

Ultrasensitive biohybrid mechanoluminescent materials

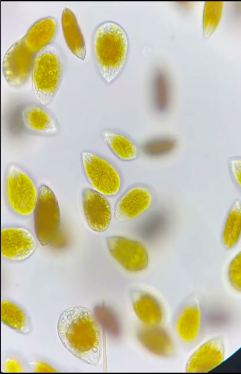
Shengqiang Cai

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UCSD

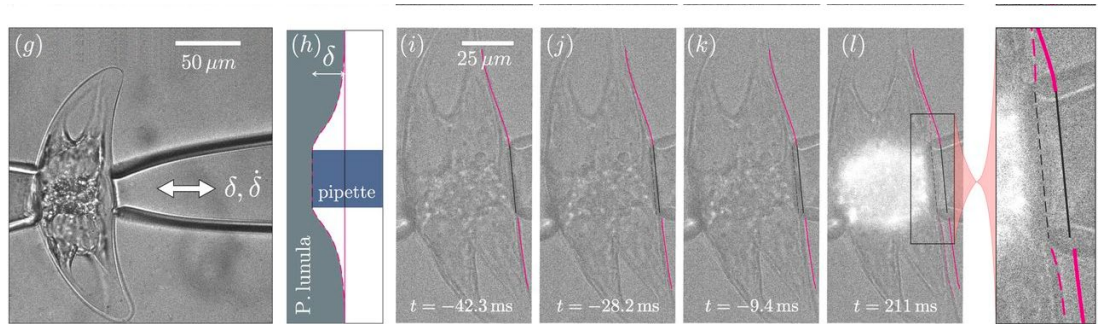
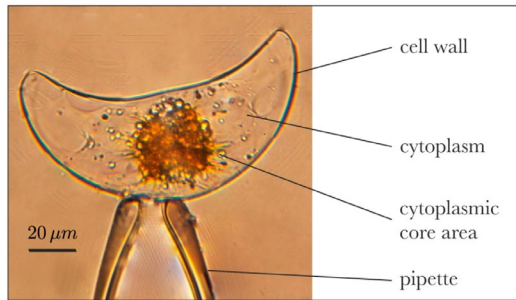
CMMRC workshop, Frontiers of Materials that Learn, 2025, Washington, D.C.



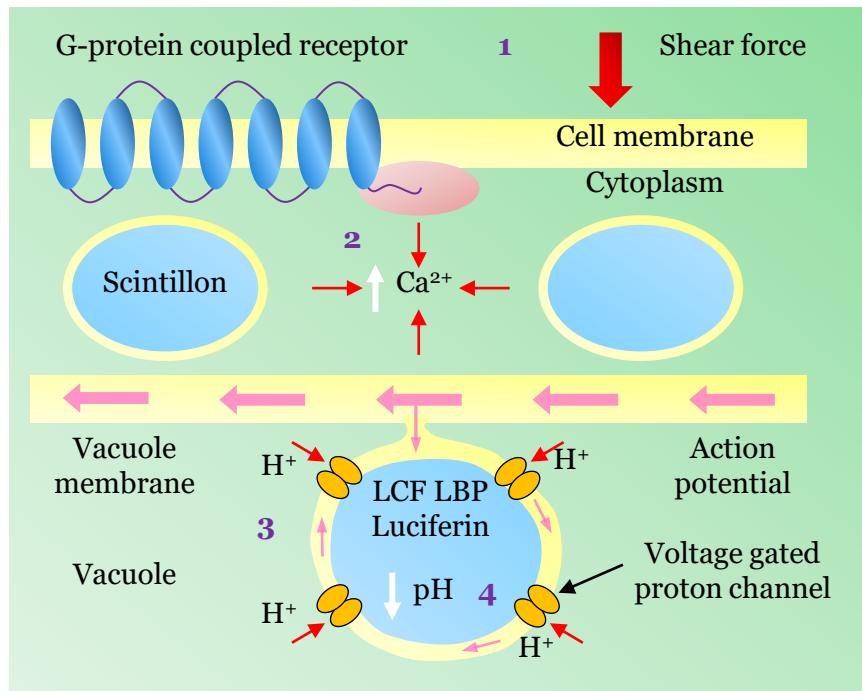
Bioluminescent wave in San Diego



Force-induced bioluminescence



Jalaal, Maziyar, et al. *Physical Review Letters* 125.2 (2020): 028102.



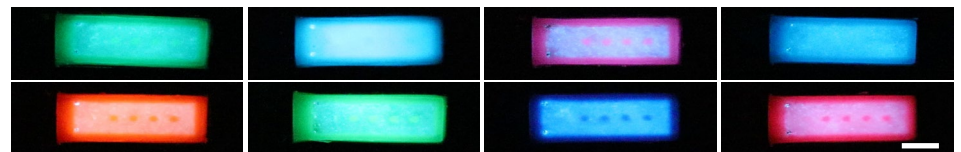
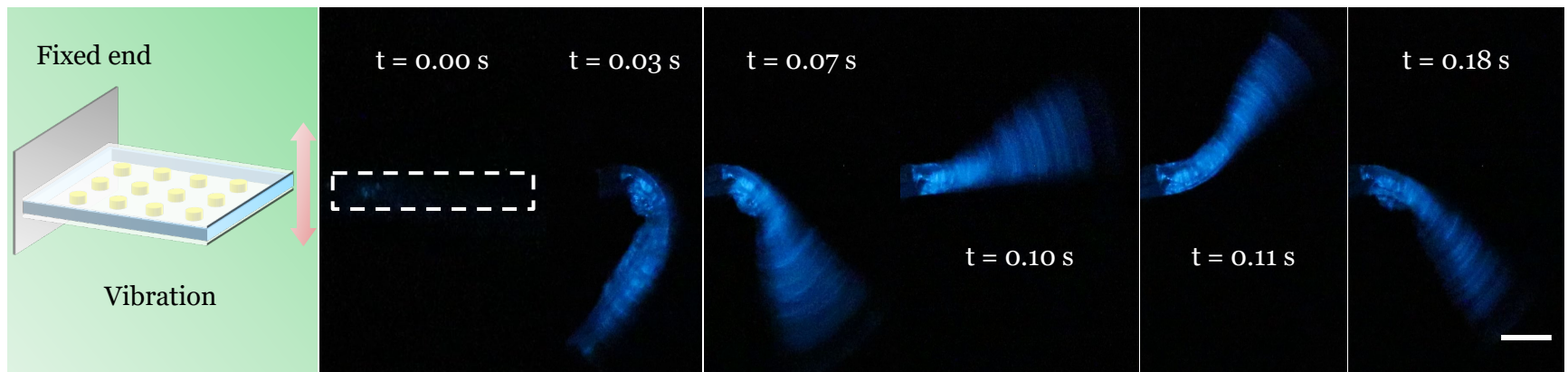
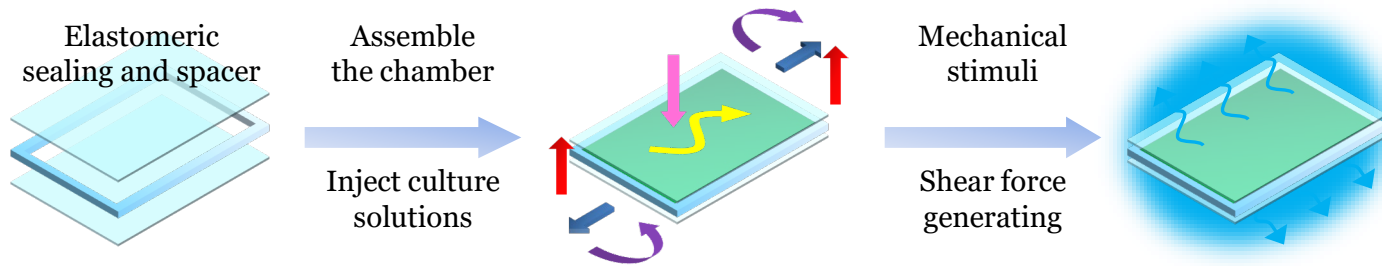
- Complex chemo-mechanical coupling processes are involved
- Extremely high force sensitivity
- Small scale

