Leaf Inspired Self-Healing Polymers

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Abstract: Developments of self-healing polymers are driven by the demand to prolong their lifetime and maintain high performance. Significant synthetic efforts have been made over the last two decades by incorporating dynamic bonds capable of reversible breaking and reforming. However, the role of physical network design in optimizing self-healing properties of tough polymers remains unclear. Leaves of plants encode self-healing functions by incorporating viscoelastic responses to their multi-layered tissue during growth, thus enabling rapidly wound closure after damage. Inspired by this behavior, self-healing properties were built into polycaprolactone-polyurethane fibers by morphology control. These studies show that while micro-phase separation facilitates high-efficiency self-healing, chemically identical but nano-phase separated fibers exhibit poor healing. Molecular imaging analysis was utilized to understand the underlying mechanisms of the morphology controlled self-healing, which showed that the presence of gradient interphase in micro-phase separated polymers enables storage of entropic energy upon mechanical damage. Release of the stored energy induces a shape memory effect (SME), which is responsible for self-healing. Therefore, the wound closure is attributed to favorable viscoelastic properties originate from the interphase structures. Using this approach, autonomous damage closure and subsequent self-healing can be achieved by morphology control for a variety of commodity polymers. The underlying principles can also be applied to achieve other controllable dynamics with applications in soft robotics, electronics, and medical devices.