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Rationally Designed Synthetic Protein Hydrogels with Predictable and Controllable Mechanical Properties

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Abstract: A key challenge in biomaterials research is to produce synthetic hydrogels that can replicate the diverse mechanical properties of the naturally occurring tissues for various biomedical applications, including tissue engineering, stem cell and cancer research, cell therapy, and immunomodulation. However, currently, the methods that can be used to control the mechanical properties of hydrogels are very limited and are mainly focused only on the elasticity of hydrogels. In this work, combining single molecule force spectroscopy, protein engineering and theoretical modeling, we show that synthetic protein hydrogels with predictable mechanical properties can be rationally designed using protein building blocks with known mechanical properties at the molecular level. We have successfully tuned the elasticity, extensibility, toughness and self-healing of hydrogels using this approach [1]. We have also demonstrated the engineering of physically crosslinked muscle-mimic hydrogels which are strong, tough, elastic and able to function under significant load and spontaneously self-heal when damaged [1]. Next, by using light-responsive proteins as building blocks, we have been able to engineer hydrogels whose mechanical properties are reversibly tunable by light illumination [2]. These hydrogels can capture the dynamic mechanical environments of naturally occurring extracellular matrices and are potentially suitable for cell culture and tissue engineering. Finally, we show that the hydrogel network structure is also important for the mechanical properties of hydrogels. The hydrogels made of the same protein building blocks but with different network structures can have distinct mechanical responses. These studies provide a biomechanical basis for the rational design of synthetic proteins hydrogels with predictable and controllable mechanical properties.

Keywords: Hydrogel; mechanical properties; protein; cell culture; light responsive

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