Hydrogels with tunable dissipation for mechanotransduction studies

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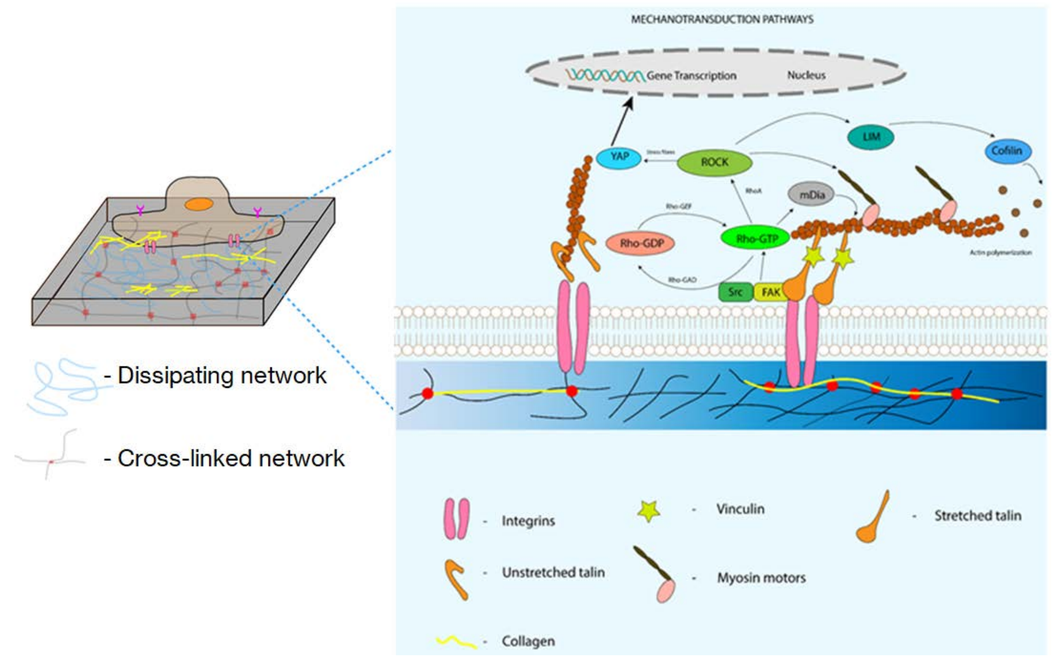
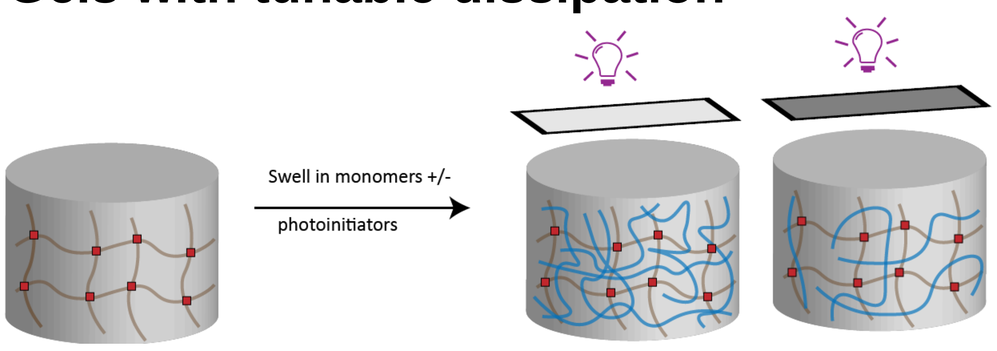
Introduction

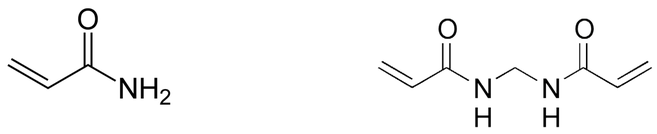
The ability of cells to sense and adapt to the mechanical properties of the surrounding matrix plays a crucial role in various processes such as spreading and migration as well as in diseases such as cancer. Cells sense ECM mechanical properties by applying traction forces and the sensing mechanism is mediated by cellular machinery, including integrin receptors, actomyosin and other focal adhesion associated proteins. Both elastic and viscous properties of substrates were shown to play important roles in mechanotransduction events [1,2]. In our research, we focus on understanding the responses of cells to dissipating substrates i.e. substrates with high loss modulus. By photopolymerizing monomers that can hydrogen bond with the first poly (acrylamide) hydrogel network under a photomask, we have created substrates with similar elastic properties but different viscous properties. We envisage that such substrates will be helpful in studying cells' responses to different levels of loss modulus and loss modulus gradients. Further, we found that the gels produced with polymerized oligomers of tannic acid resulted in stiff and tough hydrogels. In future, we plan to study the structure-property relations in such hydrogels using neutron scattering.



