



Light-Driven Polymeric Bimorph Actuators

Simple, relatively-low-power actuators could be integrated into MEMS and MEOMS.

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Light-driven polymeric bimorph actuators are being developed as alternatives to prior electrically and optically driven actuators in advanced, highly miniaturized devices and systems exemplified by microelectromechanical systems (MEMS), micro-electro-optical-mechanical systems (MEOMS), and sensor and actuator arrays in “smart” structures. These light-driven polymeric bimorph actuators are intended to satisfy a need for actuators that (1) in comparison with the prior actuators, are simpler and less power-hungry; (2) can be driven by low-power visible or mid-infrared light delivered through conventional optic fibers; and (3) are suitable for integration with optical sensors and multiple actuators of the same or different type.

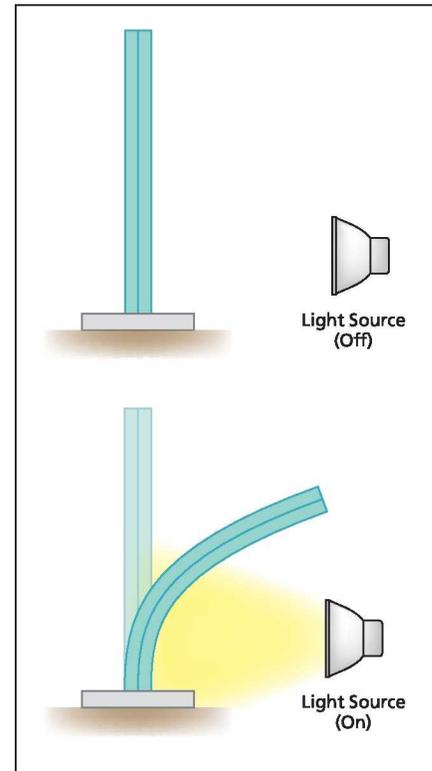
The immediate predecessors of the present light-driven polymeric bimorph actuators are bimorph actuators that exploit a photostrictive effect in lead lanthanum zirconate titanate (PLZT) ceramics. The disadvantages of the PLZT-based actuators are that (1) it is difficult to shape the PLZT ceramics, which are hard and brittle; (2) for actuation, it is necessary to use ultraviolet light (wavelengths < 380 nm), which must be generated by use of high-power, high-pressure arc lamps or lasers; (3) it is difficult to deliver sufficient ultraviolet light through conventional optical fibers because of significant losses in the fibers; (4) the response times of the PLZT actuators are of the order of several seconds — unacceptably long for typical applications; and (5) the maximum mechanical displacements of the PLZT-based actuators are limited to those characterized by low strains beyond which PLZT ceramics disintegrate because of their brittleness.

The basic element of a light-driven bimorph actuator of the present development type is a cantilever beam comprising two layers, at least one of which is a polymer that exhibits a photomechanical effect (see figure). The dominant mechanism of the photomechanical effect is a photothermal one: absorption of light energy causes heating, which, in turn, causes thermal expansion. The lay-

ers are made thin enough that the difference in temperature between the two layers in the presence of illumination is negligible. If the materials in the two layers are tailored to exhibit different degrees of the photomechanical effect, then the two layers undergo differential expansion when illuminated. As in other bimorph actuators, the differential expansion causes bending of the cantilever, and this bending constitutes the desired actuation. When the illumination is turned off, the illuminated spot cools and the cantilever returns to its previous shape. The typical response time of the photothermal mechanism is of the order of milliseconds, and the magnitude of the effect is relatively large (characterized by a strain of as much as 1 percent or greater).

One suitable photosensitive polymer is poly(vinylidene fluoride) [PVDF], which, heretofore, has been better known as a piezoelectric material. Processing conditions used in fabricating the two layers from PVDF or other polymer(s) can be chosen so that the coefficients of thermal expansion of the two layers differ by a significant amount, as needed to obtain the desired differential expansion. This polymer is flexible and, in comparison with PLZT ceramics, can be made to produce greater maximum strain using less light power. This polymer can be shaped by use of a variety of techniques, including molding, stamping, bending, cutting, and rolling. This polymer is also suitable for such thin-film techniques as spin casting, spraying, dipping, vapor deposition, contact printing, and photolithography that would be used in fabricating MEMS and MEOMS containing actuators of the present type.

The visible or infrared light needed to drive actuators of this type can be delivered via conventional communication-type optical fibers without incurring large losses like those of ultraviolet light needed to drive PLZT-based actuators. Lenses and/or other optical components can be used in conjunction with the optical fibers to shape the light



The Cantilever Beam depicted here comprises two layers that exhibit different degrees of a photomechanical effect. Consequently, illumination causes differential expansion that, in turn, causes bending of the beam.

beams and focus them at specific locations along actuator cantilevers as need for specific applications. Optionally, by use of a suitable number of optical fibers and lenses, light can be delivered to an actuator at one or more locations in pulses, and the pulses can be shaped and timed to cause the actuator to execute a desired trajectory.

This work was done by Gregory Adamovsky of Glenn Research Center and Sergey S. Sarkisov and Michael J. Curley of Alabama A&M University. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17473-1.