'Wet' Electrons Provide Easiest Way to Transport Charge

May 24 2005

Technology has potential to produce clean fuel "if we could make it more efficient"

The task of transporting electrical charges between metal-oxide and water phases is critical in such technologies as catalysis, sensors, and electrochemistry. In a paper published in this week's issue of the journal Science, University of Pittsburgh researchers report that "wet" electrons afford the lowest energy pathway for transporting electrons between solid and liquid states.

In their paper, titled "Wet electrons at the H2O/TiO2(110) Surface," Hrvoje Petek, Pitt professor of physics and codirector of Pitt's Institute of NanoScience and Engineering, and Kenneth Jordan, professor and chair of Pitt's Department of Chemistry, extend Jordan's previous work on the structure of electrons in small water clusters, which was named one of the top 10 breakthroughs of 2004 by Science.

Wet electrons, which occur on metal oxide surfaces, represent a transition point for electrons between solid and liquid states of matter. A tiny amount of water from the atmosphere sticks to the surfaces of the oxides and forms hydroxide molecules, which then act like "molecular-scale Velcro®," said Petek. In the presence of energy, their positively charged hydrogen atoms attract negatively charged electrons. Those so-called "wet" electrons then determine how other molecules interact with the surfaces of metal oxides.

The researchers gave the electrons sufficient energy to achieve the wet state by directing short bursts of laser light at titanium dioxide. Titanium dioxide was used because it is a photocatalyst: Exposure to light excites its electrons, which split water molecules into hydrogen and oxygen. Because of this potential for making hydrogen from water, it is possible that titanium dioxide could be used to make a clean fuel—but the process remains inefficient, said Petek. “If we could find out how to make it more efficient by observing how electrons interact with hydrogen atoms, it would have a huge economic impact,” he added. Petek’s research could also illuminate the interaction between protons and electrons in such biological processes as photosynthesis, in which the light energy is converted to chemical energy through correlated transport of protons and electrons, which Petek calls similar to a wet electron system “on a fundamental level.”

Petek plans to continue research on the properties of other oxide materials. In their paper, the researchers note that conditions exist to support similar states on all oxide surfaces in contact with water or with a humid atmosphere.

The paper’s other authors are Ken Onda, Bin Li, and Jin Zhao, graduate students and postdoctoral researchers in Pitt’s Department of Physics and Astronomy, and Jinlong Yang, a professor at the University of Science and Technology of China.

Source: University of Pittsburgh