**Biomimicry,
Bioinspiration**

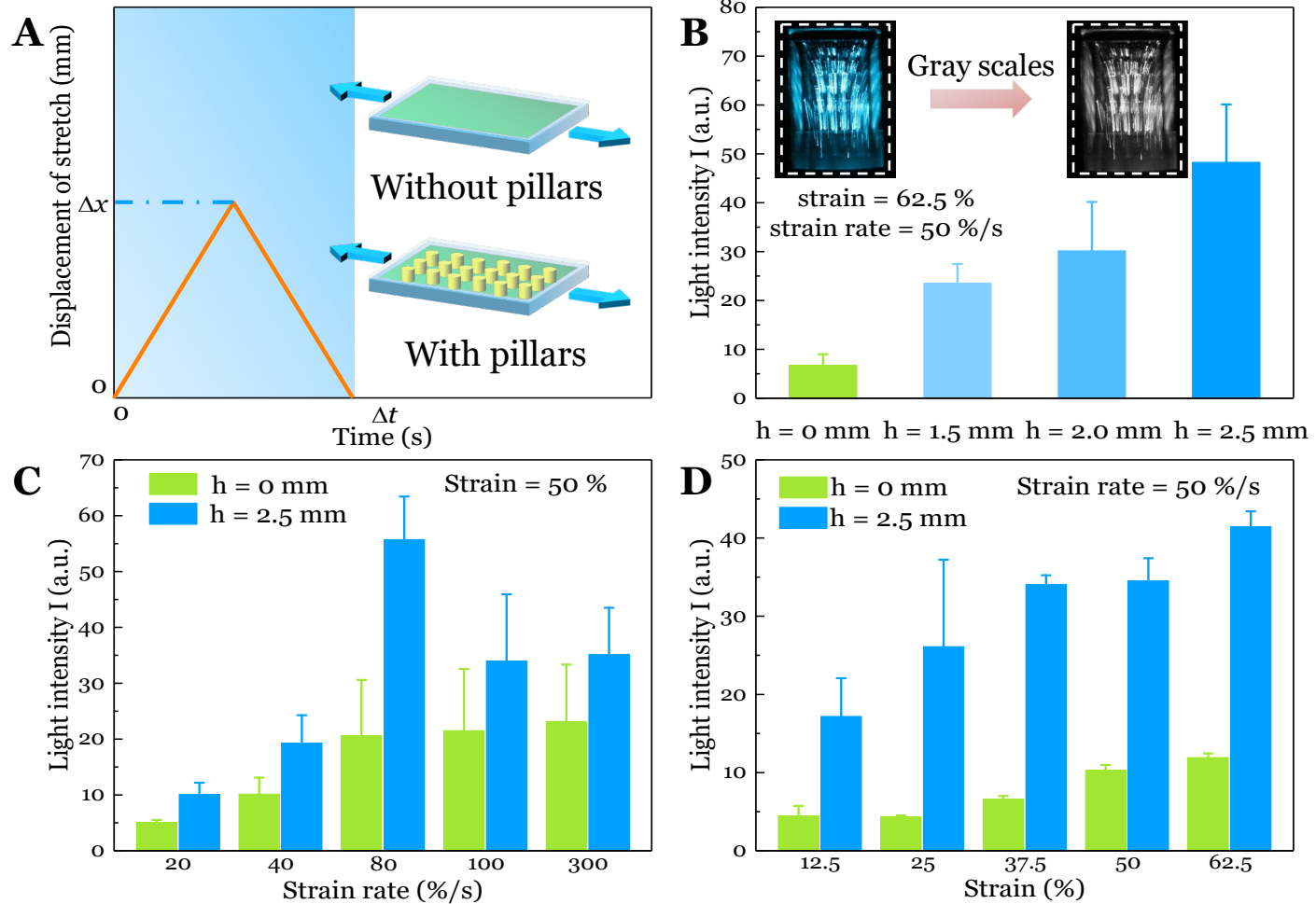


Biohybrid

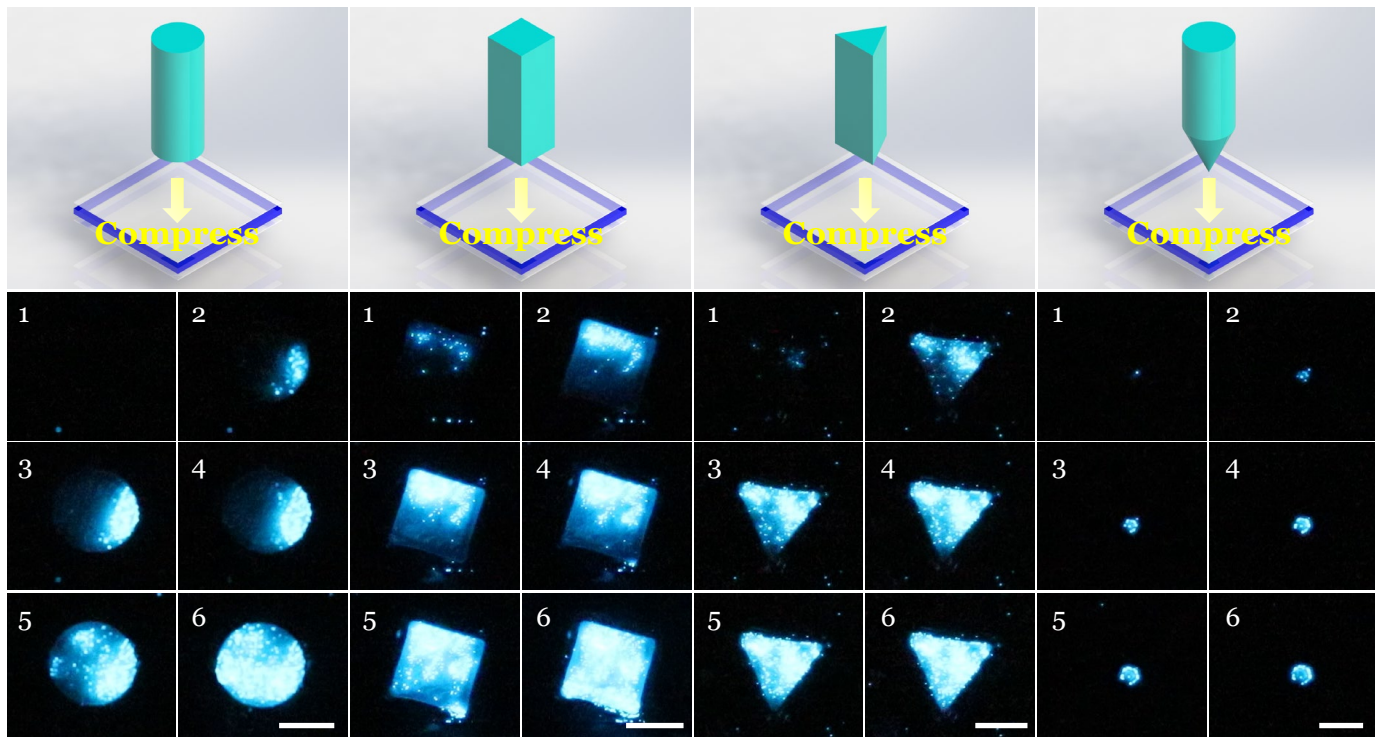
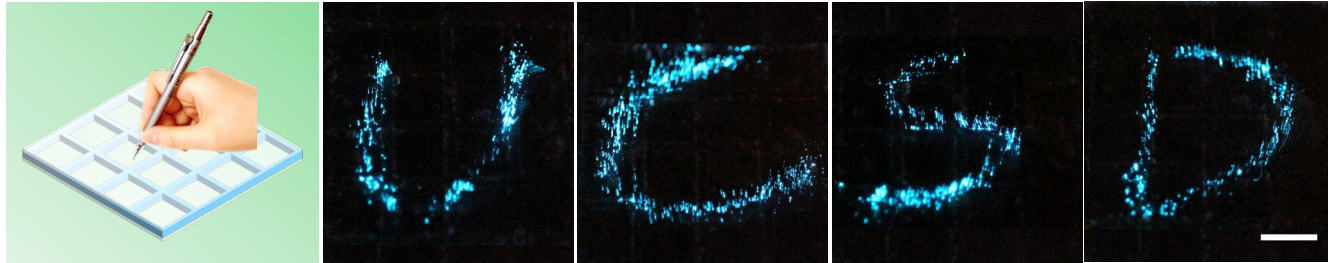
Biohybrid mechanoluminescent device



