Researchers explore energy-saving catalysts that operate at room temperature

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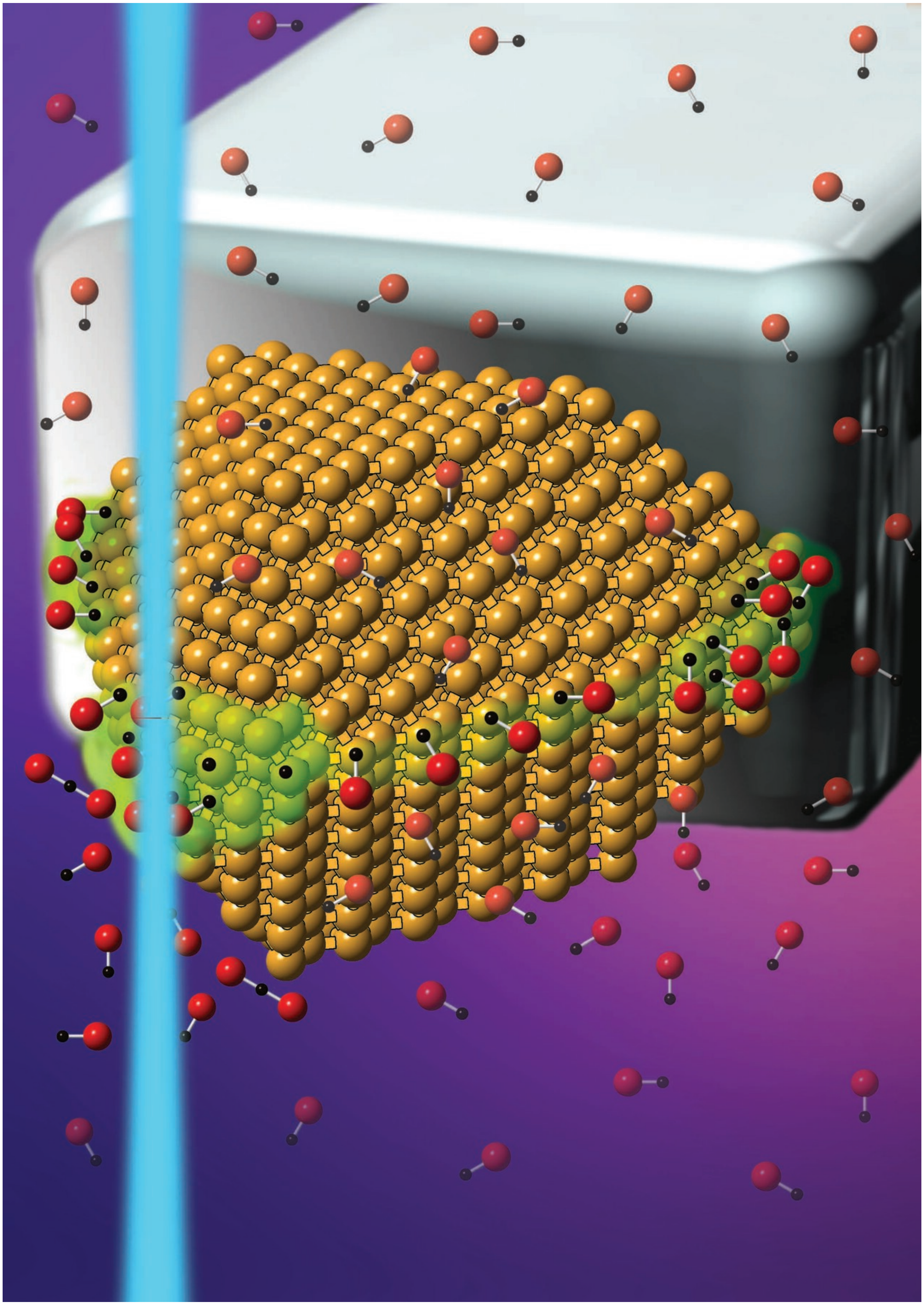

Illustration shows location of a chemical reaction on gold nanoparticles mediated by localized surface plasmons—oscillations of group of electrons on the surface of the nanoparticle. The plasmons (green) act as catalysts that allow the reaction, in which pairs of carbon monoxide (white lines) transform into atoms of carbon (red) and oxygen (black) at room temperature. Gold balls represent the gold nanoparticles. Credit: K. Dill/NIST

NIST researchers have explored in unprecedented detail a new breed of catalysts that allow some chemical reactions, which normally require high heat, to proceed at room temperature. The energy-saving catalysts use sunlight or another light source to excite localized surface plasmons (LSPs)—oscillations of groups of electrons on the surface of certain metal nanoparticles, such as gold, silver and aluminum. The energy derived from the LSP oscillations drives chemical reactions among molecules that adhere to the nanoparticles.

Scientists had previously shown that molecular hydrogen can be split into its individual atoms by the energy generated by the LSP oscillations. The NIST team has now discovered a second LSP-mediated reaction that proceeds at room temperature. In this reaction, LSPs excited in gold nanoparticles transform two molecules of carbon monoxide into carbon and carbon dioxide. The reaction, which ordinarily requires a minimum temperature of 400 degrees C., plays an important role in converting carbon monoxide into widely used carbon-based materials such as carbon nanotubes and graphite.

Probing the nanoparticles with an electron beam and combining the data with simulations, the NIST researchers pinpointed the sites on the gold nanoparticles where the reactions occurred. They also measured the intensity of the LSPs and mapped how the energy associated with the oscillations varied from place to place inside the nanoparticles. The measurements are key steps in understanding the role of LSPs for initiating reactions at room temperature, mitigating the need to heat the samples.

Wei-Chang Yang of NIST and the University of Maryland NanoCenter, along with Henri Lezec and Renu Sharma and other collaborators, describe their work in the April 15 *Nature Materials*.

The scientists relied on deposits of solid carbon deposits—-one of the products of the carbon monoxide reaction they studied—-as markers for the exact locations on the gold nanoparticles where the reaction took place. The team found that the reaction concentrated at the intersection where the carbon monoxide gas molecules preferentially adhere to the gold nanoparticles and where the amplitude of the electric field associated with the LSPs was highest. Although many LSPs can be excited with sunlight, the team chose an electron beam to trigger the oscillations and studied the carbon monoxide reaction in a scanning transmission electron microscope that can operate in a room-temperature environment.

The findings, says Sharma, lay the foundation for searching for other systems that directly harness sunlight to generate LSPs in nanoparticles to drive room-temperature chemical reactions. By reducing energy consumption, such systems could have an enormous impact on industry and the environment.

More information: Wei-Chang D. Yang et al. Site-selective CO disproportionation mediated by localized surface plasmon resonance excited by electron beam, *Nature Materials* (2019). DOI: 10.1038/s41563-019-0342-3

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