Tough physical hydrogel membranes prepared by spin-coating

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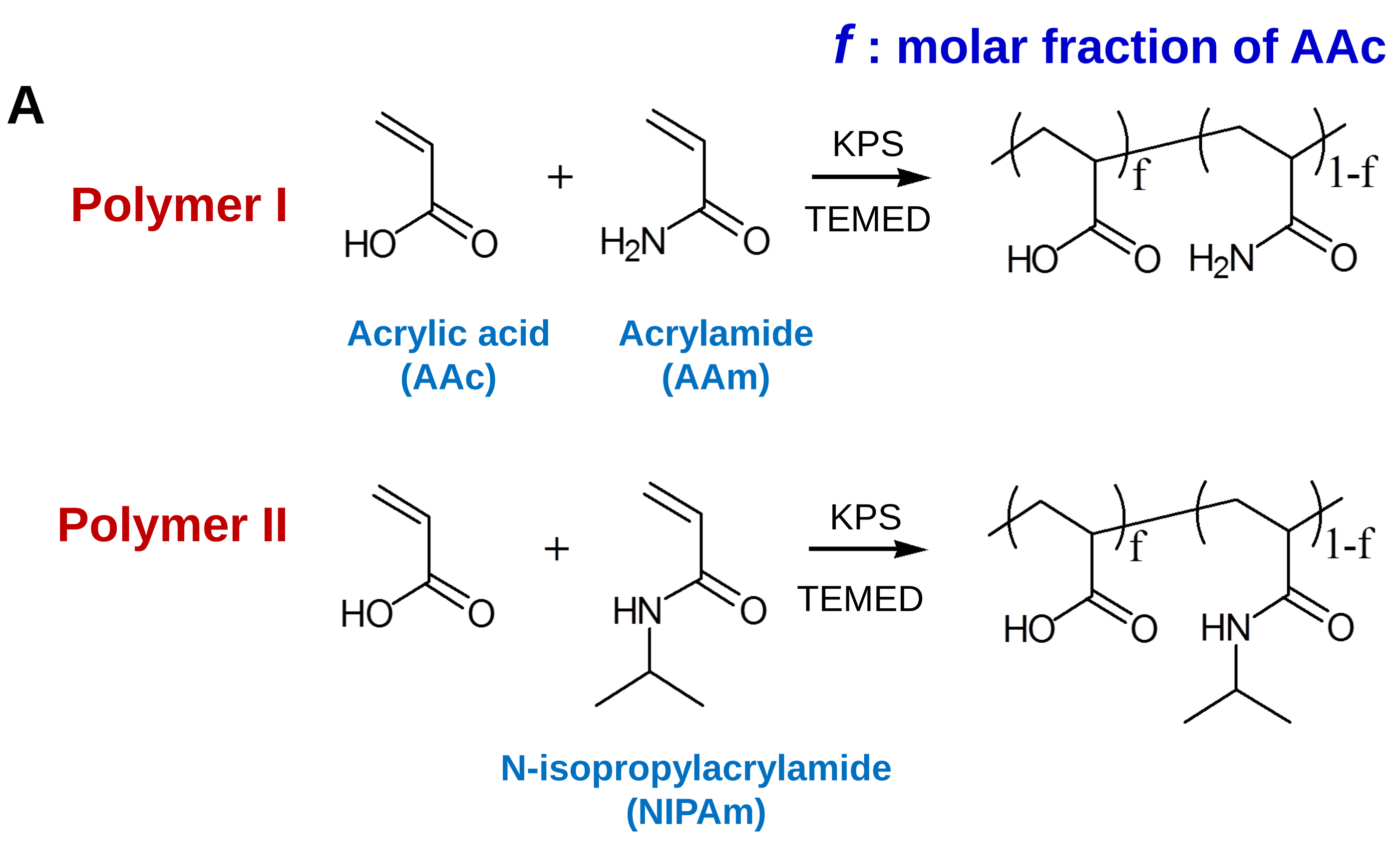
Hydrogel membranes received increasing attentions due to their promising applications in molecular separation, medical dressings, etc. However, they are usually mechanically weak, limiting the handling and applications of these materials. Here we demonstrate the preparation of tough physical gel membranes by spin coating and subsequent physical gelation of poly(acrylic acid-co-acrylamide) in $FeCl_3$ solution. The thickness and mechanical properties of gel membranes can be facilely tuned by polymer composition and spin-coating conditions. Furthermore, thermoresponsive gel membranes are fabricated by spin-coating of poly(acrylic acid-co-*N*-isopropylacrylamide) solution in a similar way; the obtained membranes show fast response and large stroke, which are an ideal material of artificial muscles and soft actuators.

