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PROCEEDINGS

Mechanics of Shape-Locking-Governed R2G Adhesion with Shape Memory Polymers

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ABSTRACT

Shape memory polymers (SMPs), with unique properties such as tunable elastic modulus, temporary shape-locking, and shape-recovery upon external stimulations, are emerging as a new class of smart materials with switchable adhesion capabilities. A prominent feature of the adhesion between SMP and a spherical indenter is the so-called R2G adhesion, defined as making contact in the rubbery state to a certain indentation depth followed by detachment in the glassy state. While it has been demonstrated that the R2G adhesion with SMPs can achieve orders of magnitude higher adhesive strength compared to conventional elastic adhesive systems, the fundamental mechanics of R2G adhesion and why it leads to such tremendous adhesion enhancement remain poorly understood. Here [1], combined experimental testing, theoretical analysis, and finite element analysis (FEA) based on a thermomechanical constitutive model of the SMP are carried out to investigate the mechanics of R2G adhesion with a rigid spherical indenter. The study shows that the orders of magnitude enhancement of R2G adhesion over conventional elastic adhesion systems is governed by the shape locking effect during the transition from the rubbery to glassy states. The shape locking effect freezes the deformed configuration of the SMP substrate, resulting in nearly conformal contact between the spherical indenter and the glassy-state SMP substrate, thus greatly increasing the effective radius of curvature of the contact surface. Our experimental measurements and FEA analysis demonstrate that the net effect of shape locking leads to a pull-off force of a sphere nearly the same as that of a flat punch on an elastic half-space with the same contact radius. An explicit expression of the pull-off force for R2G adhesion is proposed based on flat-punch adhesion. Our results from the combined experimentation, modelling and simulations reveal the fundamental mechanics of R2G adhesion. Such understanding provides guidance for the design of SMP smart adhesives.

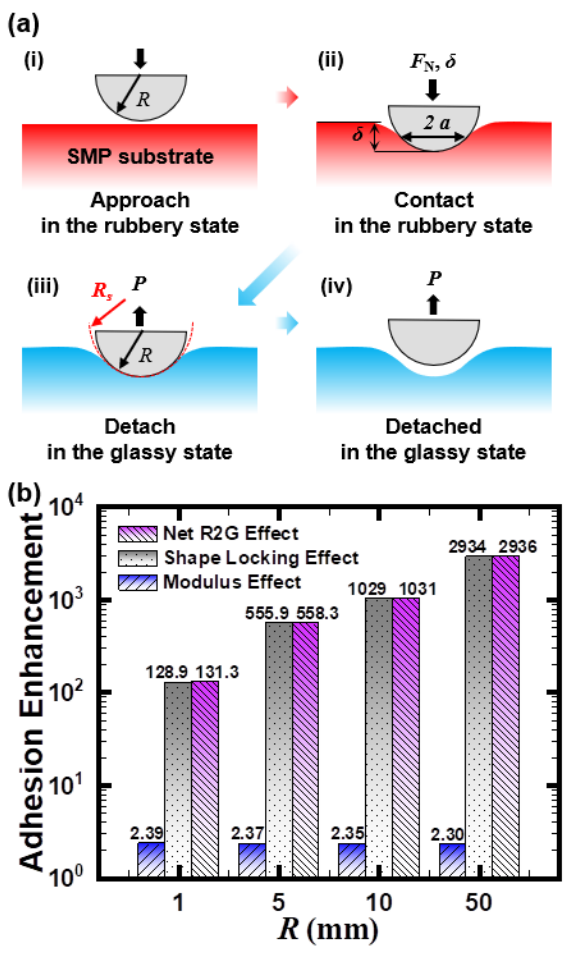

Fig. 1. R2G adhesion between a spherical indenter and the SMP adhesive substrate.

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