Molecular Tools Make the Cut

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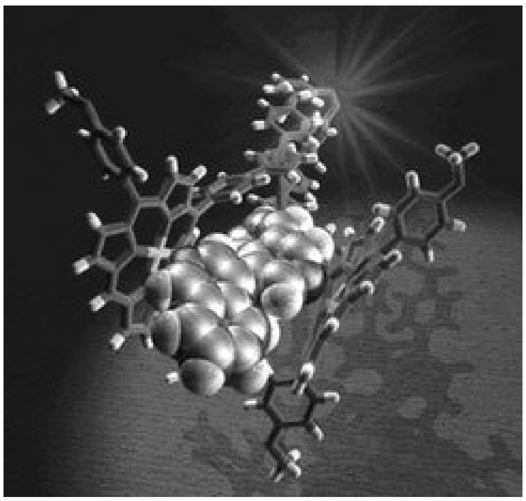

The scissors-like molecular machine extends or folds in response to different wavelengths of light. Credit: Takuzo Aida

Researchers in Japan have developed a pair of molecular-scale scissors that open and close in response to light. The tiny scissors are the first example of a molecular machine capable of mechanically manipulating molecules by using light, the scientists say.

The scissors measure just three nanometers in length, small enough to deliver drugs into cells or manipulate genes and other biological molecules, says principal investigator Takuzo Aida, Ph.D., professor of chemistry and biotechnology at the University of Tokyo.

“Chemists and biochemists may also use the scissors to precisely control the activity of proteins,” Aida says. He presented details of the new technique today at the 233rd national meeting of the American Chemical Society.

Scientists have long been looking for ways to develop molecular-scale tools that operate in response to specific stimuli, such as sound or light. Biologists, in particular, are enthusiastic about development of such techniques because it would provide them with a simple way to manipulate genes and other molecules.

“It is known, for example, that near-infrared light can reach deep parts of the body,” says Kazushi Kinbara, Ph.D., associate professor of chemistry and biotechnology at the University of Tokyo and co-investigator of the study. “Thus, by using a multi-photon excitation technique, the scissors can be manipulated in the body for medicinal applications such as gene delivery.”

The scissors-like molecular machine uses a photo-responsive chemical group that extends or folds when light of different wavelengths falls upon it.

Just like "real" scissors, the molecular scissors consist of a pivot, blades and handles. The pivot part of the scissors is a double-decker structure made of chiral ferrocene, with a spherical iron (II) atom sandwiched between two carbon plates. The three-piece unit creates a shaft that allows the scissors to rotate and swivel.

Driving the motion are two handles strapped with photo-responsive molecules called azobenzene, which not only has the ability to absorb light, but comes in two isomeric forms: a long-form and short-form. Upon exposure to UV light, the long-form of azobenzene is converted into the short-form. Exposure to visible light transforms the short-form into the long-form.

When UV and visible light are used interchangeably, the length of the azobenzene decreases and increases, which drives the handles in an open-close motion. The movement activates the pivot, followed by an opening-closing motion of the blades.

Attached to the scissors' blades are organometallic units called "zinc porphyrin." When the zinc atom in the zinc porphyrin binds with a nitrogen-containing molecule, such as DNA, the zinc and nitrogen act like magnets, securing a firm grip on the molecule.

“As the blades open and close, the guest molecules remain attached to the zinc porphyrin, and as a result, they are twisted back and forth,” Kinbara says.

In a recent study, the scientists demonstrated how the light-driven scissors could be used to grasp and twist molecules. The group is now working to develop a larger scissors system that can be manipulated remotely. Practical applications still remain five to 10 years away, the scientists say.

Source: ACS

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