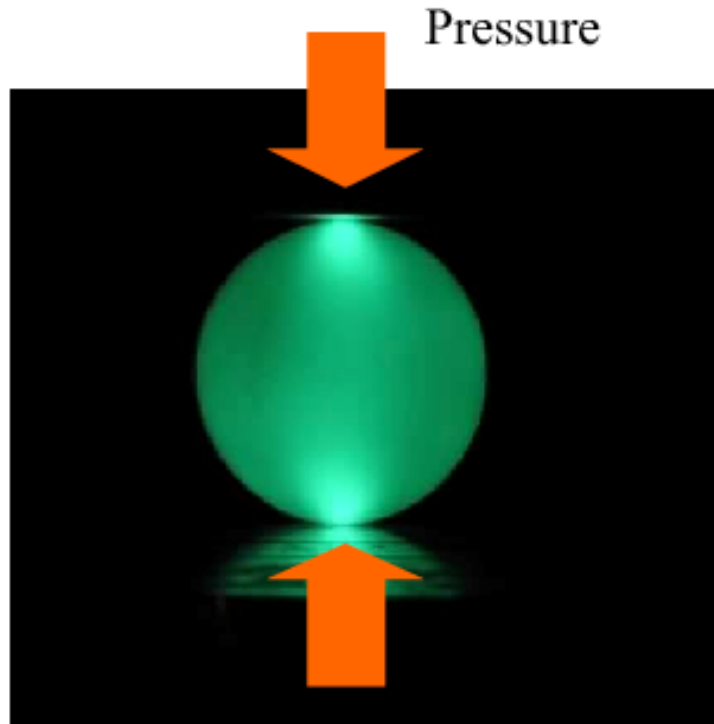
Enhancement of shear stress



Contact sensing

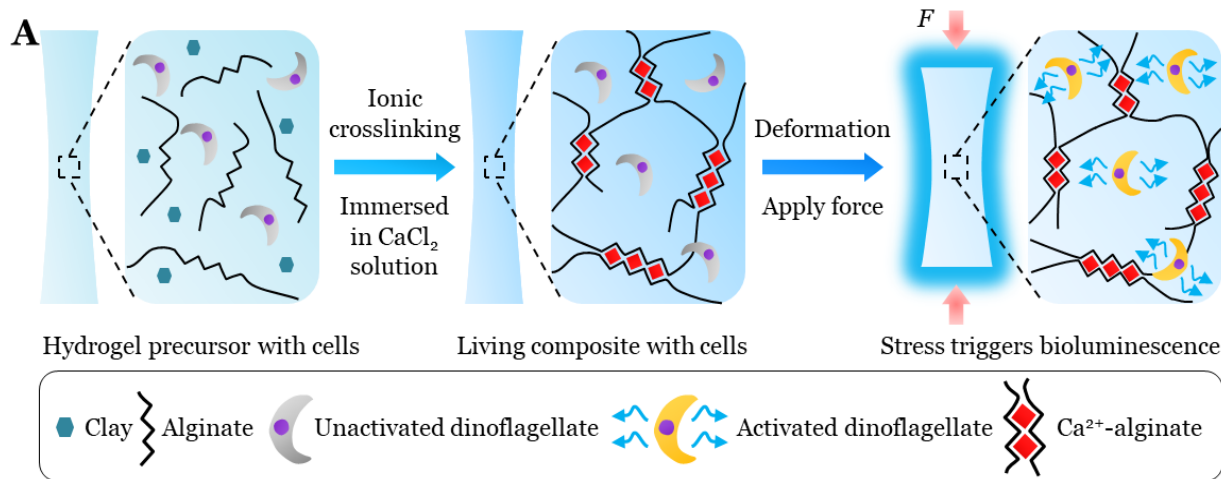


Mechanoluminescent ceramic



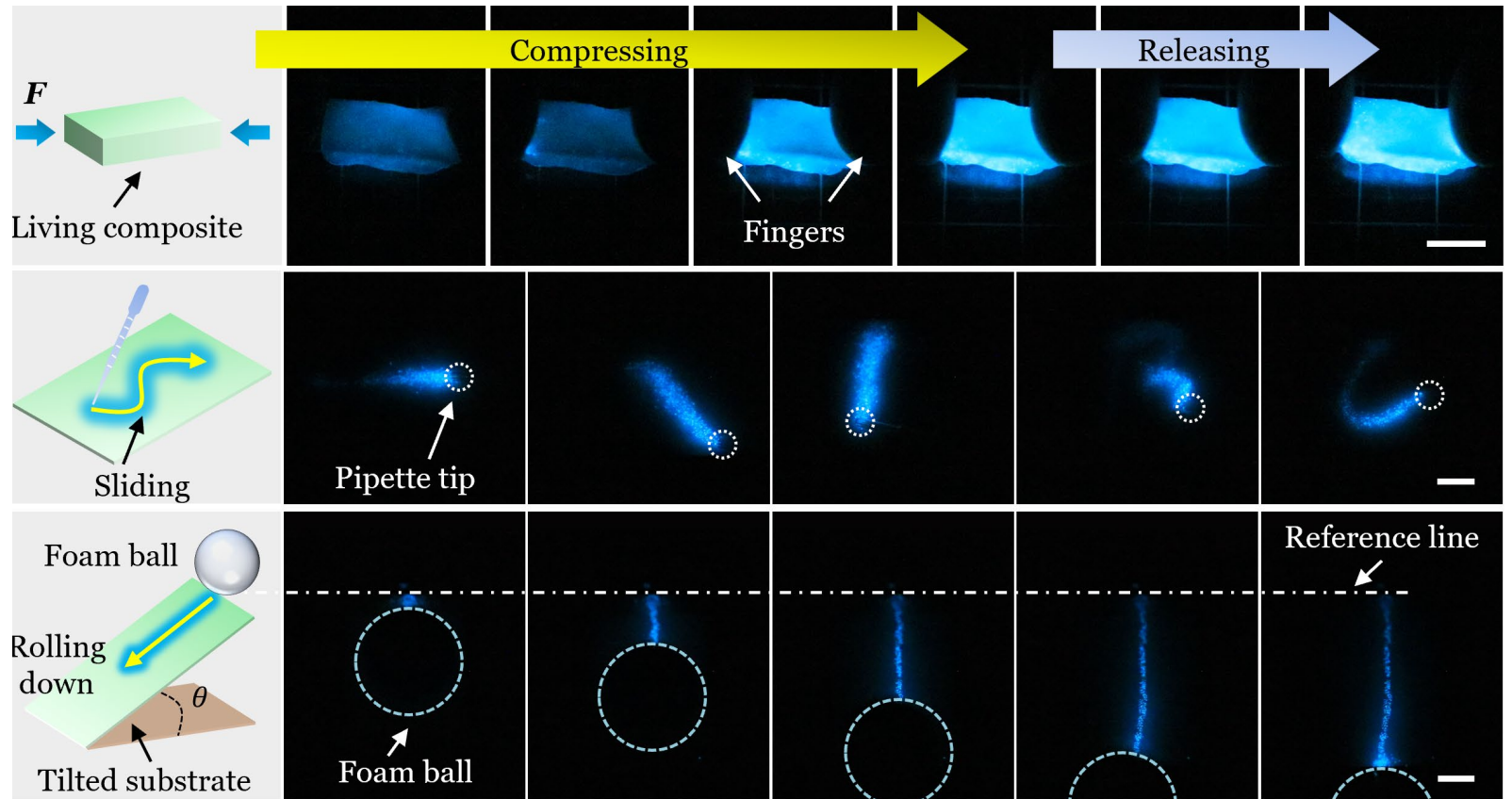
