MATERIALS ENGINEERING
SEMINAR
"Adhesive Properties of Topographically Patterned and Mechanically Deformed Silicones"
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ABSTRACT

Adhesives are becoming more widely used for applications that previously relied on mechanical methods to secure the interface of two materials due to their cost effectiveness, lower weight, and ease of use. Examples of these new adhesive spaces include robotic systems in manufacturing used to "pick-and-place" objects for assembly, automotives and aircrafts that use composite materials with layers held together by adhesives, and medical devices such as birth control patches that adhere to skin. These materials often undergo constant deformation during use and require precise control of adhesion strength. Consequently, new methods must be developed to control their adhesive properties as adhesives continue to push into new spaces. Furthermore, understanding how the adhesive properties of these materials change due to deformation is critical for selection or design of new adhesives used in specific applications. In this thesis, two experimental studies are conducted to address these needs: (1) design of an adhesive with continuously tunable adhesion strength and (2) investigation of changes in the adhesive properties of silicone elastomers with respect to deformation.

A new material system termed a pressure tunable adhesive (PTA) is developed by patterning a soft adhesive substrate with rigid microscopic and axisymmetric asperities. Unlike traditional pressure sensitive adhesives that exhibit little change in adhesion beyond the threshold pressure required for successful adherence, the PTA is designed to have continuously tunable adhesion over a range of applied pressures. Contact adhesion testing reveals that the adhesion strength of the PTA increases with increasing applied pressure. Experimental and theoretical results show that changes in the pattern geometry can alter the relationship between adhesion strength and applied pressure. A simple and scalable fabrication method, polymer thin film dewetting, is used to pattern the adhesive silicone elastomer (polydimethylsiloxane) with rigid polystyrene asperities. While there are materials that use surface patterning to switch between adhesive and non-adhesive states, there had yet been developed a facile method to fabricate materials with continuous, pressure-tunable adhesion before the development of the PTA.

The surface properties of amorphous elastomers have long been assumed to be independent of deformation. However, experimental studies within the last 15 years have shown this to be false for very soft solids and gels with moduli on the order of 10s-100s KPa. The molecular origin of this phenomenon and its effect on a material's adhesion strength is not well understood in current literature. Therefore, a study on the adhesion strength of crosslinked networks under various degrees of uniaxial, tensile deformation is performed to probe factors that contribute to this effect. The materials tested are rubbers (polydimethylsiloxane) differing in crosslinking density and composition. Contact adhesion testing results indicate that material composition, specifically particle reinforced versus non-particle reinforced rubber, effects adhesion strength while crosslinking density does not have a significant impact.

This thesis demonstrates the importance of adhesion mechanics in the performance of novel and established adhesive systems. In the first study, patterning of the PTA results in a unique contact formation and separation mechanism that yields a pressure tunable adhesion response. In the second study, changes in the silicone molecular architecture impacts the interfacial mechanics during deformation leading to strain-dependent adhesion response. Findings from these studies can be used to inform the design and selection of new adhesive materials.

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