DNA MACHINES

Pump fiction

DNA provides a unique opportunity to mimic natural nanopumps

A pH-driven, reversible DNA pump that can be immobilized on a gold surface without losing functionality was presented by Xiaolei Zuo and colleagues in *Advanced Materials*.

Natural nanoscale pumps channel water and molecules in and out of cells in an organized way. “Bottom-up and top-down methods can be used to construct pumps of a size comparable to that of natural nanopumps,” explains Zuo, “however, replicating their functions remains challenging.” Artificial nanopumps based on carbon nanotubes have been devised, but they are incompatible with biological systems and cannot self-organize in a precise way. “DNA provides a unique opportunity to mimic natural nanopumps,” says Zuo.

Several DNA-based devices that can work in homogeneous solutions already exist, including switches, motors and multicomponent machines. However, to fully exploit their potential, and to use them in real-world applications, these devices must be anchored on surfaces. This is problematic because adsorption often results in random device orientation, poor performance and the loss of functionality.

The researchers synthesized DNA tetrahedra exhibiting high rigidity and structural stability, with a pH-sensitive sequence

incorporated on one of the edges. In a homogeneous solution, the tetrahedra can rapidly and reversibly switch from a relaxed state, in which the pH-sensitive edge is loose and the internal volume is small, to a 3D conformation with stiff edges — the switching happens if the pH is changed from basic to acidic. They then added thiol groups to three of the tetrahedral vertices to immobilize the structures on a gold surface, finding that the adsorbed tetrahedra are correctly oriented and well separated from each other. On the surface, the nanodevices exhibit the same reversible and robust switching that is observed in the homogeneous solution. Modifying the lateral size of the devices does not cause any loss in functionality, demonstrating the tunability of the system.

Because DNA is hydrophilic, water molecules are trapped in the tetrahedral cavity when the device is in the stiff conformation; by contrast, they are pumped out of the

cavity when the volume is reduced as a consequence of switching to the relaxed state. Hence, the tetrahedra act as pH-driven nanopumps.

The system is highly tunable, because tetrahedra of different sizes can be synthesized and sequences that respond to different stimuli (for example, the presence of ions or small molecules in solution) can be used instead of the pH-sensitive sequence. Moreover, these nanopumps are assembled rapidly and reliably with high yield. As Zuo explains, “these results open the way to research on several exciting applications, such as mass transport through cell membranes, target-responsive cancer detection, drug delivery for cancer therapy, super-resolution imaging in living cells and the creation of synthetic cells.”

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