Smart Polymers: From Shape Memory to Self-Healing

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The recent several years have witnessed significant advances in the field of shape memory polymers (SMP's) with elucidation of new compositions for property tuning, new mechanisms for shape fixing and recovery, and the initiation of phenomenological modeling. In this talk, I will reveal design paradigms and research findings from our lab on new polymeric compositions and architectures that enable shape memory and self-healing phenomena. Emphasis will be placed on exciting progress in the areas of composites, novel recovery triggering, and applications to medical and mechanical device fields. The talk will be divided into two primary parts, summarized below.

Shape Memory Elastomeric Composites. Shape memory polymers (SMPs) are a class of smart polymeric materials that have the ability to "memorize" a permanent shape, be manipulated to retain, or "fix" a temporary shape, and later recover to its original (permanent) shape upon a stimulus such as heat, electricity, or irradiation. While a large number of SMPs have been developed and studied, very few of the existing SMPs are soft and elastomeric at the application temperature. In this part of the talk, the development of a unique shape memory elastomeric composite (SMEC) using a new and broadly applicable approach, specifically an interpenetrating combination of a crystallizable thermoplastic microfiber network (functioning as the "switch phase" for shape memory) with an elastomeric matrix, will be described. The results show excellent shape memory fixing and recovery and the potential for broad applicability as a functional elastomer.

Self-Healing Blends. A new strategy to produce thermally mendable polymeric materials is demonstrated with an epoxy/poly(ε-caprolactone) (PCL) phase-separated blend. The initially miscible blend composed of 15.5 wt-% PCL undergoes polymerization-induced phase separation (PIPS) during crosslinking of the epoxy, yielding a "bricks and mortar" morphology wherein the epoxy phase exists as interconnected spheres (bricks) interpenetrated with a percolating PCL matrix (mortar). The fully cured material is stiff, strong, and durable. A heating-induced "bleeding" behavior was witnessed in the form of spontaneous wetting of all free surfaces by the molten PCL phase and this bleeding is capable of repairing damage by crack-wicking and subsequent recrystallization with only minor concomitant softening during that process. The mechanism of healing will be revealed. When a moderate force was applied to assist crack closure, thermal mending efficiencies exceeded 100%. We further observed that the DEB phenomenon enables strong and facile adhesion of the same material to itself and to a variety of materials, without any requirement for macroscopic softening or flow.