A Tiny Cage of Gold Responds to Light, Opening to Empty Its Contents

November 19 2009

(PhysOrg.com) -- Researchers at Washington University in St. Louis have developed a polymer-coated gold nanocage that not only opens in response to light to release a small amount of a drug payload, but then closes when the light is turned off, leaving this nanodevice ready to deliver another dose of drug on command. Releasing carefully titrated amounts of a drug only near the tissue that is the drug's intended target, this delivery system has the potential to maximize a drug's beneficial effects while minimizing its side effects.

This work, led by Younan Xia, Ph.D., was published in the journal Nature Materials.

The key to the nanocage's responsiveness to light lies with a physical phenomenon known as surface plasmon resonance. Some of the electrons in the gold nanocage are not anchored to individual atoms but instead form a free-floating electron gas. Light falling on these electrons can drive them to oscillate as one. This collective oscillation, the surface plasmon, occurs at a particular wavelength, or color, that depends on the thickness of the cage walls. As more gold is deposited on the cages and their walls thicken, a suspension of nanocages shifts from red to wavelengths in the near-infrared. Biological tissues are largely transparent to near-infrared light.

The surface plasmon resonance actually has two parts. At the resonant frequency, light can be scattered off the cages, absorbed by them, or a combination of these two processes. It's the absorption component the

scientists exploit to open and close the nanocages. As the nanocages absorb light, they become warm, triggering a change in a special polymer that responds to heat in an interesting way. The polymer, poly(N-isopropylacrylamide), and its derivatives have what's called a critical temperature. When they reach this temperature they undergo a transformation called a phase change.

If the temperature is lower than the critical temperature, the polymer chains are water-loving and stand out from the cage like brushes. The brushes seal the cage's pores and prevent its cargo from leaking out. But as the gold cage responds to light and warms above the critical temperature, the polymer chains shun water, shrink together and collapse. As they shrink, the pores of the cage open, releasing its contents. The amount of drug that diffuses out of the cages depends on how long the cages stay warm, which in turn depends on how long light shines on them.

In order for this open-and-shut process to be medically useful, the investigators tailored the polymer's critical temperature to fall above body temperature (37 °C) but well below 42 °C, the temperature at which heat would begin to kill cells. Tests with doxorubicin-loaded nanocages showed that light triggered drug release as expected, triggering the death of breast cancer cells growing culture.

This work is detailed in a paper titled, "Gold nanocages covered by smart polymers for controlled release with near-infrared light." An abstract of this paper is available at the journal's Web site.

Provided by National Cancer Institute (news : web)