Large stress is required!

Engineered living composite

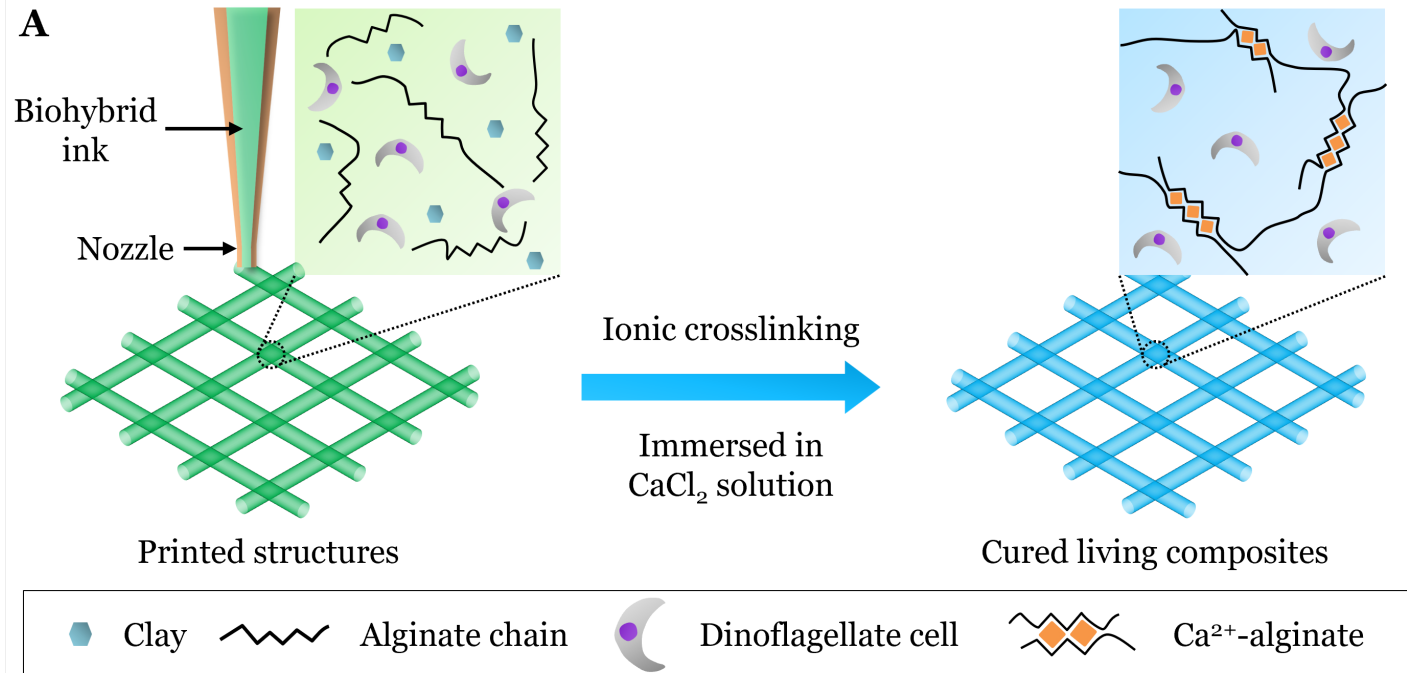


- Biocompatibility
- Robust mechanical properties
- Long life-time
- ...

