UC San Diego NEWS RELEASE University Archives. RSS 6020

UCSD scientist uses laser and x-ray technologies to watch a different way of 'melting' semiconducting material

November 11, 1999

EMBARGOED FOR RELEASE BY SCIENCE: 2 P.M. EST, THURSDAY, NOV. 11, 1999 Media Contact: Mario Aguilera, (858) 534-7572, maguilera@ucsd.edu

Take an ice cube, plop it into a glass of water and the cube will slowly undergo the very ordinary melting transition from the solid to liquid phase. Using ultrafast pulses of light and x- rays, an interdisciplinary group at the University of California, San Diego has directly observed the melting of material without taking the route of a typical melting process.

An international team of scientists in the Wilson-Squier Group in UCSD's Chemistry and Biochemistry Department have changed the structure of a semiconducting material, sending it from an ordered symmetrical crystal structure to a disordered liquid state and back again. This

non-traditional, or non-thermal, melting occurs as a result of the electrons in the material being pushed by the powerful laser light pulses into an extremely excited state. The forces among the crystal's atoms are so dramatically different in this state that the crystal goes from a cold solid to a hot liquid state and never passes through the classical equilibrium stage of a hot solid.

The study is described in the Nov. 12 issue of the journal Science.

"During classic melting, atoms become hotter, vibrate and pop out of their positions. In the case of non-thermal melting, the short laser pulse neutralizes the glue that keeps atoms in a crystal and they are instantaneously freed, regardless of the vibrations," said Andrea Cavalleri, a paper co-author. "The initial and final state are the same as in traditional melting, but the pathway is very different."

Scientists have used ultrashort pulses of laser light for more than two decades in a "pump-and-probe" research approach. The technique has been actively pursued because of its alluring ability to explore many fundamental processes in nature, including problems in physics, chemistry and biology. A leader in this field, Ahmed Zewail, won the Nobel Prize in chemistry in October, 1999.

The technique developed by the UCSD team of physicists, chemists, and engineers described in the Science paper also employed the pump-and-probe approach. But their method also included extremely short bursts of x-rays that allowed them to directly observe the non- thermal melting of germanium, a metalloid element somewhat like silicon that is used in cellular phones and other semiconductor devices.

"This is the first time that we have been able to directly see such non-thermal rearrangement of the atoms and molecules in a material," said the paper's first author, Craig Siders. "With ultrafast x-rays we could watch this rigorously symmetric crystal lattice of germanium atoms just fall apart in an incredibly short period of time. The x-rays allowed us to see this not just at the surface, but importantly inside the material, too."

The laser pulses, which are used on the scale of a femtosecond, or one quadrillionth of a second, can push matter into states outside of normal boundaries. In this experiment, they produced germanium excited to levels unattainable by other means, and in similar experiments they can produce temperatures and pressures not possible in laboratory settings.

"So here in front of you is this condition of matter that might normally only be accessible in the interior of the Earth, another planet or even a star," said Siders. "You can produce it for the briefest of instances here in the laboratory with these lasers, and with ultrafast x-rays you can go in and study its structure and watch its constituent atoms move about. So in essence this technique lets us go to the center of the Earth."

Based on the results of the study, the researchers believe these technologies can be used for future ultrafast investigations of processes in physics, chemistry and biology.

Principle experimentalists, in addition to Siders and Cavalleri, included co-author Klaus Sokolowski-Tinten of the University of Essen in Germany. Additional UCSD co-authors include Kent Wilson of the Department of Chemistry and Biochemistry, Csaba Toth of the Institute for Nonlinear Science and Christopher Barty of Applied Mechanics and Engineering Science. International co-authors include Dietrich von der Linde of the University of Essen in Germany and Martin Kammler and Michael Horn von Hoegen of the University of Hannover in Germany. Co-author Ting Guo, formerly with the UCSD Chemistry and Biochemistry Department, is now at UC Davis.

(November 11, 1999)