Preparation of gel membranes



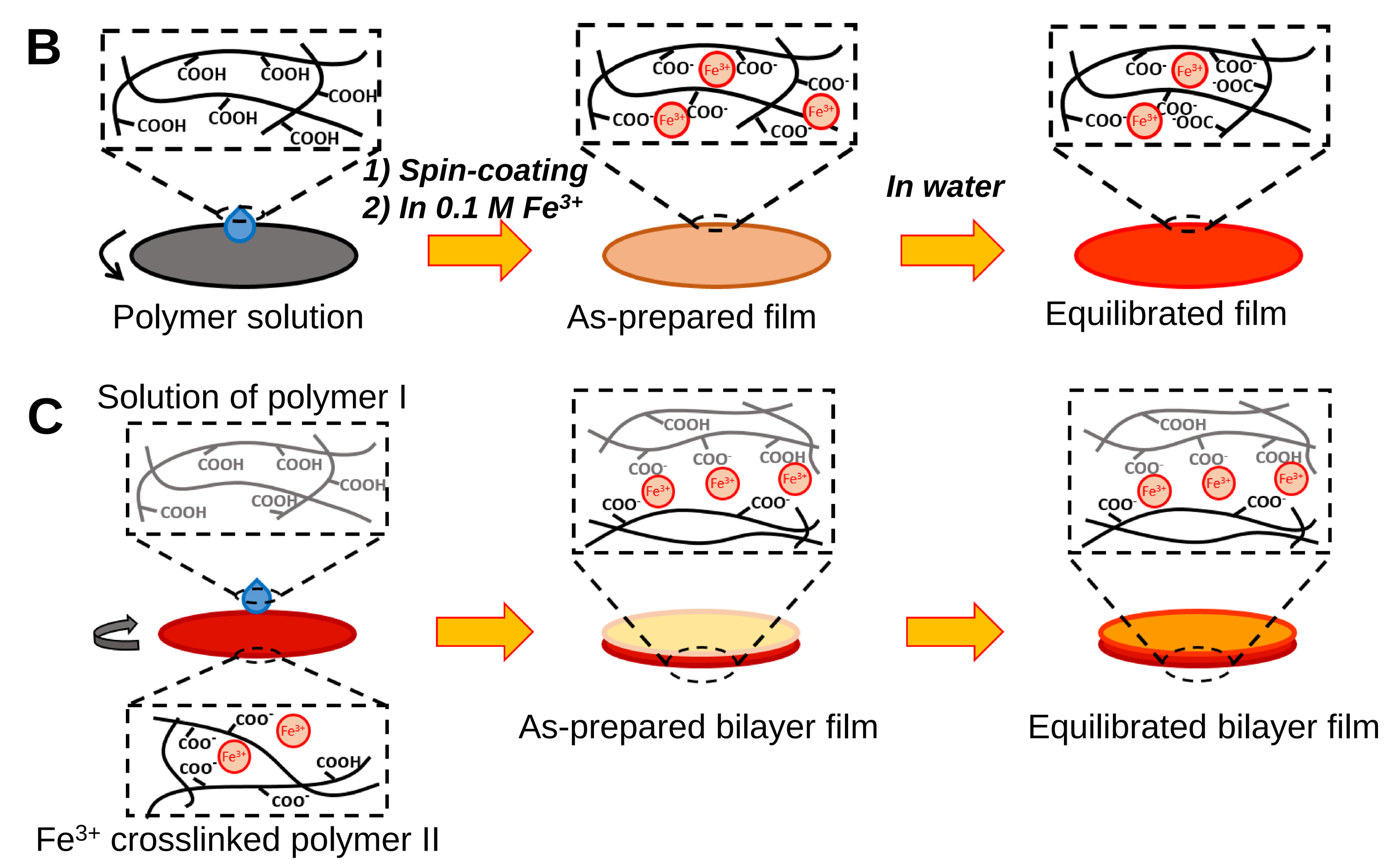


Figure 1. (A) Synthesis of the copolymers of P(AAc-co-AAm) and P(AAc-co-NIPAm) with different compositions. (B,C) Schematic for the preparation of single layer physical hydrogel membrane (B) and bilayler hydrogel membrane.

f: molar fraction of AAc;
Cp: polymer concentration;
V: spin-coating speed.

P(AAc-co-AAm) gel membranes

