Fabrication, measurements, and applications of thermoresponsive and double network hydrogels

Yvonne Yeh, Shuang Cui, Professor Renkun Chen

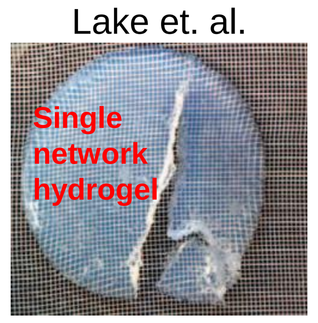
The Department of Mechanical and Aerospace Engineering, University of California San Diego, 9500 Gilman drive, La Jolla, California

Introduction

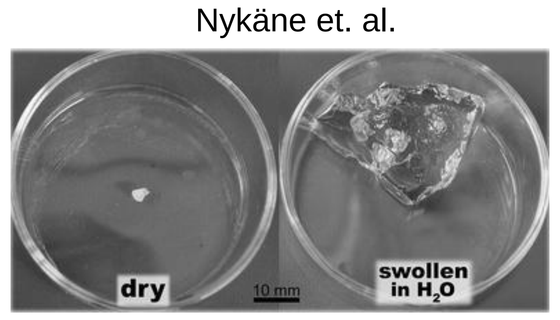
Hydrogels are cross linked polymers with hydrophilic groups that are highly absorbent. They are used in cooling technologies, and stimuli-responsive hydrogels have applications as adaptive lenses, artificial muscles, vehicles for drug deliveries, scaffolds or matrices for tissue engineering, and sensors and actuators for soft robotics and soft machines.

Double network hydrogels (tough hydrogel) crosslink the polymers with covalent bonds and ionic bonds. Ionic bonds break under stress, and it reforms that help hydrogel recover. This structure of double network hydrogel yields greater strength and better mechanical properties than single network hydrogel, and extend the application field for hydrogels

Lake et. al.



Nykäne et. al.



Thermoresponsive hydrogels based on NIPAM can transition across the lower critical solution temperature (LCST). With a low LCST, the properties of the gel can be changed with temperature, which further widen the application to temperature based actuators, robotics, self-folding structures, and pattern formation.

Fabrication

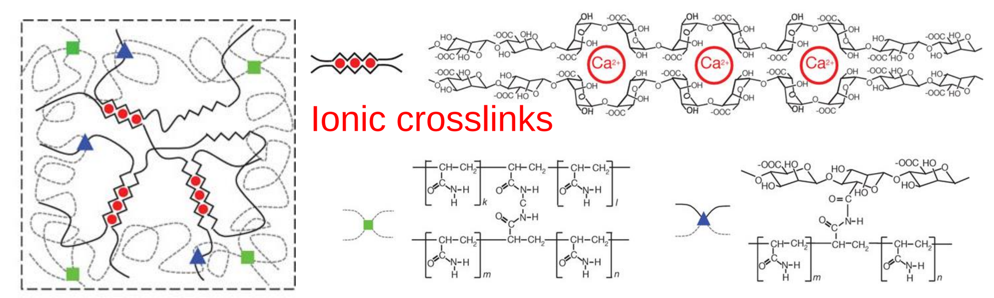
Materials: Alginate, Acrylamide, $CaSO_4.2H_2O$
Ammonium persulfate (AP),
N - Isopropylacrylamide (NIPAM),
Tetramethylethylenediamine (TEMED),
N, N'-Methylenebisacrylamide (MBAA)

Syringe 1: Dissolve the materials in a beaker and cover the beaker with aluminum foil. Stir the solution for 1 hour at 450 rpm. Degas the resulting solution until there is no bubbles.
Syringe 2: Dissolve the materials in another beaker and place it in ultrasonic cleaner for 5 minutes until it is well-mixed.

Syringe 1 : Syringe 2 = 1 : 0.16 by volume

Pour the solutions into respective syringes until the tip of open end is filled. Connect the two syringes and quickly mix the solution 10 times.
Pour the solution into petri-dish and place the dish on a hot plate at 50°C. Shine UV light (254 nm) on the dish and cover with box for 1 hour.
Put the hydrogel in the petri-dish into a humid box for 24 hours. Put the humid box in fume hood.

Double Network Hydrogel

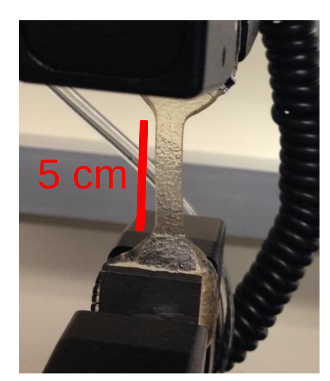


Sun et. al.

