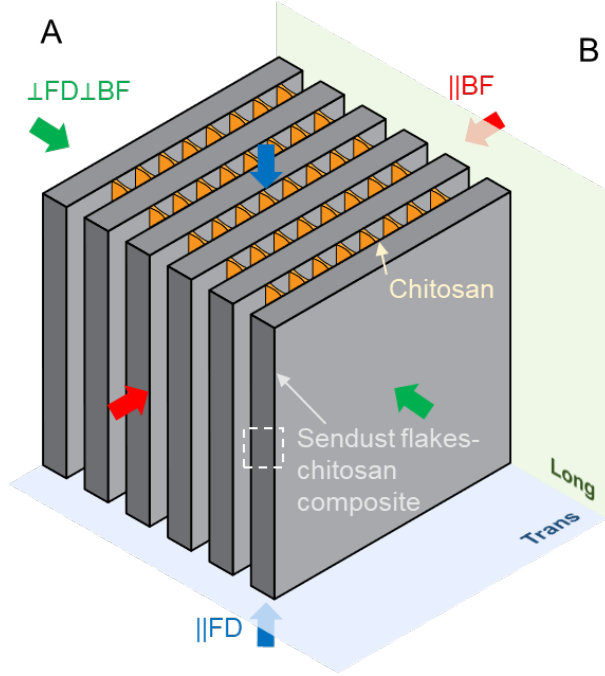


Excellent Flake Alignment in 2 Directions



Yin, Reese, Sullivan, Wegst (2020), Adv. Funct. Mater. 31, 2007743.

Enhanced Mechanical Properties



Yin, Reese, Sullivan, Wegst (2020), Adv. Funct. Mater. 31, 2007743.



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Improved Permeability and Quality Factor

Alternating Magnetic Field

$$H = H_0 e^{j\omega t} \quad B = H_0 e^{j(\omega t - \delta)}$$

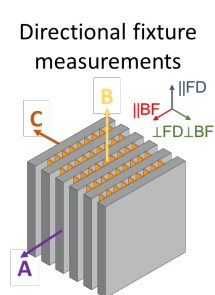
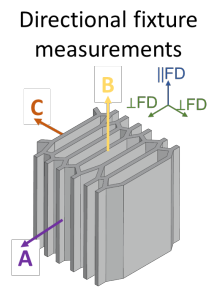
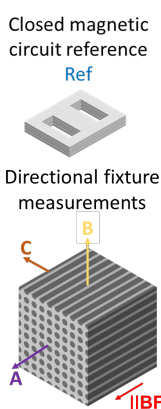
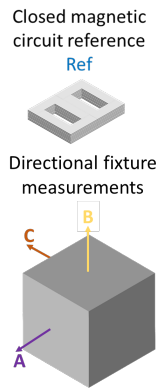
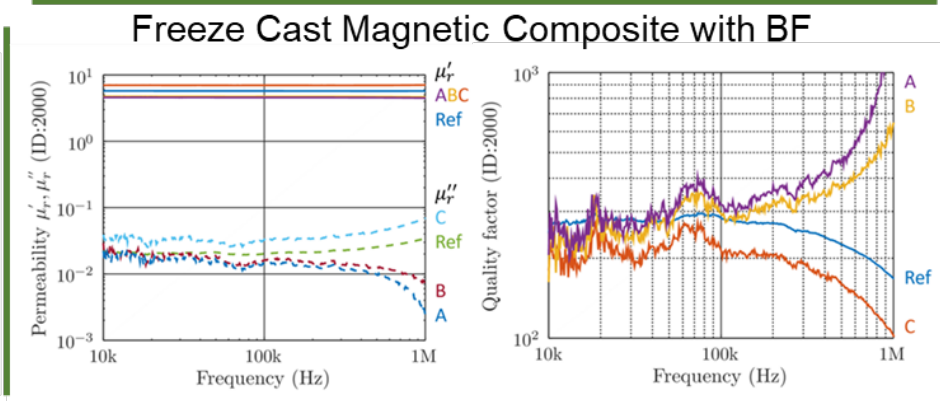
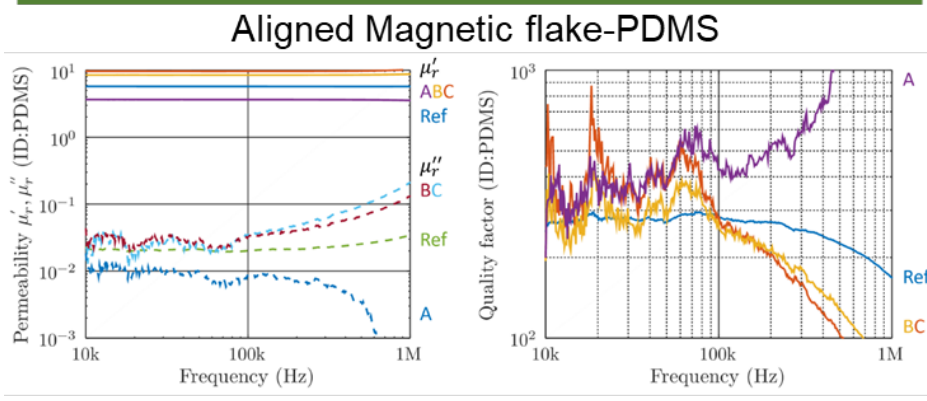
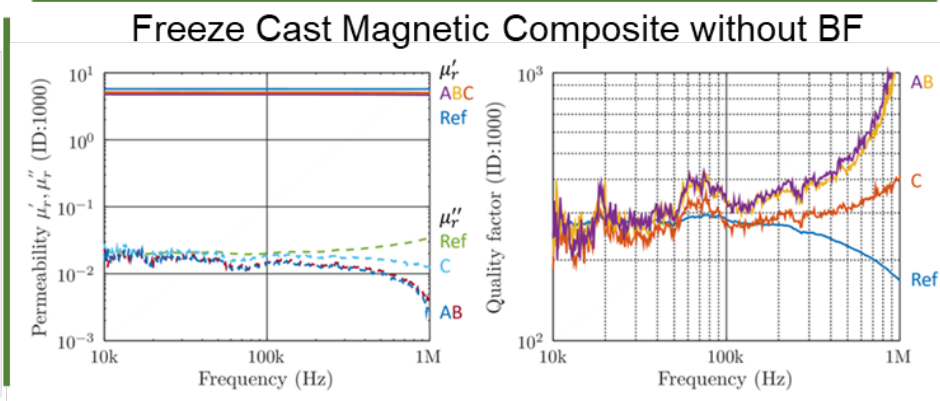
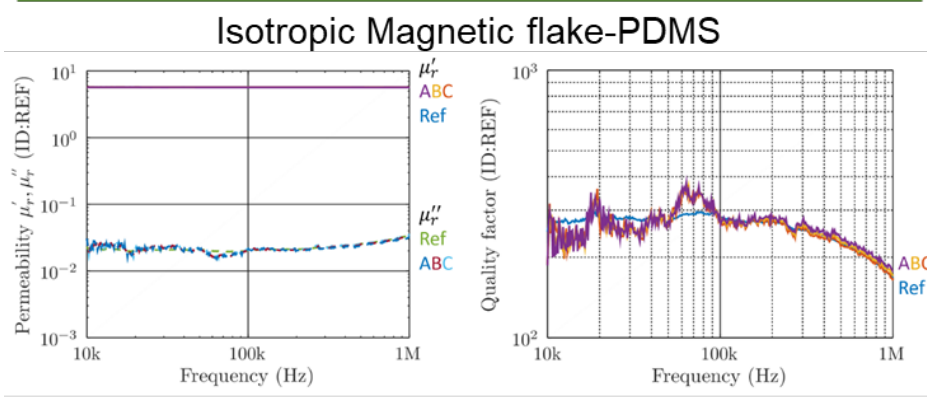
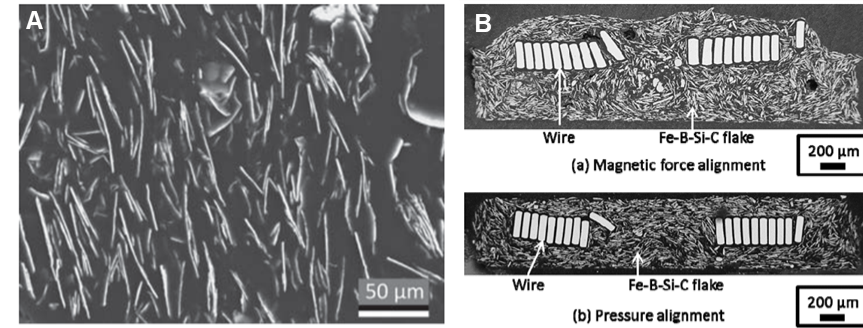
Permeability

