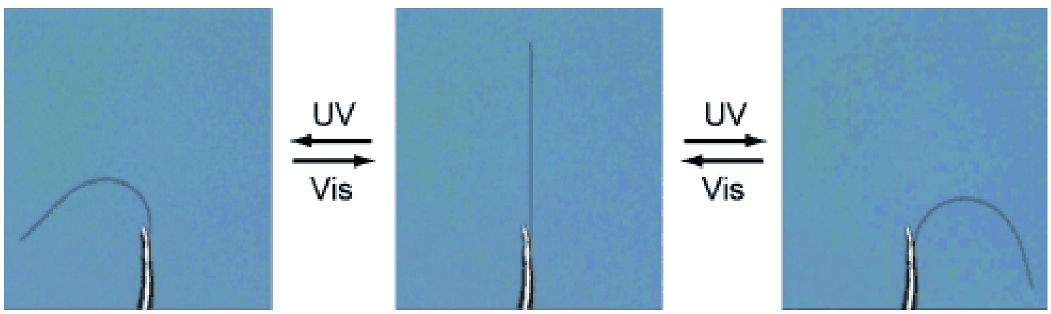
Bow down to the light: Light-triggered microscale robotic arm makes bending and stretching motions

November 21 2011



(PhysOrg.com) -- As miniaturization progresses, microrobots and nanomachines have moved beyond the realm of pure speculation. This technology requires tiny components that can respond to stimulation by undergoing controlled movements. Piezoelectric crystals are known to make a bending motion when subjected to an electric field, however the cables required are a barrier to microscale applications or those in liquids. In the journal *Angewandte Chemie*, a research team led by Masahiro Irie at Rikkyo University (Tokyo, Japan) has now introduced a cable-free microrobotic arm that can be triggered to bend and stretch by light.

The tiny robotic arms are made of crystals shaped like micro- or millimeter-sized flat rods. When they are irradiated with UV light (365 nm), the rods bend toward the light source; when irradiated with visible light (>500 nm) they stretch back into their original straight shape.

What causes the bending motion? The molecules in the crystals are an organic ring system containing five rings. The central structural unit is a diarylethene group. UV light induces rearrangement of the chemical bonds (isomerization) and causes a ring closure within the molecule. This results in the shape change of each molecule, which leads to a geometry change of the crystal. The crystal contracts, but only where it was exposed to the UV light, that is, on the outer layer of the irradiated side of the rod. This causes bending similar to that of a bimetallic strip. Visible light triggers the reverse reaction, the newly formed sixth ring opens, the original crystal structure is restored, and the crystal straightens out.

The trick lies in the mixture of two slightly different diarylethene derivatives that are present in just the right ratio. In this type of mixed crystal, the interactions between the individual molecules are weaker than those in a homogeneous crystal. The crystals can withstand over 1000 bending cycles without evidence of fatigue. Depending on the irradiation, it is possible to induce extreme bending—to the point of a hairpin shape.

In contrast to previous concepts for “molecular muscles”, this new approach offers the unique possibility of translating the motion of individual molecules to the macroscopic level. Also, unlike synthetic micromuscles based on polymers, this new microrobotic arm is wireless and responds very fast—even at low temperatures and in water.

If one end of the crystal rod is anchored, alternating irradiation with UV and visible light can be used to induce the loose end to cause a small gear to turn. It can also work as a freight elevator: If attached to a ledge, the rod can lift a weight that is over 900 times as heavy as the crystal itself. This makes it stronger than polymer muscles and equivalent to piezoelectric crystals.

More information: Masahiro Irie, Light-Driven Molecular-Crystal Actuators: Rapid and Reversible Bending of Rodlike Mixed Crystals of Diarylethene Derivatives, *Angewandte Chemie International Edition*, dx.doi.org/10.1002/anie.201105585

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