Shape memory polymers detect changes in temperature or light level

Figure 1. Photo sequence demonstrating the thermally induced shape memory effect for a poly (e-caprolactone dimethacrylate) polymer. Starting from room temperature, the polymer, in its temporary shape (cube, left) is heated up to 70 ºC, which is above its glass-transition temperature. Within 60 seconds, the sample recovers its permanent shape, which is a nearly planar film (right). Reproduced from Lendlein, A. et al. *Encyclopedia of Materials Sci. and Tech*., 1-9.

Sandia scientists are creating composite materials that use shape memory to generate electrical signals

Active polymer composites are an emerging class of materials offering innovative strategies and readily customized capabilities for intrinsic detection and embedded surveillance. Newly developed active polymer composites for embedded sensors detect and mechanically respond to abnormal thermal and optical environments by combining the capabilities of shape memory polymers (SMP), piezoelectric films, and ceramic fibers. These composites undergo a shape change in response to a specific temperature or light stimuli. The shape change is detected when it simultaneously generates an electrical signal to be transmitted, archived, or implemented. The temperature sensitivity varies with the polymer systems; for example, some current commercial systems are designed to expand at body temperature and have possible medical applications. Sandia is exploring different applications at higher temperatures.

Thermally activated SMPs are characterized by a critical polymer cross-link density and molecular spacing, which enables partial rearrangement of the polymer microstructure in the heated, mobile state, but does not enable full equilibration to a stress-free state. A thermally activated SMP device is processed into a permanent shape and then programmed to fix its temporary shape. The permanent shape is recovered by reheating beyond the transition temperature (Figure 1). Optically induced SMPs are elastomers with cross-links that undergo a photo-reversible chemical change. This process allows the elastomer to reversibly change shape through a microstructural rearrangement of the freed polymer chain segments.

Sandia is combining the sensing and mechanical actuation capabilities of SMPs with the electronic signaling capability of piezoelectrics to create flexible temperature and light-triggered actuators to perform work and generate an electrical signal to verify the actuation event. Thermal SMPs do not possess attractive combinations of processing and performance properties, and novel systems are being formulated and evaluated. The optical SMPs are based on white-light activated spiropyran cross-linkers that are neutral, rigid, ring-closed molecules under ambient light environments. In the dark, the spiropyran converts to the charged, planar, ring-opened, colored merocyanine form (Figure 2, next page). Light sensitive materials are very new, and Sandia plans to optimize and adjust this structural transformation to produce shape changes in a variety of polymers.

Because of the inherent complexity of the material response, we are developing physically based constitutive models of the SMP. We are also using finite element models of the shape memory and electromechanical behavior of active composite structures and devices (Figure 3, next page).

Sandia is seeking new and valuable applications for SMPs, which have many significant features. A unique feature is that SMPs require no power—no battery—as do other sensors. They are self-powered whether used as sensors or in any other way.

Technical Contact:
Linda Domeier
925-294-2350
esherte@sandia.gov

Science Matters Contact:
Alan Burns, Ph.D.
505-844-9642
aburns@sandia.gov

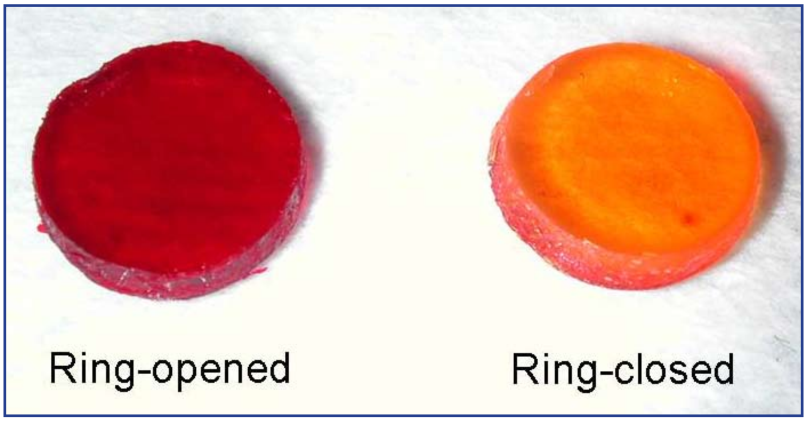

Figure 2. Activated spyropyran gels

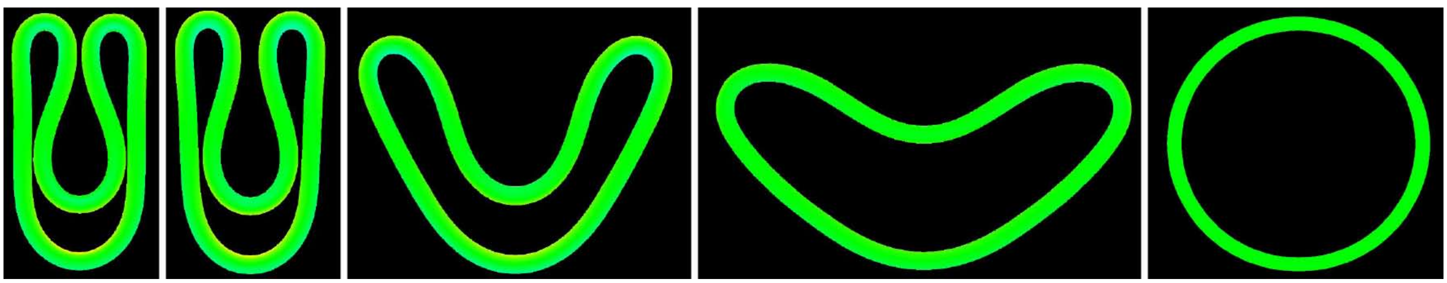

Figure 3. Finite element simulation demonstrating the thermo-viscoelastic relaxation mechanism of the recovery of a thermally induced shape memory polymer. The polymer is initially in its temporary folded shape. It recovers its permanent circular ring shape upon heating to above the glass-transition temperature.

Sandia National Laboratories

6/2007

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND 2007-3337P

National Nuclear Security Administration