Covalent crosslinking in polyacrylamide gel

Covalent crosslinking between alginate and polyacrylamide

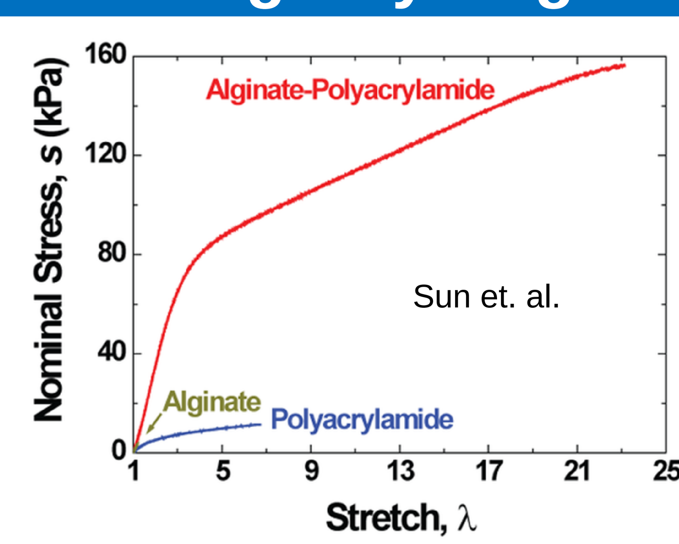
Tensile Test



During tensile test

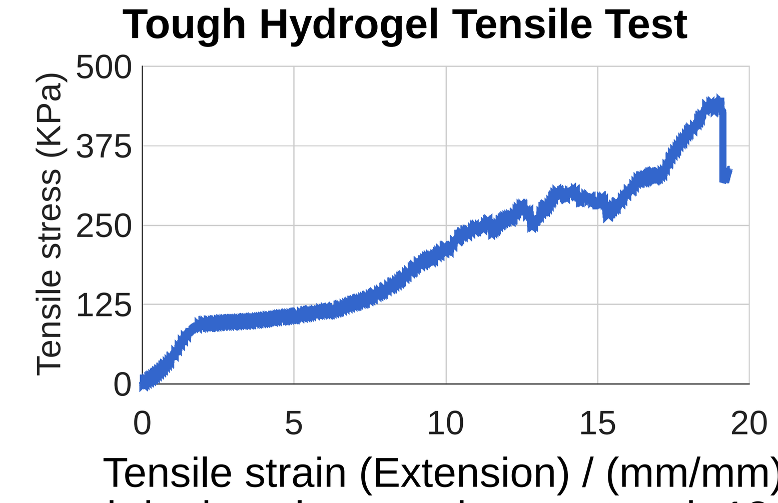
After tensile test

Tough Hydrogel



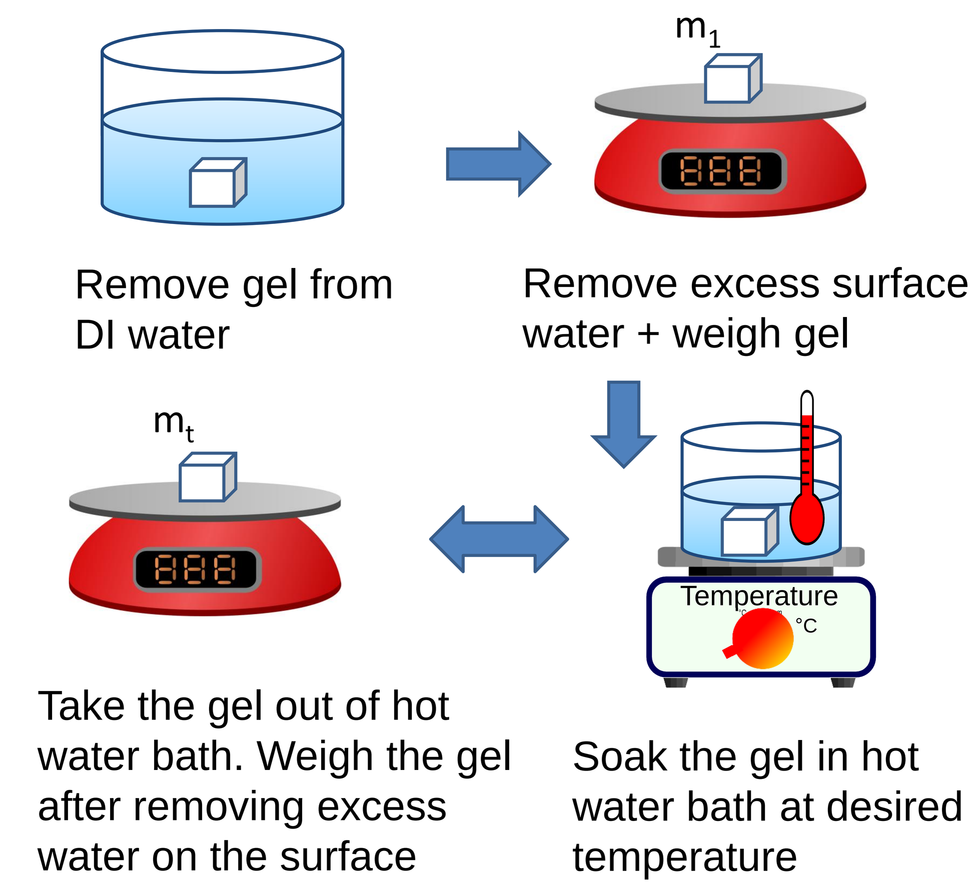
Single network hydrogel made of alginate or polyacrylamide does not exhibit strong mechanical properties. However, as they combine to form double network hydrogel, the strength enhanced dramatically.

