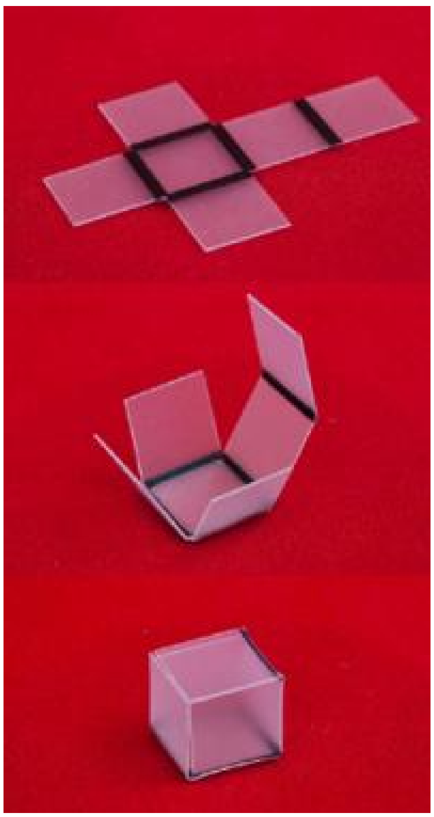
Using light, researchers convert 2-D patterns into 3-D objects

November 10 2011



The new technique can be used to create a variety of objects, such as cubes or pyramids, without ever having to physically touch the material.

(PhysOrg.com) -- Researchers from North Carolina State University have developed a simple way to convert two-dimensional patterns into three-dimensional (3-D) objects using only light.

“This is a novel application of existing materials, and has potential for rapid, high-volume manufacturing processes or packaging applications,” says Dr. Michael Dickey, an assistant professor of chemical and biomolecular engineering at NC State and co-author of a paper describing the research.

The process is remarkably simple. Researchers take a pre-stressed plastic sheet and run it through a conventional inkjet printer to print bold black lines on the material. The material is then cut into a desired pattern and placed under an infrared light, such as a heat lamp.

The bold black lines absorb more energy than the rest of the material, causing the plastic to contract – creating a hinge that folds the sheets into 3-D shapes. This technique can be used to create a variety of objects, such as cubes or pyramids, without ever having to physically touch the material. The technique is compatible with commercial printing techniques, such as screen printing, roll-to-roll printing, and inkjet printing, that are inexpensive and high-throughput but inherently 2-D.

By varying the width of the black lines, or hinges, researchers are able to change how far each hinge folds. For example, they can create a hinge that folds 90 degrees for a cube, or a hinge that folds 120 degrees for a pyramid. The wider the hinge, the further it folds. Wider hinges also fold faster, because there is more surface area to absorb energy.

“You can also pattern the lines on either side of the material,” Dickey says, “which causes the hinges to fold in different directions. This allows you to create more complex structures.”

The researchers developed a computer-based model to explain how the process works. There were two key findings. First, the surface temperature of the hinge must exceed the glass transition temperature of the material, which is the point at which the material begins to soften.

Second, the heat has to be localized to the hinge in order to have fast and effective folding. If all of the material is heated to the glass transition temperature, no folding will occur.

“This finding stems from work we were doing on shape memory polymers, in part to satisfy our own curiosity. As it turns out, it works incredibly well,” Dickey says.

More information: The paper, “Self-folding of polymer sheets using local light absorption,” was published Nov. 10 in the journal *Soft Matter*, and was co-authored by Dickey; NC State Celanese Professor of Chemical and Biomolecular Engineering Jan Genzer; NC State Ph.D. student Ying Liu; and NC State undergraduate Julie Boyles. The work was supported, in part, by the U.S. Department of Energy.

Abstract
This paper demonstrates experimentally and models computationally a novel and simple approach for self-folding of thin sheets of polymer using unfocused light. The sheets are made of optically transparent, pre-strained polystyrene (also known as Shrinky-Dinks) that shrink in-plane if heated uniformly. Black ink patterned on either side of the polymer sheet provides localized absorption of light, which heats the underlying polymer to temperatures above its glass transition. At these temperatures, the predefined inked regions (i.e., hinges) relax and shrink, and thereby cause the planar sheet to fold into a three-dimensional object. Self-folding is therefore achieved in a simple manner without the use of multiple fabrication steps and converts a uniform external stimulus (i.e., unfocused light) on an otherwise compositionally homogenous substrate into a hinging response. Modeling captures effectively the experimental folding trends as a function of the hinge width and support temperature and suggests that the hinged region must exceed the glass transition temperature of the sheet for folding to occur.

Provided by North Carolina State University