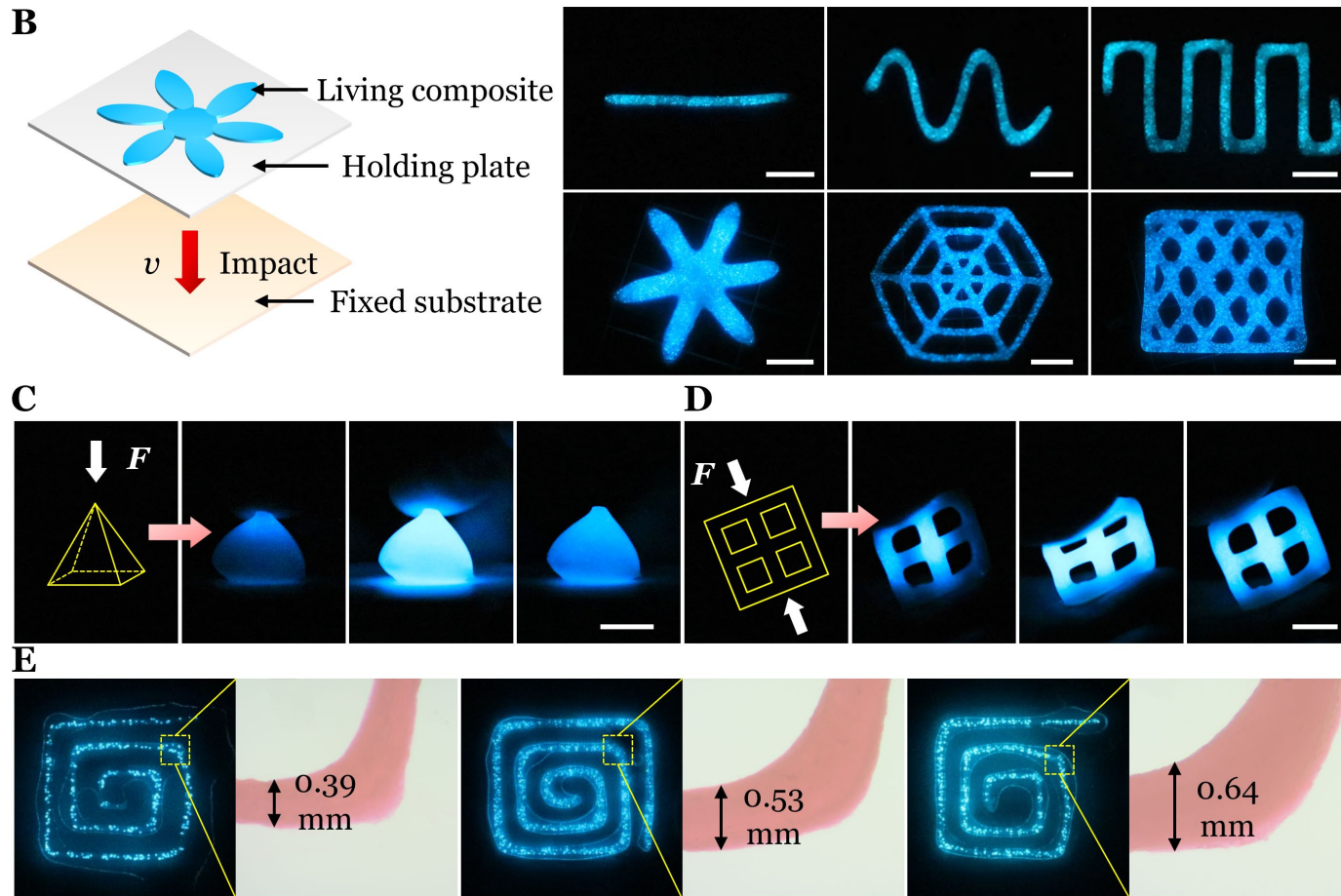
Extremely high sensitivity



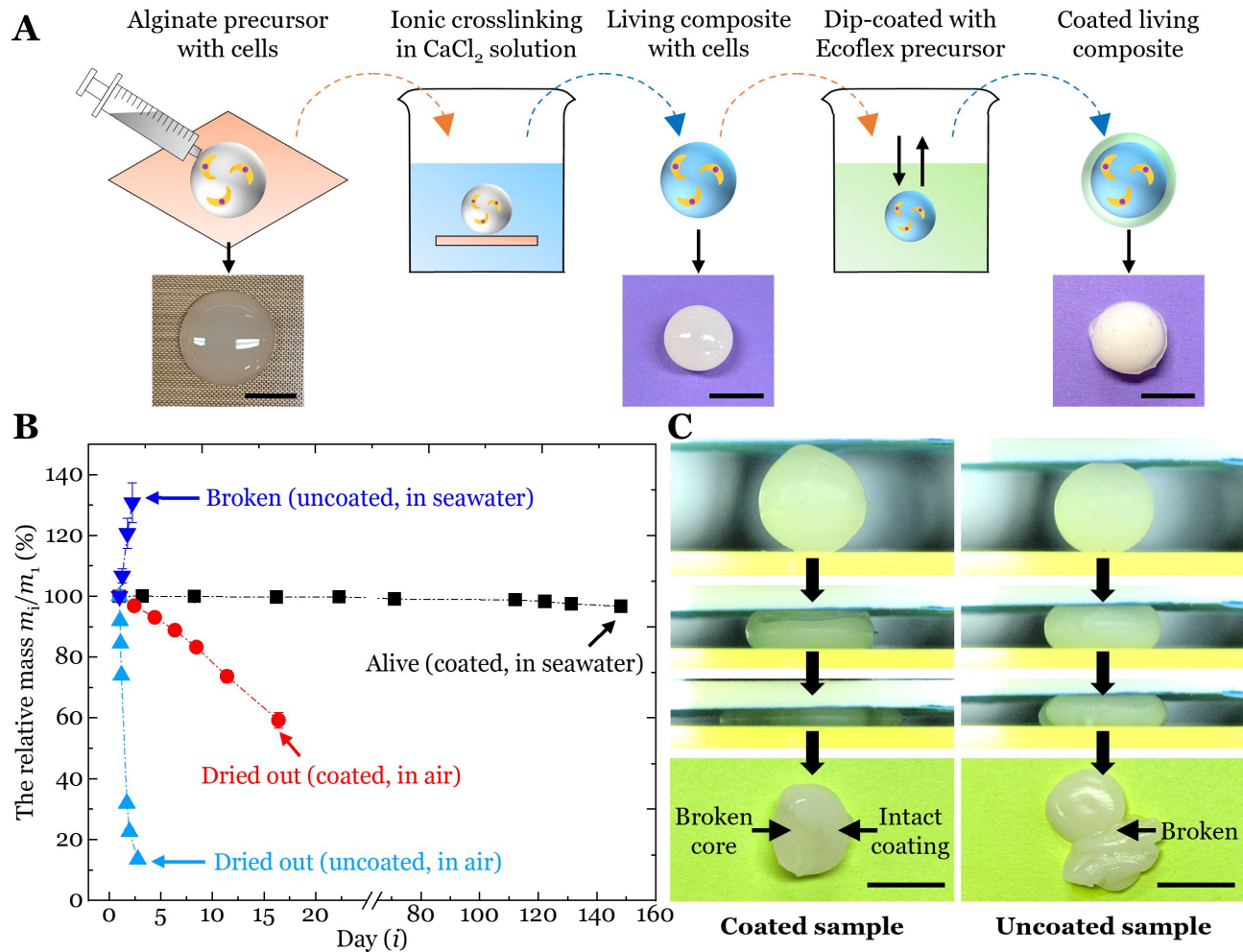
Printing of the living composite



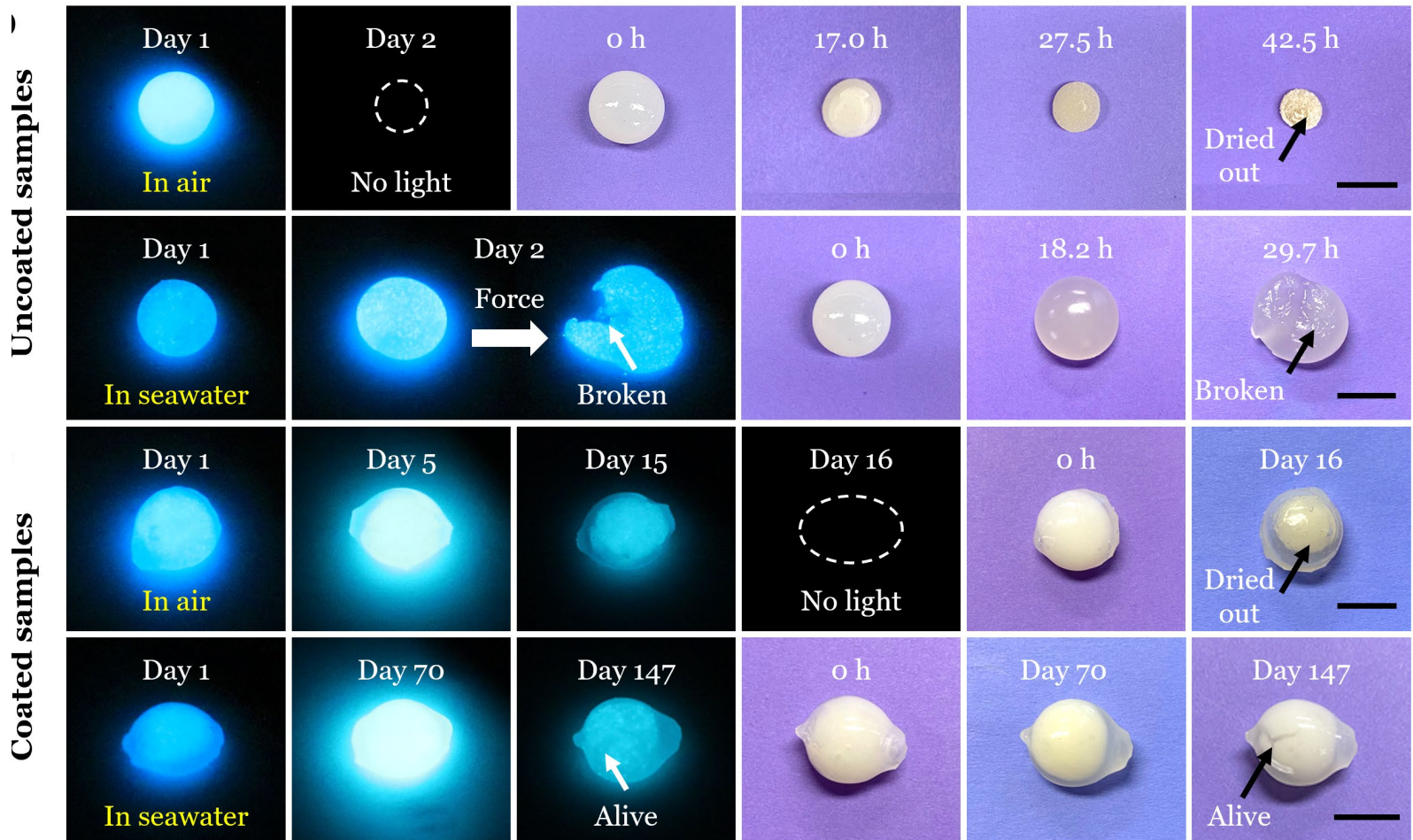
Printing of the living composite