Tough Hydrogel Tensile Test

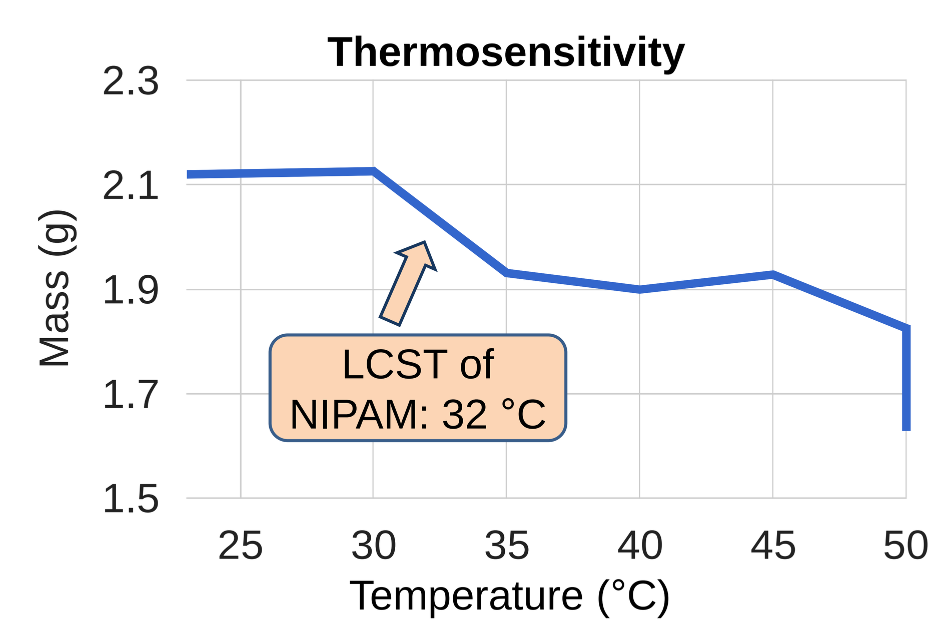


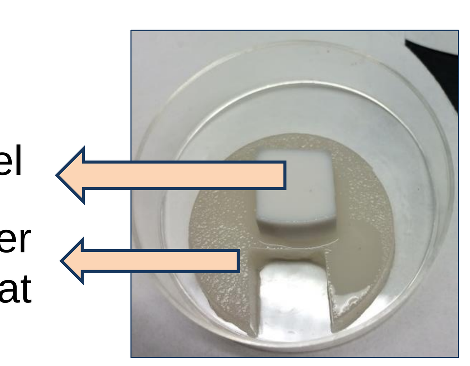
The tough hydrogel we made can stretch 18 times its original length and withstand 490 KPa tensile stress.