Gels with tunable dissipation



First network components

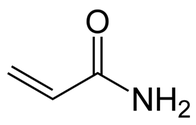


Acrylamide monomer

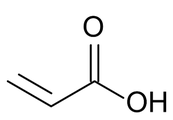
Bis-acrylamide cross-linker

\+ **Redox pair of initiators**

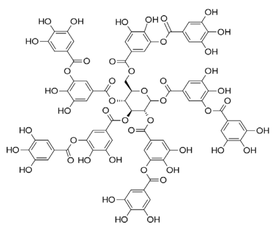
Different second network monomers



Acrylamide



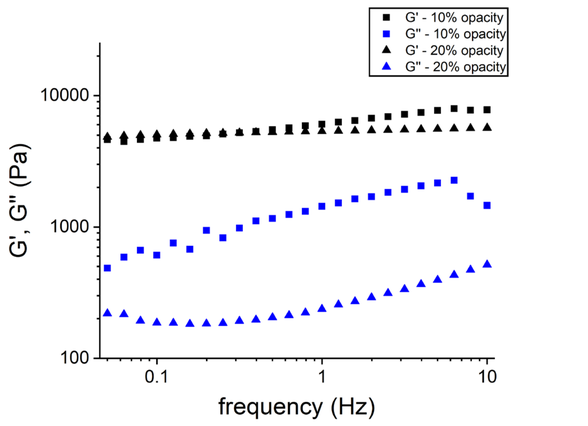
Acrylic acid

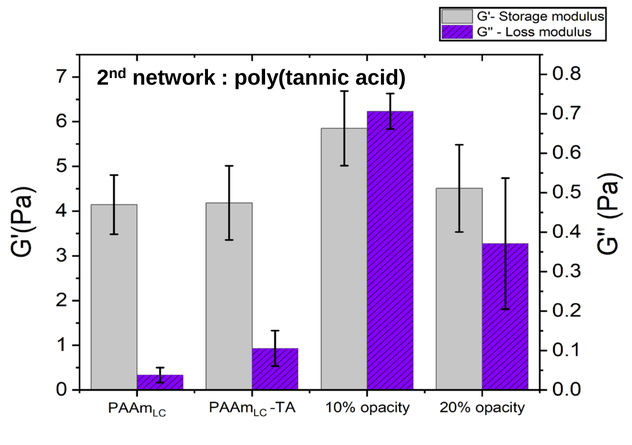


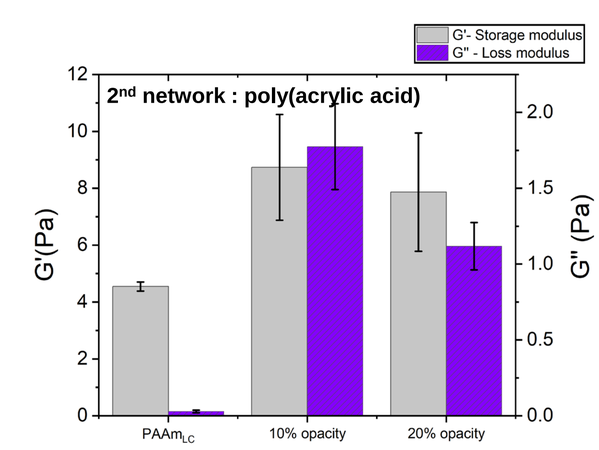
Tannic acid

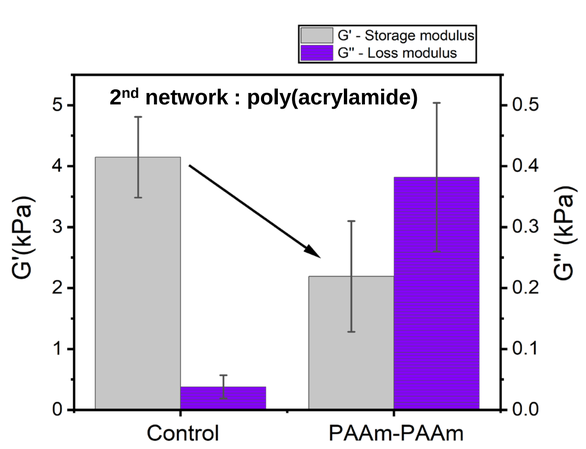
- Poly(acrylamide) gels produced by free radical polymerization of acrylamide monomer and bis-acrylamide cross-linker were soaked overnight with monomers and/or UV photo initiators.
- The gels were then exposed to UV under photomasks of varying opacity.
- Mechanical properties evaluated by rheology, tensile and compression testing.