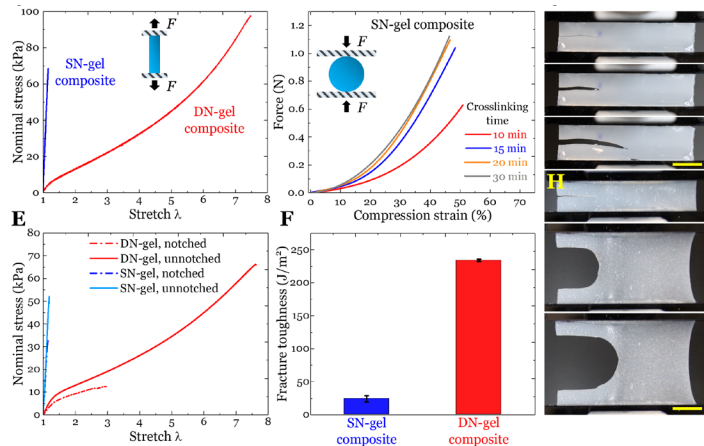
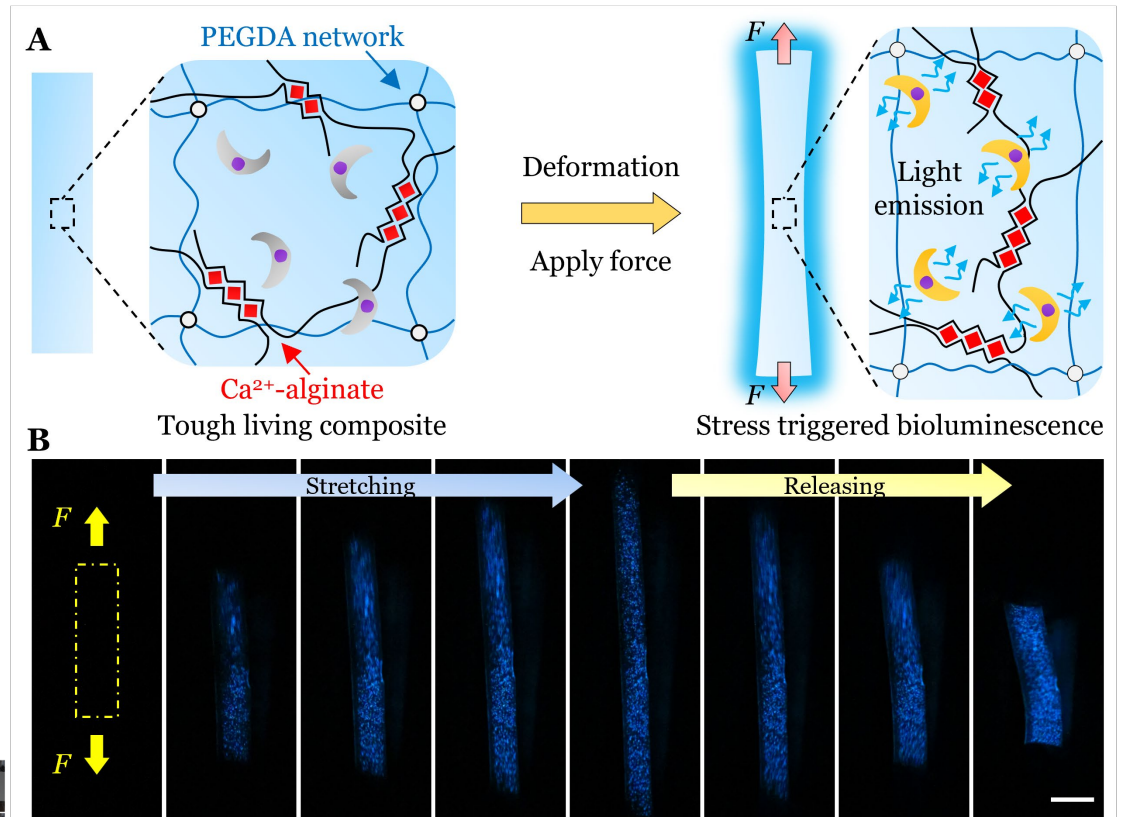
Elastomer coating



Elastomer coating



Interpenetrating network



UCSD Lab demonstration



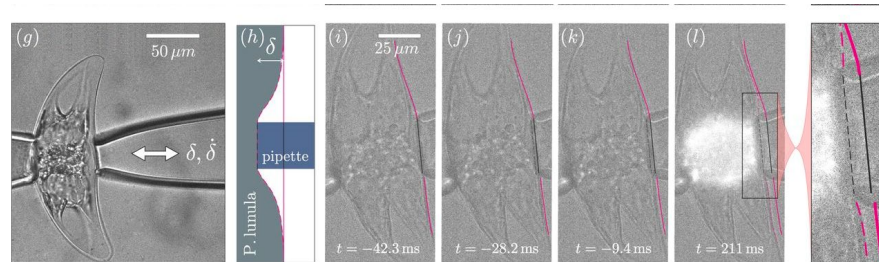


Iris Van Herpen
(Dutch Fashion Designer)