Thermoresponsive Test



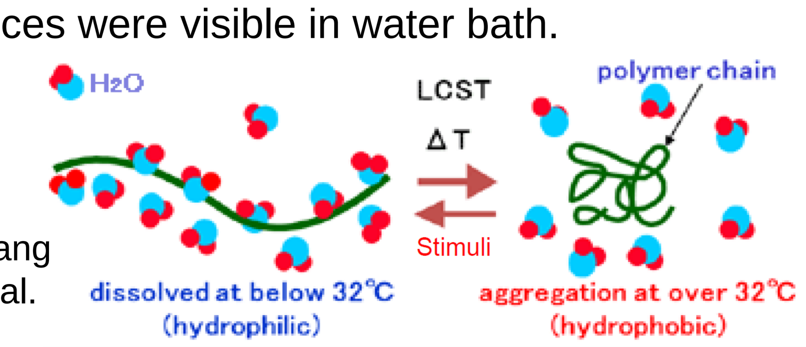
Temperature Sensitive Hydrogel



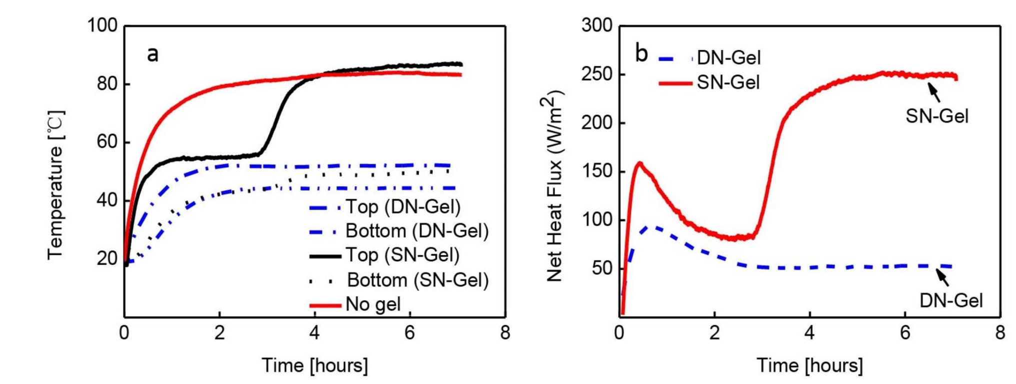


When the temperature passed LCST of NIPAM, hydrogel became hydrophilic and turns opaque. The mass of the gel generally decreased as the temperature increased, which showed the gel is thermoresponsive. However, the gel was very brittle and it broke down in the process. This may contribute to the decrease in mass as some small pieces were visible in water bath.

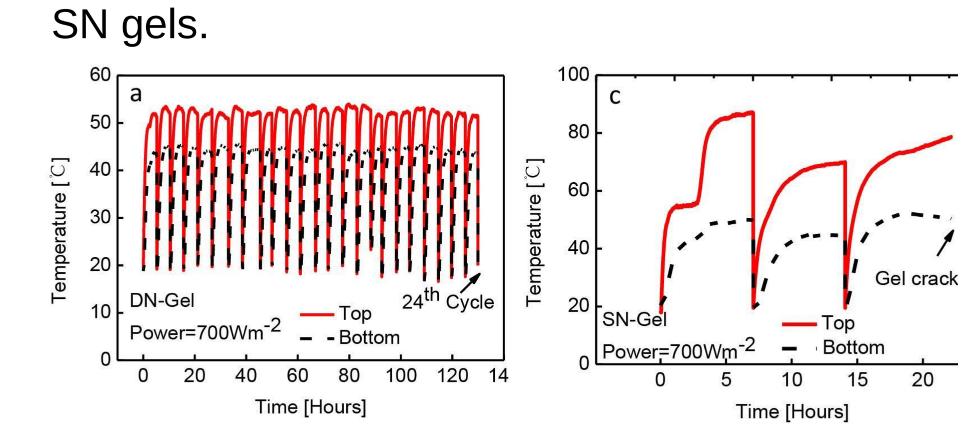
Zhang et. al.



Tough Hydrogel for Cooling Buildings



Double network (DN) hydrogels proved to have better cooling effect than single network (SN) hydrogels. DN gels have longer cooling duration and provides a better insulation for the house than SN gels.



DN hydrogels are more better cyclability than SN hydrogels.

Conclusion/Future Research

Tough hydrogel was fabricated that can withstand 490 KPa tensile stress and 18.5 uniaxial stretch. It demonstrated capability to reduce the surface temperature of wood roofs by 25-30 °C, and it is regenerable. Thermoresponsive hydrogel was also synthesized. We suspect the 6:1 ratio of NIPAM:Alginate made the thermoresponsive hydrogel brittle. For future research, we could alter the ratio for better results, and apply it to more effective roof cooling. Also, applications for hydrogels as preparation for aerogels can be further explored.

Acknowledgements

I would like to thank Dr. Komives for organizing this program and giving me the opportunity to work in UCSD. Special thanks to Leonard Chen for helping me throughout the project, and thanks to Melisa Averina and Brianna Fernandez for the help with experiments.

Nykäne, et. al. Soft Matr, 2011, 7, 4414-4424
Lake, at. al. Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences 1967, 300, 108.
Sun, et. al. "Nature,2012,Vol 489, 133-136
Zhang, et. al. X Journal of colloid and interface science, 223(2), 311-313.

.