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Scaling Reversible Adhesion in Synthetic and Biological Systems
MICHAEL BARTLETT, Polymer Science and Engineering Department, University of Massachusetts Amherst, DUNCAN IRSCHICK, Department of Biology, University of Massachusetts Amherst, ALFRED CROSBY, Polymer Science and Engineering Department, University of Massachusetts Amherst — High capacity, easy release polymer adhesives, as demonstrated by a gecko's toe, present unique opportunities for synthetic design. However, without a framework that connects biological and synthetic adhesives from basic nanoscopic features to macroscopic systems, synthetic mimics have failed to perform favorably at large length scales. Starting from an energy balance, we develop a scaling approach to understand unstable interfacial fracture over multiple length scales. The simple theory reveals that reversibly adhesive polymers do not rely upon fibrillar features but require contradicting attributes: maximum compliance normal to the substrate and minimum compliance in the loading direction. We use this counterintuitive criterion to create reversible, easy release adhesives at macroscopic sizes (100 cm^2) with unprecedented force capacities on the order of 3000 N. Importantly, we achieve this without fibrillar features, supporting our predictions and emphasizing the importance of subsurface anatomy in biological adhesive systems. Our theory describes adhesive force capacity as a function of material properties and geometry and is supported by over 1000 experiments, spanning both synthetic and biological adhesives, with agreement over 14 orders of magnitude in adhesive force.

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