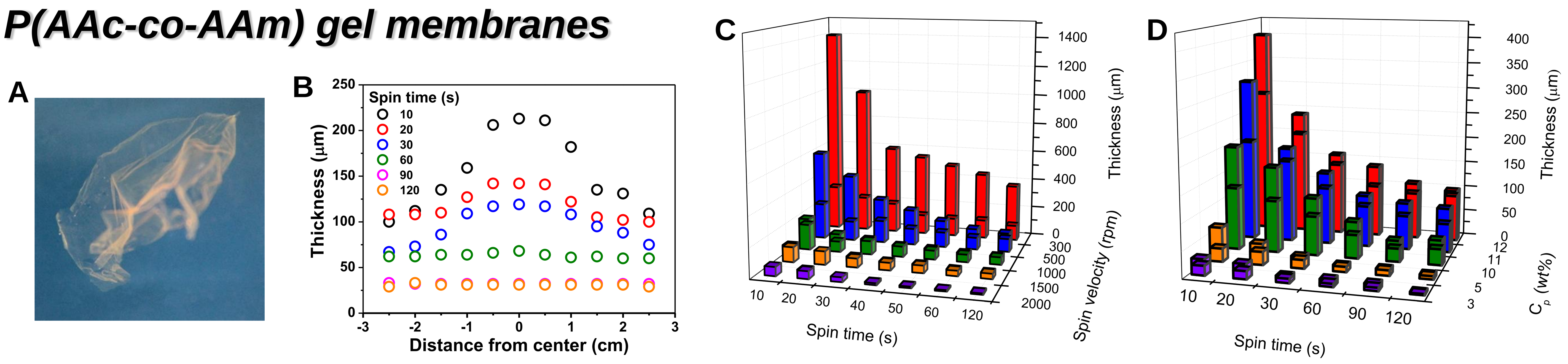


Figure 2. (A) Appearance of P(AAc-co-AAm) gel membrane. (B) Thickness of gel membranes prepared with different time of spin-coating (*f*=15%, V=1000 rpm, C_p=10 wt%). (C) Influences of spin time, speed (C_p=10 wt%) and (C) polymer concentration (V=1000 rpm) on the membrane thickness. The tall and short bars in the same color represent the maximum and minimum thickness of the membrane.

