Single molecule is in driver's seat of molecular machine

July 30 2005

While the human body has plenty of specialized molecular motors and machines powering the mechanical work necessary for cells to function properly, scientists themselves face many hurdles as they try to create their own molecular machines in the laboratory.

The downsides of conventional molecular machines are that they are driven as an ensemble, by external light or chemistry, for example, and they are big -- made up of many molecules. These factors make these machines difficult to control.

In a theoretical paper published in the journal Physical Review Letters, two Northwestern University chemists have shown how molecular machines can be driven individually (relying on only one molecule) by applying an electric current that creates an internal energy source.

"People envision using molecular machines for computing techniques, sensors, bioengineering and solar cells, for example," said Tamar Seideman, professor of chemistry, who led the research team. "Molecular machines have unique functions and properties that are different from macroscopic machines, not only and not primarily because they are of the nanoscale. Rather, they use truly molecular features such as their energy level structure, their dynamics and their response to external stimuli.

"The many beautiful examples already in the literature include analogues of mechanical devices that operate on the molecular scale, such as

shuttles, brakes, ratches, turnstiles and rotors. For some applications, such as drug delivery, it doesn't matter that the molecules are randomly oriented, but the majority of applications require the molecular machines to be driven individually in a coherent and controllable manner."

In their proposed molecular machine, Seideman and Chao-Cheng Kaun, a post-doctoral fellow in Seideman's lab, place a small carbon molecule (C60), known as a fullerene or "buckyball," in between two gold electrodes. (This is called a molecular junction.) When an electric current is run through the electrodes, the electrons transfer energy to the molecule, causing the molecule to vibrate and creating an internal energy source.

Essentially, the buckyball oscillates between the electrodes, as if on an invisible spring. Because the conductivity of this tiny junction depends strongly on the location of the buckyball between the electrodes, the current oscillates with time at the frequency of the C60 oscillations. The spontaneous oscillating current translates into an oscillating electromagnetic field, so the fullerene junction becomes a nanoscale generator of a radiation field -- something not demonstrated before.

Because the single molecule can be driven individually the resulting motion can be controlled, giving an advantage to such a molecular machine.

"The results are very exciting," said Seideman. "Since we understand the processes that produce the movement we can control the dynamics and hence hope to make use of this tiny molecular motor. We are encouraged by the rapid progress of experimental methods of making little molecular junctions of this type."

Source: Northwestern University