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Nanoswitches Toggled by Light

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Microscopic fissures in a tiny crystal open and close—on command. Researchers led by Ahmed H. Zewail successfully used ultrafast electron microscopy (UEM) to observe nanoscopic structures at their “exercises”, as they report in the journal Angewandte Chemie. Such switchable nanochannels could be useful for future nanoelectronics and nanoscopic “machines”.

Zewail and his team at the California Institute of Technology (Pasadena, USA) are renowned for their work in ultrafast science and technology. Zewail received the Nobel Prize in Chemistry in 1999 for the development of ultrafast laser techniques that are capable of revealing the motions of individual atoms within a molecule during a reaction.

The most recent development to spring from Zewail’s Laboratory is ultrafast electron microscopy. This technique is a combination of a femtosecond optical system (a femtosecond equals 10-15 seconds) with a high-resolution electron microscope; the result is a new tool with extremely high resolution in time as well as in space.

Zewail and his team have now discovered that needle-shaped microcrystals of copper and the organic compound TCNQ (7,7,8,8-tetracyanoquinodimethane, C12H4N4), a crystalline, quasi-one-dimensional semiconductor, exhibit optomechanical phenomena that could be of use in nanoelectronic applications.

The investigation showed that these crystals stretch out to become longer (but not wider) when they are irradiated with laser pulses in the microscope. If the irradiation is switched off, they contract back to their original size. This effect was most obvious when one of these needles was broken by the shock of a short, strong laser pulse: A small crack of some ten to one hundred nanometers forms at the break. When the crystal is stretched out under irradiation, the nanoscale channel closes up; upon contraction, it reappears. The phenomenon is reversible, as confirmed by UEM.

Why do these micromaterials stretch under light? Within the crystal, the negatively charged TCNQ ions are arranged so that their central, flat, six-membered rings are piled up on top of each other in the long direction of the needle. The energy of a laser pulse excites electrons; part of this energy is transferred, resulting in uncharged TCNQ molecules. For the uncharged TCNQ, the stacked arrangement is no longer favorable, they now require more space and cause the crystal to grow longer. The degree of stretching depends on the strength of the energy absorbed.

“Our fundamental in situ UEM observations, which reveal the behavior of nanoscopic matter in space and time, opens up new areas to explore, especially in materials science, nanotechnology, and biology,” says Zewail.

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