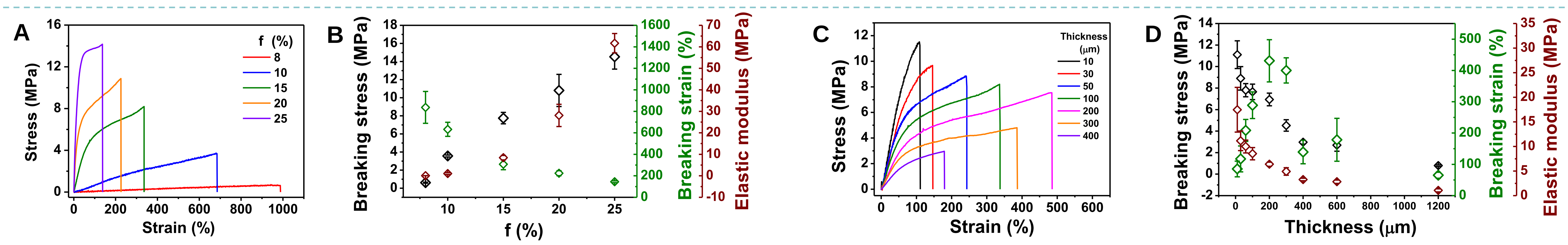


Figure 3. (A,B) Tensile stress-strain curves (A) and corresponding mechanical parameters (B) of gel membranes with different *f* (thickness~100 μm). (C,D) Tensile stress-strain curves (C) and corresponding mechanical parameters (D) of gel membranes with different thickness (*f* =15%).

P(AAc-co-NIPAm) gel membranes

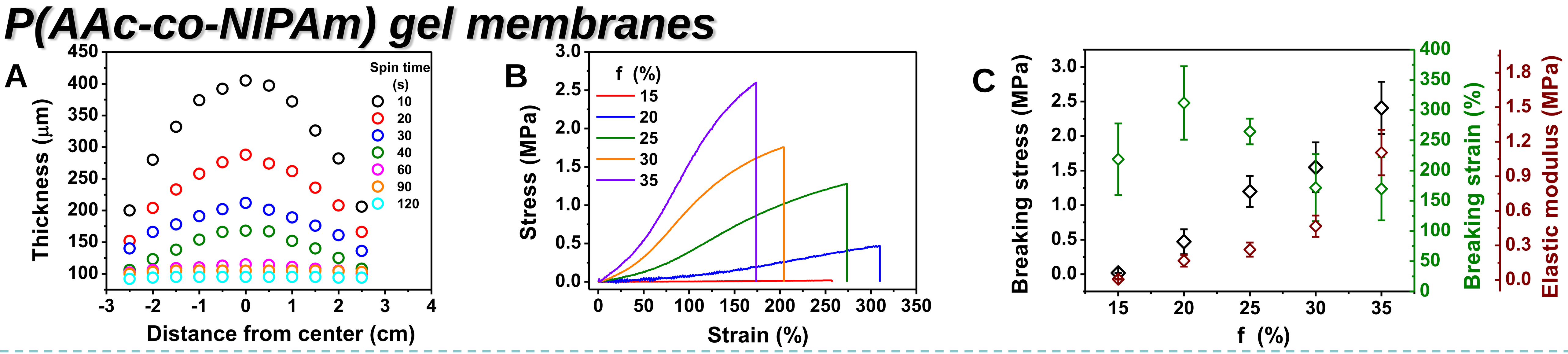


Figure 4. (A) Thickness of P(AAc-co-NIPAm) gel membranes prepared with different time of spin-coating (V=1000 rpm, C_p=10 wt%). (B,C) Tensile stress-strain curves (B) and corresponding mechanical parameters of gel membranes with different *f*.