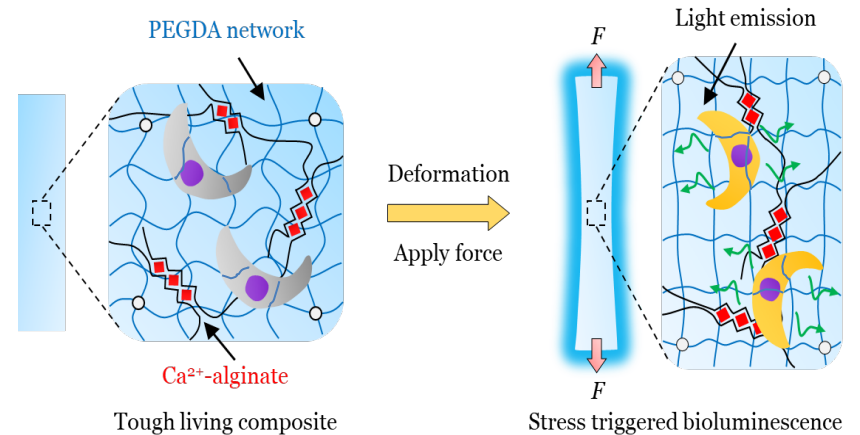
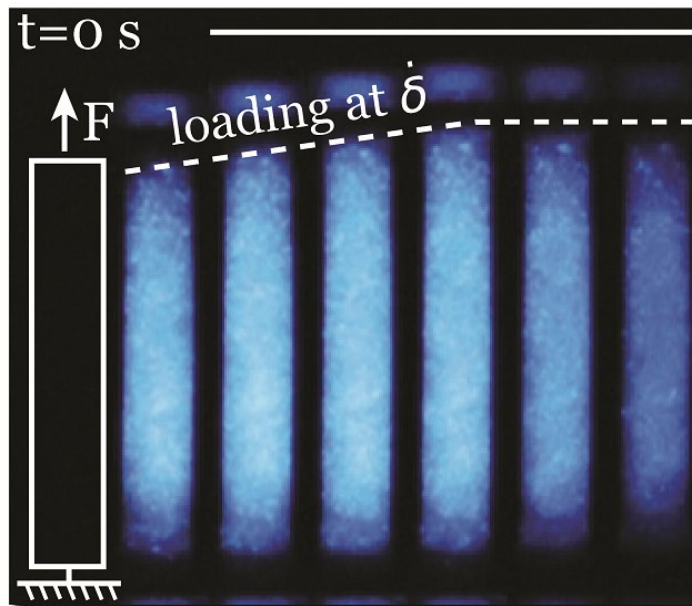


**ELM as a novel platform for better
understanding biology!**

Single cell vs. high throughput experiments



Jalaal, Maziyar, et al. *Physical Review Letters* 125.2 (2020): 028102.

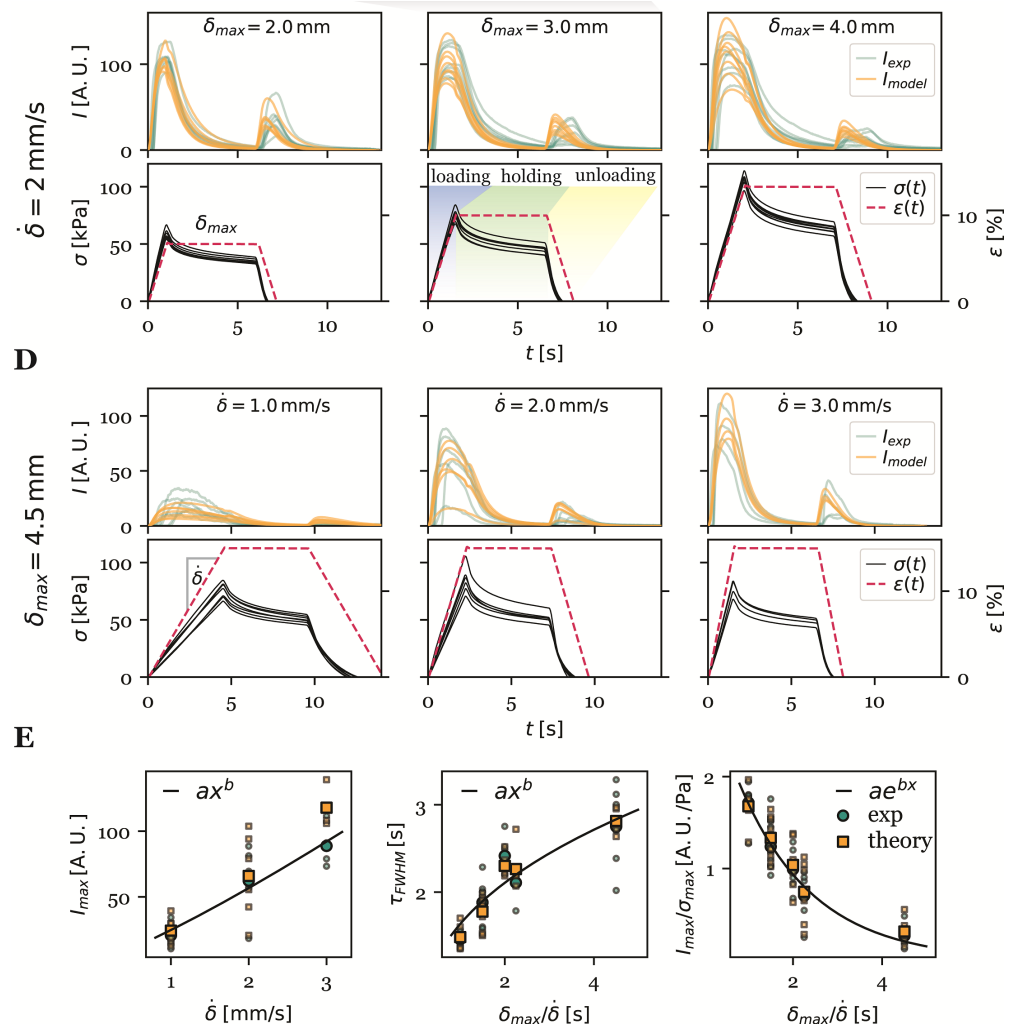
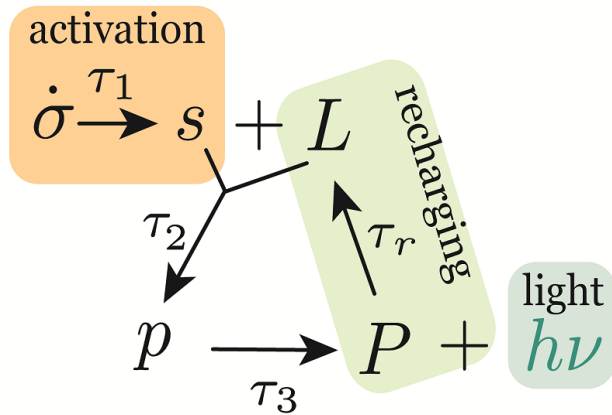


Li, Chenghai, et al. *Science Advances* 9.42 (2023): eadi8643.



