Droplets of 'Liquid Electricity'

Excitons (combinations of an electron and a hole) are one of a number of curious phenomena that occur inside solid materials when they are chilled to temperatures near absolute zero. Excitons are important in some of the ways solid-state physicists try to explain bulk phenomena. (Typically the physicists are confronted with a bulk effect, like superconductivity, and they must explain it with reference to the behavior of things inside the solid.) The latest about excitons is that they can gather in groups that behave like a kind of liquid drop, a very curious liquid indeed.

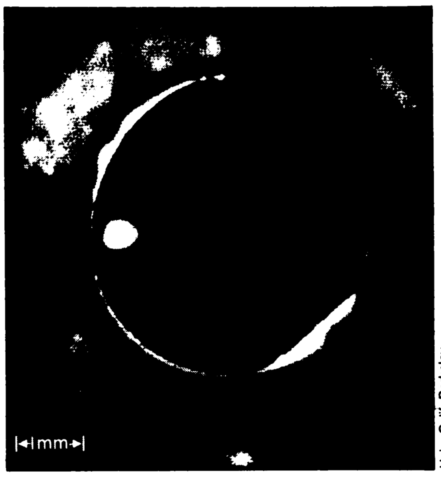
A technique for visualizing these droplets has now been developed by physicists at the University of California at Berkeley and at the Lawrence Berkeley Laboratory and is reported in the May 19 PHYSICAL REVIEW LETTERS. The work was done by James P. Wolfe, Robert S. Markiewicz, Carson D. Jeffries and Charles Kittel of the University physics department and William L. Hansen and Eugene E. Haller of LBL.

Some descriptions have referred to the phenomenon as "pure electricity in liquid droplet form." They are electron-hole droplets, and if you take electrons to be pure electricity—a philosophical point—then they are pure electricity in liquid form. Electrons are objects, elementary particles that under certain circumstances can propagate through the bulk of a solid. Holes are the absence of electrons, places where electrons ought to be but aren't. They are localized; they have the effect of positive charges, and they can move through the solid as if they were particles.

At very low temperatures an electron and a hole can bind together to form an exciton. About seven years ago some Soviet scientists discovered that a gang of excitons formed by the energy from intense illumination of a germanium crystal gathered in droplets. The Soviets were unable to visualize the droplets directly, but inferred their presence from a large increase in electrical conductivity.

Now the visualization is done. It uses infrared radiation given off by the droplets, which is converted to an image on a television screen by an infrared-sensitive image tube. There was a bit of luck involved: Droplets of the proper size will form only where the germanium is under stress. The experimenters found that the pressure of a plastic screw used to hold the germanium chip in place provided just the right stress.

In a branch of science where the weird is commonplace, these droplets of "pure electricity" are really exotic. They behave like a liquid that can flow through the bulk of solid matter. They are huge compared to single electrons, being slightly less than a millimeter in diameter. They have surface tension, and flow fluidly and neutrally (since charges within them are balanced) through the interstices of the crystal lattice.



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"Liquid electricity's" television image.

The droplets can undergo phase changes from "liquid" to "gas" and even possibly to "solid" depending on the temperature. At seven degrees above absolute zero they dissociate into dispersed electrons and holes. Because they are made up of positive and negative charges, they can be regarded as a kind of low-temperature plasma.

Solid-state physicists all over the world are showing great interest in the electron-hole drops. Who knows what curious phenomena may lurk within them? Or what novel practical result? Solid-state physicists have always been good at finding practical uses for things. It is one of the prides of their craft. □

Putting a star on ice

Whether the world will end by fire or by ice (or by Frost, as an unimpressed poetry critic once suggested) it appears that both phenomena attend the births of at least some stars. The discovery of a young T Tauri class star that appears to be embedded in a cloud of ice crystals was made by Martin Cohen of the University of California at Berkeley as part of a search for interstellar ice. He reported it at last week's meeting of the Astronomical Society of the Pacific in Ensenada, Baja California. The result is a triumph for highly sensitive, ground-based infrared observing techniques.

Interstellar space is pervaded by clouds that contain both gaseous molecules and solid particles. Astronomers wondered whether there was interstellar water and whether any of the interstellar water came in the form of ice crystals. A balloon-borne infrared search for ice by John E. Gaustad and David Cudaback during the 1960's gave a negative result, indicating that any ice there was below their sensitivity limit. Water molecules were found somewhat later by Charles Townes and William J. Welch, who used radio techniques. The first positive indication of ice was found by Fred Gillette in 1972.

Cohen has observed 22 of the T Tauri stars, most of them located in the actual constellation Taurus, for which they are named. He uses an extremely sensitive apparatus located on Mt. Lemmon, near Tucson, Ariz. The equipment was built by Michael Merrill, a student at the University of California's San Diego campus, and Cohen attributes much of the credit for the discovery to him.

The brighter stars that Cohen observed showed no evidence of ice, but when he turned, as a long-shot possibility, to a very faint one, it snowed on him. In the spectral region between 2.8 and 3.6 microns, where the signature of ice is located, he found a pronounced feature. To be certain, he went back and did it again and found a perfect match. He figures the size of the ice particles at about 40 angstroms and their temperature at 170 degrees K.

The combination of data—that the brighter T Tauri stars show no ice and a faint one does—tend to indicate that early in life, when they are faint, these stars are surrounded by ice clouds, which they gradually melt and vaporize as they age and brighten. Additional support to this scenario are two fairly young stars that showed water vapor in their atmospheres. These were then observed to brighten suddenly and remain brighter. Cohen theorizes that the sudden brightening occurred as the stars burned through a shell of dust and melted the ice.

(Incidentally, the finding could have a bearing on the origin of comets, which have been described as dusty snowballs. They could be remnants of an ice cloud that surrounded the sun at its birth.)

Cohen figures that his ice star is extremely young, early in the process that makes stars by gravitational collapse of matter in the dust clouds. He makes it a few hundred thousand years old, compared with the sun's five billion. □