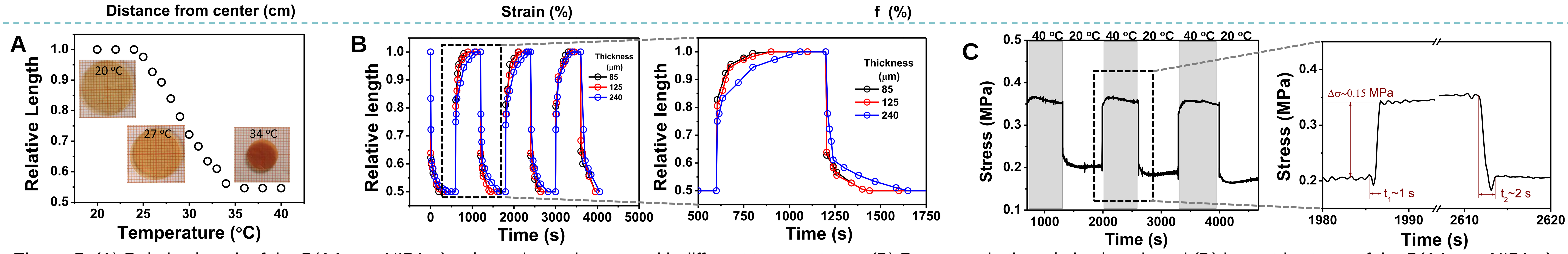


Figure 5. (A) Relative length of the P(AAc-co-NIPAm) gel membrane in water with different temperatures. (B) Response in the relative length and (D) isometric stress of the P(AAc-co-NIPAm) thin film periodically incubated in 20 and 40 °C water bath.

Bending of bilayer gel membrane

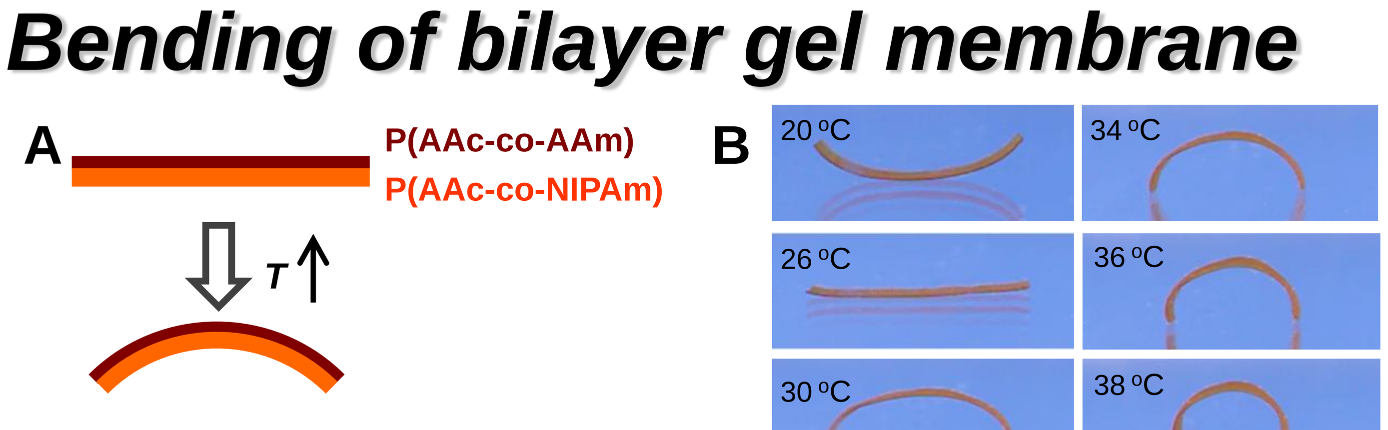


Figure 6. Schematic (A) and photos (B) to show the temperature-triggered bending of P(AAc-co-AAc)/P(AAc-co-NIPAm) bilayer gel membrane.

Conclusions

In summary, tough physical hydrogel membranes with tunable thickness and mechanical properties have been facilely prepared through spin-coating. The thermoresponsive P(AAc-co-NIPAm) gel membranes showed fast response and large stroke, which can be used to fabricate soft actuators.

References

[1] Zheng, S. Y.; Ding, H. Y.; Qian, J.; Yin, J.; Wu, Z. L.; Song, Y. H.; Zheng, Q. *Macromolecules*, **2016**, *49*, 9637.
[2] Kelly, K. D.; Schlenoff, B. J. *ACS Appl. Mater. Interfaces.*, **2015**, 7, 13980.