Teaching Nano to Swim

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(PhysOrg.com) -- Ayusman Sen, head of the Department of Chemistry at Penn State, makes tiny, metallic objects do something extraordinary -- he makes them swim. Sen's work is driven by catalysis, the chemical phenomenon whereby a substance accelerates a chemical reaction but emerges unchanged at the end of the process.

The chemical reaction upon which he and his team of students and colleagues focus their efforts is the well-known redox reaction, in which electrons and protons are broken away from their parent atoms and are pumped back and forth between substances, resulting in the liberation of energy during the process.

That energy manifests itself as an electrical gradient in the fluid surrounding a micro particle or nanomotor. Frequently, the motor is one of the group's two-micron-long platinum-gold nanorods. In most cases, the fluid starts out as a dilute solution of hydrogen peroxide which, upon being catalytically oxidized by the platinum tip of a nanorod, results in oxygen and also in electrons and protons that flow from bow to stern; electrons inside the rod; and an equal number of protons in the fluid along the outside of the rod. At the stern, the electrons and protons catalytically reduce hydrogen peroxide to water. The protons flowing from stem to stern function like paddles propelling the nanorod toward its platinum forward end, or if the nanorod is stationery, pumping water around it toward the aft end.

While getting metal particles to move under their own power is one thing, getting them to ambulate purposefully toward a specific location is another. In response, the Penn State team has developed three methods of steering their motors: magnetism, chemistry, and light.

The magnetic system employs magnetized nickel segments built into the platinum and gold-layered rods that respond to an external magnetic field by coaxing the rods to swim parallel to it.

The chemical system uses chemotaxis, traditionally defined as the movement of living organisms toward or away from a chemical attractant or toxin. In the first example of chemotaxis in a non-living system, Sen's platinum-gold nanorods propel themselves along a gradient of hydrogen peroxide diffused in water toward a higher concentration of hydrogen peroxide.

Phototaxis uses light to initiate catalytic activity. In a demonstration, silver chloride particles suspended in distilled water do not move until ultraviolet light is shone on them, whereupon they migrate en masse toward the light.

As a practical matter, getting metal particles to move toward specific targets is not very valuable unless they do something like deliver a drug, assemble a structure, sense a material, or pump a liquid once they get there. In order to prove the feasibility of such activities, Sen's group has developed electrostatic and chemical linkers to attach cargo to their nanomotors.

Although at this juncture the group knows how to make the motors, attach cargo to them, and transport them to designated points, off-loading remains a problem. In response, the group is beginning work on a photosensitive linker molecule that will break and drop the cargo when exposed to light.

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