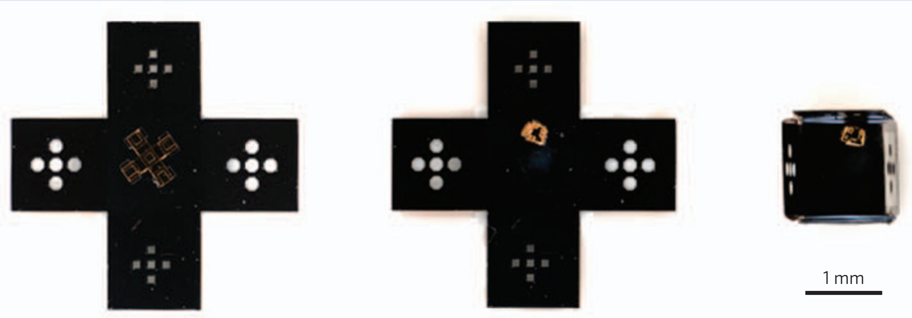
LASER FABRICATION

# Folding three-dimensional microstructures



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The ability to fold microstructures allows the fabrication of complex three-dimensional shapes. Unfortunately, current laser-based folding techniques require the use of extremely intense laser beams reaching thousands of watts per square centimetre.

Now, by exploiting a polymer trigger layer on a pre-stressed metallic bilayer, Kate Laflin and co-workers from John Hopkins University and the US Army Research Laboratory in the USA have developed a laser-triggered sequential folding method that requires a beam intensity of just 680 mW cm$^{-2}$ (*Appl. Phys. Lett.* **101,** 131901; 2012). Their laser-triggered actuation also provides spatial control over the individual hinges, thus allowing three-dimensional patterned cubes to be folded sequentially.

The key to their technique is the hinged actuation, which is based on the intrinsic stress built into metallic thin films. The thin-film hinges contain a layer of chromium, which has high intrinsic stress, and a layer of gold, which has low intrinsic stress. The researchers fabricated their bilayer hinges on copper-coated silicon wafers by vapour deposition and photolithography, and then placed a polymer trigger on top. Bending occurred when the polymer was softened upon heating by laser irradiation.

The team used a commercially available green laser (wavelength of 532 nm, beam power of 40 mW and beam diameter of 1.5 mm) to trigger folding of the smaller cruciform. They then used the same laser to trigger folding of the larger cruciform. This high-precision demonstration of sequential folding across two size scales offers considerable control over the complexity of structures that can be fabricated using laser-triggered actuation.

The researchers also investigated the folding behaviour of various sizes of microstructure, ranging from 300 µm to 3 mm, using both the green laser and a near-infrared laser (wavelength of 808 nm, beam power of 100 mW and beam diameter of 3 mm). When the photoresist in each microstructure was heated above 40 °C, it softened and no longer retained the stressed bilayer, resulting in spontaneous bending. The time taken for each hinge to close varied between 67 ms and 21 s, depending on the wavelength and intensity of the laser irradiation. By analytically and numerically modelling heat losses from the microstructure, the researchers discovered that the time taken for the hinge to close is determined by thermal conduction into the surrounding air domain, and is therefore proportional to the inverse of the irradiance.

These microdevices could be useful for defence applications such as the remote initiation of energetic materials and for attaching transponder tags or other electronics to various surfaces.

NORIAKI HORIUCHI

OPTICAL MATERIALS

# Inspired by strain

Researchers at Peking University and the Massachusetts Institute of Technology propose the use of strain engineering to create a broadband solar 'funnel' in an atomically thin sheet of MoS$_2$.

Arend van der Zande and James Hone

Strain engineering is the process of tuning a material's electronic properties by altering its structural or mechanical properties. This technique is widely used throughout the semiconductor industry as a means of enhancing the mobility of electrons in silicon by depositing strained silicon nitride layers on top of transistor channels. The understanding and optimization of strain-engineered materials is also a major milestone in the international technology roadmap for semiconductors[1]. However, the low maximum strains of brittle bulk crystalline materials limit the extent to which their electronic properties can be changed by mechanical means. Bulk silicon, for example, can be strained only 1.2% before breaking, although silicon nanowires with breaking strains of nearly 5% have recently been reported.

The past few years have seen an explosion of interest in two-dimensional (2D) crystals derived from layered materials that possess strong in-plane bonding and weak van der Waals bonding between crystal planes. The most prominent member of this family is graphene; other 2D crystals include hexagonal boron nitride and a number of transition metal dichalcogenides