Quantitative Modelling

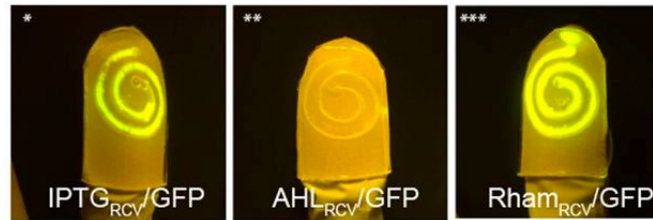
Nico Schramma & Mazi Jalaal
(University of Amsterdam)



Engineered living materials that Learn

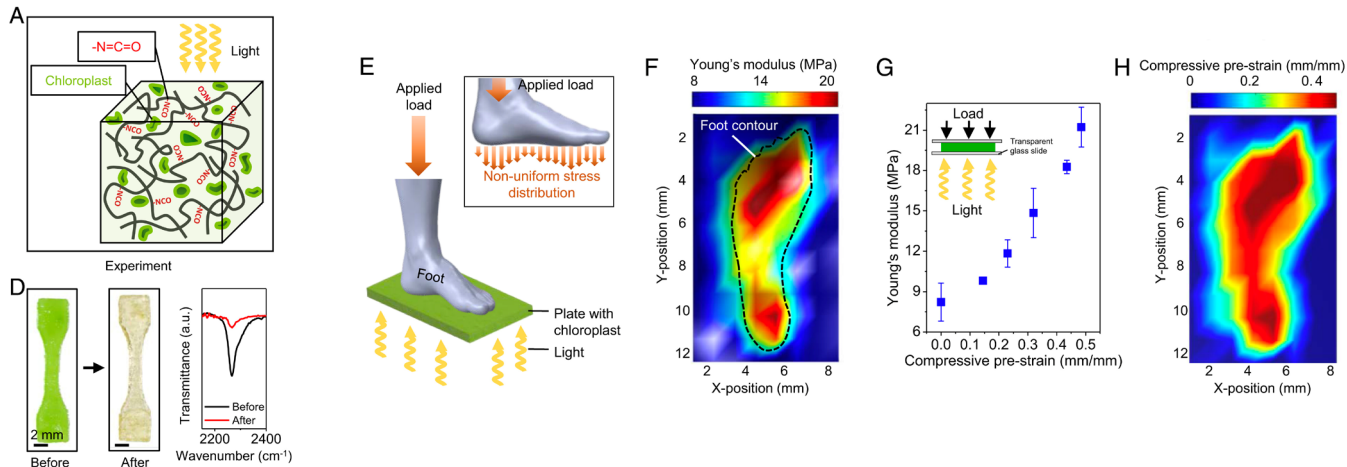
Learning in a material : Desired **response** to (a) perturbation(s)

➤ Responsive to external stimuli



X. Liu et al, *Proc. Natl. Acad. Sci. U.S.A.* 2017

➤ Adaptivity/plasticity



K. Yu, et al, *Proc. Natl. Acad. Sci. U.S.A.* 2021

Engineered living materials that Learn

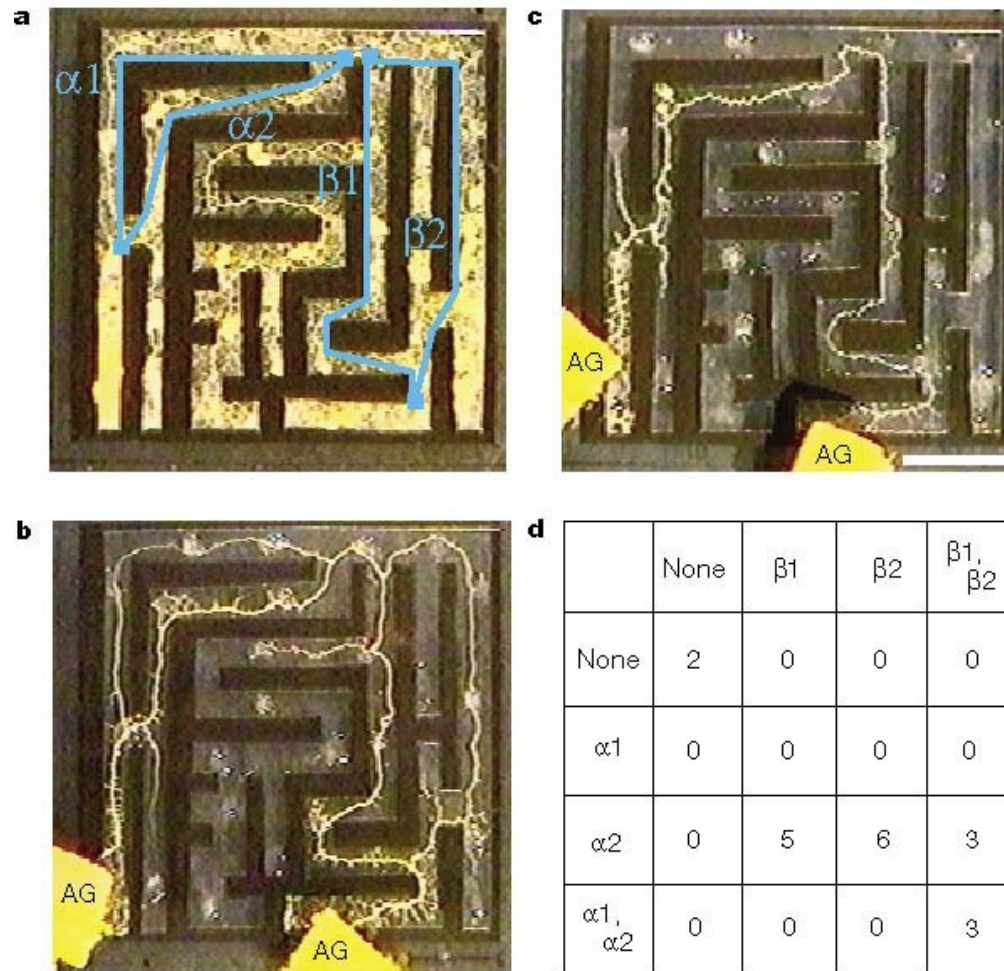
Unique strengths:

- Sophisticated processes in spatially constrained conditions
- Capable of harvesting various forms of energy from the environment
- Possesses unique and unconventional sensing abilities

What are still missing:

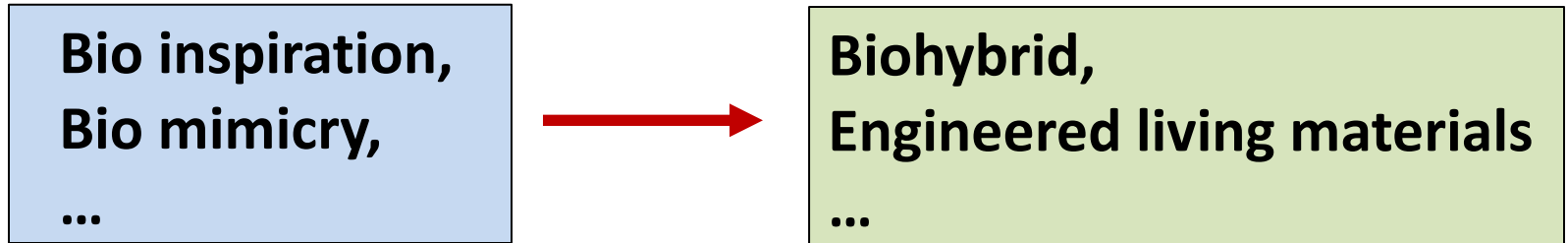
- Implementation of learn rules (minimizing the cost function)
- Feedback loop

Through learning, a slime mould can solve a maze



Nakagaki, T., Yamada, H. & Tóth, Á. *Nature* **407**, 470 (2000).

Summary



Research opportunities:

Design,

Fabrication, processing,

Characterization,

Modelling,

Better understanding biology

Engineered living materials that learn

Thanks for your attention!