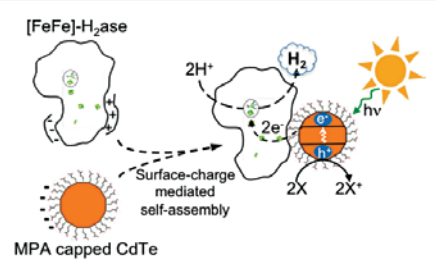
NREL Highlights SCIENCE

Lighting Up Enzymes for Solar Hydrogen Production

Hybrid molecular assemblies composed of hydrogenase enzymes and quantum dots helps to pave the way for the development of next-generation photocatalytic materials for water-to-hydrogen conversion technologies.



Scientists at the National Renewable Energy Laboratory (NREL) have combined quantum dots, which are spherical nanoparticles that possess unique size-tunable photophysical properties, with the high substrate selectivity and fast turnover of hydrogenase enzymes to achieve light-driven hydrogen (H_2) production. They found that quantum dots of cadmium telluride coated in carboxylic acids easily formed highly stable complexes with the hydrogenase and that these hybrid assemblies functioned to catalyze H_2 production using the energy of sunlight.

During biological photosynthesis, ferredoxin functions to mediate the transfer of photoexcited electrons to hydrogenase, which results in light-driven H_2 production. This interaction of hydrogenase with ferredoxin during electron transfer relies on surface charge interactions such that the positive (hydrogenase) and the negative (ferredoxin) regions can interact.

In the biohybrid, the negatively charged carboxcylic acid-coated quantum dot was able to interact with the positively charged hydrogenase in a way that allowed it to replace ferredoxin as the electron source for the hydrogenase. Optical measurements showed that the photocatalytic efficiency varied with the quantum dot/hydrogenase ratio, which was maximal at low enzyme coverages favoring one-to-one ratios.

The efficiency of photocatalytic H_2 production was also a direct function of the intrinsic quantum dot photoluminescent quantum efficiency. Higher quantum efficiencies led to higher H2 production rates.

In summary, carboxcylic acid-coated quantum dots and hydrogenase spontaneously assemble into complexes that, on illumination, transfer photo-generated electrons from quantum dot core states to the hydrogenase, resulting in H_2 production from water. Low hydrogenase coverages promoted optimal orientations for solar H_2 production.

Reference: Brown, Katherine A.; Dayal, Smita; Ai, Xin; Rumbles, Garry; and King, Paul W. "Controlled Assembly of Hydrogenase-CdTe Nanocrystal Hybrids for Solar Hydrogen Production." *Journal of the American Chemical Society*, June 28, 2010.

Key Research Results

Achievement

NREL researchers developed new, hybrid materials that function as H_2 producing photocatalysts.

Key Result

Carboxylic acid-coated quantum dots and hydrogenase spontaneously assemble into complexes that, on illumination, transfer photo-generated electrons from quantum dot core states to the hydrogenase, resulting in H_2 production.

Potential Impact

This collaboration of NREL's Biosciences and Materials Sciences Centers has led to a breakthrough that can help guide the development of artificial solar-to-hydrogen processes to become more efficient, viable technologies.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

1617 Cole Boulevard | Golden, Colorado 80401-3305 | 303-275-3000 | www.nrel.gov

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NREL/FS-2700-50851 • February 2011