Hydrogen bonding tunes viscous dissipation



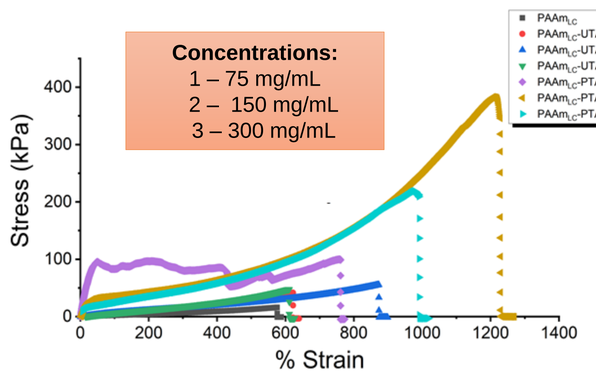


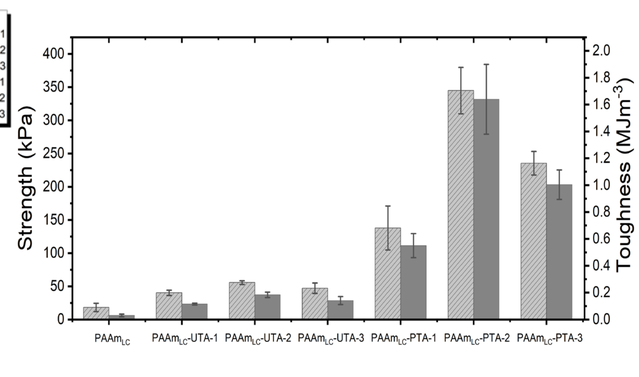


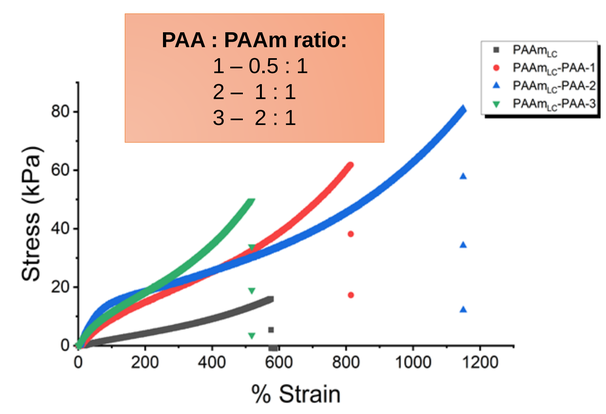


- Both tannic acid polymerized and acrylic acid polymerized gels enabled tuning of viscous dissipation.
- However, poly(acrylamide) polymerized gels (PAAm-PAAm) result in swelling dependent change in mechanical properties over time.

Double network stiff and tough hydrogels



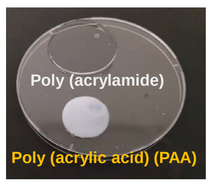




Mechanical properties of polymerized tannic acid (150 mg/mL) gel

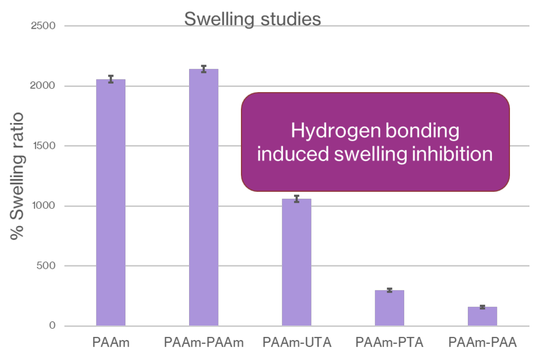
Compared gel	Tensile	Compressive
Single network $PAAm_{LC}$ gels.	19x strength and 55x toughness	13x strength and 50x toughness.
Unpolymerized tannic acid, 150 mg/mL.	6.3x strength and 9x toughness	3.6x strength and 8.3x toughness.
Acrylic acid polymerized, 1:1 molar ratio of $PAAm_{LC}$: PAA	4.3x strength and 3.6x toughness.	6x strength and 4.3x toughness.

Physical properties



Unpolymerized Tannic acid (UTA)

Polymerized Tannic acid (PTA)



- Acrylamide polymerized inside a polyacrylamide cross-linked gel resulted in highly swollen gels and were transparent.
- Polymerized with acrylic acid, the gels didn't swell much and were opaque.

Conclusions and Future works

- Dissipating hydrogels with various levels of dissipation was produced and tested using rheology.
- Hydrogen bonded oligomers with first network showed high stiffness and toughness when compared to hydrogen bonded polymers.
- Evaluation of structure-property relationships using neutron scattering and cell culture.

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References

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- Shirke, Pallavi Uday, et al. "“Viscotaxis”-Directed Migration of Mesenchymal Stem Cells in Response to Loss Modulus Gradient." bioRxiv (2019): 804492.