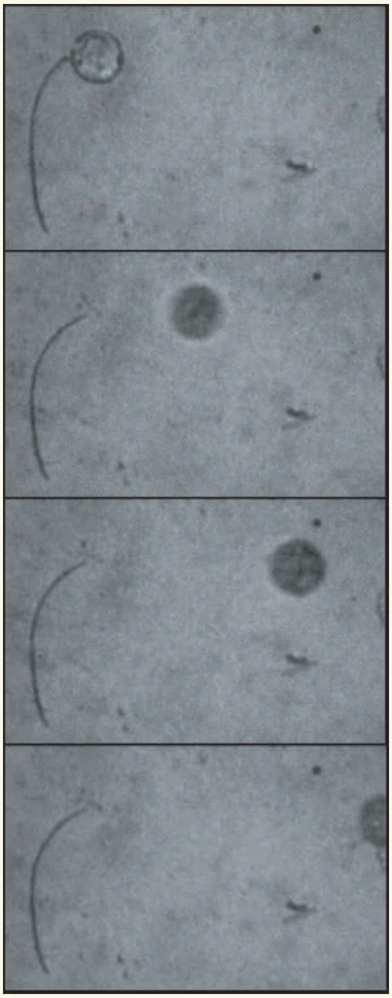

Figure 1 | Light-driven crystal movement. Irie and colleagues[3] have prepared crystals that bend rapidly in response to light. This series of images from the authors' supplemental movie shows how a single crystal fibre, when illuminated by a pulsed laser, bends within 1 millisecond to launch a 50-μm gold ball towards the light source.

the product. For this to happen, the product molecules must form randomly throughout the starting material, rather than establishing larger 'islands' of a separate crystal phase that would greatly disrupt the original bulk lattice. Such phase separation makes cracking all but inevitable, because just a 1% change in lattice spacing, caused by product formation, would force neighbouring lattices within a distance of 50 molecules to fall completely out of register.

There is a handful of special cases in which the shape change that occurs upon reaction is subtle enough to allow individual product molecules to fit into the original lattice. In such compounds, product molecules can be generated at random throughout the starting material by using wavelengths of irradiating light that penetrate the entire crystal[5], rather than using wavelengths that would be strongly absorbed in only a thin surface layer of the compound. The integrity of these crystals is sufficiently preserved to allow the arrangement of atoms in the starting material and the product to be determined by X-rays throughout the course of the transformation. With such crystals it has even been possible to perform several write–erase cycles of optical holograms, involving patterned regions with a higher concentration of product molecules and thus a different refractive index[6].

Irie and co-workers[3] now report rapid, light-induced shape-changing of tiny single crystals. Some of these resemble the rare cases described above — single crystals that change shape but remain intact, even when containing as much as 70% product. But the most impressive examples appear quite different. The authors grew crystal needles (about 200 μm long and 5 μm in diameter) by sublimation so as to be attached at one end to a microscope slide. When illuminated from the side by an ultraviolet laser pulse, the needles bent within a millisecond, displacing the free end by 50 μm. As a dramatic demonstration of this effect, the needles can launch a tiny gold sphere as if it were a tennis ball (Fig. 1; see also the movie in the Supplementary Information for the paper).

The reversibility of this movement is particularly noteworthy — the needles can undergo 80 cycles of photochemical bending and straightening with no apparent damage to the crystal integrity, nor any diminution in displacement amplitude.

To achieve this bending movement, the conversion of starting material to product must occur to different degrees across the needle's width, so that the crystal deforms in the same way as a heated bimetallic strip. As mentioned previously, such localization of conversion along one surface was specifically avoided in previous work, to avoid cracking.

It remains to be explained how organic crystals can survive intact through so many cycles of deformation. In particular, it is difficult to work out which molecular features of this system provide sufficient cohesion between crystal layers to allow bending upon differential reaction, but enough flexibility to avoid cracking. An improved understanding of this unexpected resilience is required, along with a method to assemble microscale components, if we are ever to make a useful chemico-mechanical device from such materials. But simply demonstrating this behaviour suggests a possibility that previously seemed remote. ■

J. Michael McBride is in the Department of Chemistry, Yale University, Box 208107, New Haven, Connecticut 06520, USA.
e-mail: j.mcbride@yale.edu

1. Whittaker, M. *et al. Nature* **378,** 748–751 (1995).
2. Pease, A. R. *et al. Acc. Chem. Res.* **34,** 433–444 (2001).
3. Kobatake, S., Takami, S., Muto, H., Ishikawa, T. & Irie, M. *Nature* **446,** 778–781 (2007).
4. Finkelmann, H., Nishikawa, E., Pereira, G. G. & Warner, M. *Phys. Rev. Lett.* **87,** 15501–15504 (2001).
5. Novak, K., Enkelmann, V., Wegner, G. & Wagener, K. B. *Angew. Chem. Int. Edn Engl.* **32,** 1614–1616 (1993).
6. Köhler, W., Novak, K. & Enkelmann, V. *J. Chem. Phys.* **101,** 10474–10480 (1994).

50 & 100 YEARS AGO

50 YEARS AGO

"A cæsium clock" — In the issue of *Atoms for Peace Digest* for February 23, the fortnightly periodical of the United States Information Service, brief details are given of the 'Atomichron', the first cæsium atom-beam clock to be available commercially in the United States, and probably in the world... The model costs 50,000 dollars, weighs 500 lb. and measures 84 in. × 22 in. × 18 in. It is capable of keeping time to an accuracy of five seconds over a period of 300 years... The Atomichron has already been used by the U.S. Armed Forces in navigation systems. It should find application in the improvement of astronomical observations, long-range navigation, radio communications, surveying and map-making, and in the study of basic physics, particularly the accurate determination of the velocity of light.

From *Nature* 6 April 1957.

100 YEARS AGO

The following account of a toad attacking a golden carp may be of interest to some of your readers from its bearing on the ancient belief that frogs and toads are at enmity with carp, and kill them by destroying their eyes... On March 29 my son directed my attention to a large golden carp (*C. auratus*) lying in shallow water near the edge of a pond in my garden with a frog or toad apparently resting on its head. The fish appeared to be very sluggish... On examination it was found that the head of the fish was held tightly by a medium-sized common toad (*Bufo vulgaris*), which had obtained a very firm grasp by inserting its fore-limbs as far as the second, or elbow, joint into the sockets of the eyes of the unfortunate fish... A few years ago in the same pond... I found a toad embracing a water-logged puffball so firmly that it required considerable force to release the fungus from the amphibian's grasp.

From *Nature* 4 April 1907.

©2007 Nature Publishing Group