$$\mu = \frac{B_0}{H_0} e^{-j\delta} = \frac{B_0}{H_0} \cos \delta - j \frac{B_0}{H_0} \sin \delta$$

$$= \mu' - j\mu''$$

Quality Factor

$$Q = \mu' / \mu''$$

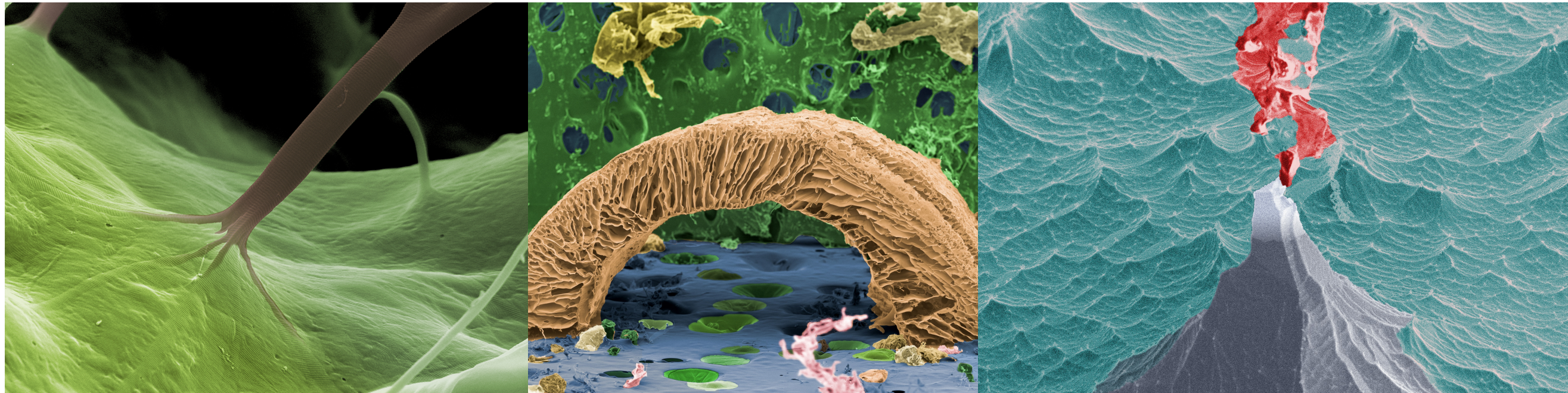


Yin, Reese, Sullivan, Wegst (2020), Adv. Funct. Mater. 31, 2007743.



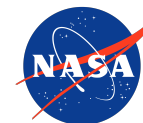
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Funding

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