POLYMER GENOME FOR STRATEGIC DESIGN OF TISSUE-LIKE MATERIALS

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Soft elastic materials enable the creation of implants, substrates, and haptic robotic digits with mechanical properties matching those of biological tissues.

Biological tissues exhibit unique mechanical properties: soft yet simultaneously strong, tough, and flexible – a combination difficult to replicate. The current design strategies for mimicking these characteristics predominately follow an *Edisonian* approach – exploratory mixing of different polymers, crosslinking schemes, and solvents, which is both inflexible in application and imprecise in property control. For example, polymer gels are frequently used to make soft and elastic biomedical implants; however, the constituent solvent leaks upon deformation and may trigger adverse inflammatory responses. Herein, we have developed a universal materials design platform that encodes targeted mechanical behaviors via precision engineering of brush-like polymer network architecture. Within single chemical-component systems, we can vary rigidity from 10^9 to 10^2 Pa, (increase from the trivial 2-fold extension of conventional elastomers to an unprecedented 100-fold, and regulate toughness through strain-adaptive hardening. Specifically, we have created polydimethylsiloxane elastomers that are superelastic (λ=1-12) and supersoft ($G=10^2 - 10^5$ Pa), even in the absence of solvent [1]. The brush-like architecture causes an increase in the diameter of individual polymer molecules, but unlike typical filaments, the molecules remain flexible. This facilitates disentanglement of polymer chains, thereby reducing the rigidity limit by 1000 times and enabling the creation of solvent-free implants, substrates, and haptic robotic digits with mechanical properties matching those of biological tissues [2]. The brush-like architecture offers three independently controlled parameters – side-chain length, grafting density, and crosslink density - that allow for combinatorial variations of elastomer mechanical properties impossible for conventional linear chain elastomers, e.g. simultaneously increasing rigidity and elasticity. Furthermore, this architecture affords many chain-ends that are amendable for chemical modifications and enhance molecular mobility, which directly affects vital physical properties ranging from glass transition and crystallization temperatures to adhesion and permeability.

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References

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