Overcoming a major barrier to medical and other uses of 'microrockets' and 'micromotors'

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An advance in micromotor technology akin to the invention of cars that fuel themselves from the pavement or air, rather than gasoline or batteries, is opening the door to broad new medical and industrial uses for these tiny devices, scientists said here today. Their update on development of the motors—so small that thousands would fit inside this "o"—was part of the 245th National Meeting & Exposition of the American Chemical Society.

Joseph Wang, D.Sc., who leads research on the motors, said that efforts to build minute, self-powered robot devices have evoked memories of the 1966 science fiction film *Fantastic Voyage*. It featured a miniaturized submarine, which doctors injected into a patient. It then navigated through blood vessels to remove a blood clot in the brain.

Fuel and propulsion systems have been a major barrier in moving science fiction closer to practical reality, Wang explained. Some micromotors and even-smaller nanomotors, for instance, have relied on hydrogen peroxide fuel, which could damage body cells. Others have needed complex magnetic or electronic gear to guide their movement.

"We have developed the first self-propelled micromotors and microrockets that use the surrounding natural environment as a source of fuel," Wang said. "The stomach, for instance, has a strongly acid environment that helps digest food. Some of our microrockets use that acid as fuel, producing bubbles of hydrogen gas for thrust and propulsion. The use of biocompatible fuels is attractive for avoiding damage to healthy tissue in the body. We envision that these machines could someday perform microsurgery, clean clogged arteries or transport drugs to the right place in the body. But there are also possible uses in cleaning up oil spills, monitoring industrial processes and in national security."

Wei Gao, a graduate student in Wang's lab, described how the team at the University of California, San Diego, has developed two types of self-propelled vehicles—microrockets made of zinc and micromotors made of aluminum. The tubular zinc micromotor is one of the world's fastest, able to move 100 times its 0.0004-inch length in just one second. That's like a sprinter running 400 miles per hour. The zinc lining is biocompatible. It reacts with the hydrochloric acid in the stomach, which consists of hydrogen and chloride ions. It releases the hydrogen gas as a stream of tiny bubbles, which propel the motor forward. "This rocket would be ideal to deliver drugs or to capture diseased cells in the stomach," said Gao.

Gao also described some of the latest advances in the technology. The newest vehicles are first-of-their-kind aluminum micromotors. One type, which also contains gallium, uses water as a fuel. It splits water to generate hydrogen bubbles, which move the motor. "About 70 percent of the human body is water, so this would be an ideal fuel for vehicles with medical uses, such as microsurgery," said Wang. "They also could have uses in clinical diagnostic tests, in the environment and in security applications."

Another type of aluminum micromotor doesn't have gallium and is the first such motor that can use multiple fuels. "We're really excited about this micromotor," said Gao. "It is our most flexible one to date. For the first time, we've made a micromotor that can use three different fuels—acids, bases and hydrogen peroxide, depending upon its surroundings. Therefore, we can use these motors in many more environments than ever before."

The scientists are working on extending the lifetimes of the vehicles so that they last longer and functionalizing them for specific biomedical applications. They also are exploring commercial partners for realizing real-life applications of this work, said Wang.

More information: Abstract

The motion of synthetic microscale objects is of considerable fundamental and practical interest, and has thus stimulated major research efforts over the past decade in connection to diverse potential applications such as targeted drug delivery. For nearly a decade, chemically-driven micro/nanomotors have relied mainly on hydrogen peroxide fuel that hinders many of their practical applications. Here we demonstrate new hydrogen bubble propelled micromotors which can be driven by their natural environments (such as acid and water in human body), without any additional chemical fuel. The tubular polyaniline/zinc microrockets (prepared by template based electrodeposition method) display effective autonomous motion in extreme acidic environments (with a speed of over 100 body lengths per second). The ejection of hydrogen bubbles from the exposed zinc inner layer, upon its contact with acid, provides a powerful directional propulsion thrust. The observed speed-pH dependence holds promise for sensitive pH measurements in extreme acidic environments. In contrast, the new water-driven Al-Ga/Ti based Janus micromotor can be propelled by the hydrogen bubbles generated from the rapid aluminum and water reaction. Although this reaction process is greatly hindered by an oxide passivation layer on the Al surface, the problem can be addressed by using aluminum-gallium alloys through liquid metal embrittlement. Factors influencing the efficiency of the aluminum–water reaction and

the resulting propulsion behavior and motor lifetime, including the ionic strength and environmental pH, are investigated. These new hydrogen bubble propelled micromotors could greatly expand the scope of applications of nano-/microscale motors toward new extreme environments (e.g., the human stomach or silicon wet-etching baths) or mild environments (e.g. human blood) and could thus lead to diverse new biomedical or industrial applications ranging from targeted drug delivery or nanoimaging to the monitoring of industrial processes.

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