provides a convincing series of data on the versatility of the quantum dots developed to kill numerous strains of antibiotic-resistant bacteria when activated."

But Webster, who was not involved in the study, is still concerned about the potential toxicity of the quantum dots. "Mammalian cell toxicity of the quantum dots was only tested against one cell line and a transformed cell line that is not an accurate representation of the numerous healthy cells in our body," Webster said, adding that Cd and Te also have toxicity concerns that need to be monitored in future studies (the researchers used a low dose of CdTe to minimize its harmful effects).

"Moving forward, we are refining the design of our nanoparticles," Chatterjee said. "We are trying to push the limit of how far can we go in designing new therapies and making nanoparticles safer." Eventually, the team hopes to conduct clinical trials using these quantum dots.

Joseph Bennington-Castro

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Bio Focus

Hybrid semiconductor-bacterium self-photosensitization improves artificial photosynthesis

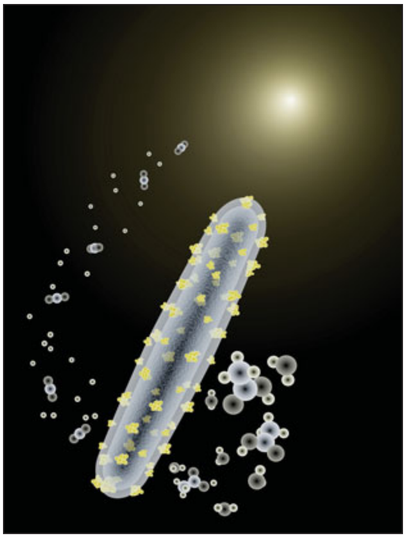
Researchers from the University of California–Berkeley and Lawrence Berkeley National Laboratory have developed a hybrid system for artificial photosynthesis by combining nanoparticles of an inorganic semiconductor with self-photosensitizing bacteria to produce acetic acid using only solar energy. Kelsey K. Sakimoto, Andrew Barnabas Wong, and Peidong Yang combined nanoparticles of the semiconductor cadmium sulfide (CdS), which is an excellent harvester of light, with a self-photosensitizing bacteria *Moorella thermoacetica*. The nanoparticles were precipitated on the surface of the bacteria, ensuring biocompatibility and a strong interface. These results are reported in a recent issue of *Science* (DOI: 10.1126/science.aad3317).

In natural photosynthesis, solar energy is used to oxidize water to oxygen and reduce carbon dioxide to make the chemicals that sustain life. Semiconductors are better at absorbing solar radiation than biological materials, but cannot compete with biocatalysts in terms of specificity, cost, or their ability to self-replicate and repair. By combining both, one can then achieve the best of both worlds.

Nonphotosynthetic bacteria are preferred in synthetic biology because they can produce a variety of products by reducing CO_2. For this study, the researchers chose *Moorella thermoacetica*, which is a nonphotosynthetic bacteria. They added cadmium nitrate and cysteine—a source of sulfur—to the growing culture so that CdS could be precipitated on the surface of the bacteria. Scanning electron microscopy, scanning transmission electron microscopy, and energy-dispersive x-ray spectroscopy confirmed the presence of CdS particles with sizes of under 10 nm. The self-photosensitization of the nonphotosynthetic bacteria was induced with the cadmium sulfide nanoparticles, enabling the photosynthesis of acetic acid. A maximum yield of 90% acetic acid, as a natural waste product of respiration, was obtained.

The cell counts of the *Moorella thermoacetica*-CdS system nearly doubled after a day, demonstrating that this self-reproducing hybrid organism can be sustained purely through solar energy. Under blue light (wavelength 435–485 nm) the quantum yield (defined as rate of production of acetic acid per unit of photon flux) was 52% ± 17%, as compared with the 22% reported previously for analogous systems. A fourfold increase in the loading of the bacteria-CdS hybrid gave a quantum yield of 85% ± 12%. When the system was exposed to simulated day-night cycles, an unexpected result followed—the acetic acid concentration increased during illumination as well as in the dark. The quantum yield was 2.44% ± 0.62%, higher than the yearlong average of 0.2–1.6% for plants and algae.

Yang, who has joint appointments with the Departments of Chemistry and Materials Science at Lawrence Berkeley National Laboratory and is a co-director of the Kavli Energy NanoSciences Institute at Berkeley, said, "This study opens up several new avenues. Exploring more materials capable of biologically induced precipitation will increase photosynthetic efficiency. Genetic engineering tools can be used in further development of the final product selectivity. Synthetic biology can play an important role in the rational design of hybrid organisms."



Inorganic–biological hybrid bacterium, *Moorella thermoacetica*-cadmium sulfide, photosynthetically produces acetic acid from CO_2 through a novel self-photosensitization mechanism. The hybrid system is self-replicating through solar energy and exhibits efficiencies comparable to natural photosynthesis. Photo credit: Kelsey Sakimoto.

The practical applications are significant. Starting with pure acetic acid, rather than biomass (which requires processing), makes it easier to produce biodegradable plastics, pharmaceuticals, and liquid fuels. This results in sustainable chemical production and least climate change. Any effort to convert CO_2 to useful products rather than burying it is welcome. With decreasing natural green cover on earth, natural photosynthesis may need to be augmented by an artificial one. The system developed in this study can also be modified for wastewater purification and biomass conversion.

N. Balasubramanian