CU apparatus probes mysterious behavior of hi-temp superconductor

By Bill Steele

With equipment so sensitive that it can locate clusters of electrons, Cornell and University of Tokyo physicists have – sort of – explained puzzling behavior in a much-studied high-temperature superconductor, perhaps leading to a better understanding of how such superconductors work.

It turns out that under certain conditions the electrons in the material pretty much ignore the atoms to which they're supposed to be attached, arranging themselves into a neat pattern that looks like a crystal lattice. The behavior occurs in a phase physicists have called a "pseudogap," but because the newly-discovered arrangement looks like a checkerboard in scanning tunneling microscope (STM) images, J.C. Séamus Davis, Cornell professor of physics, calls the phenomenon a "checkerboard phase."

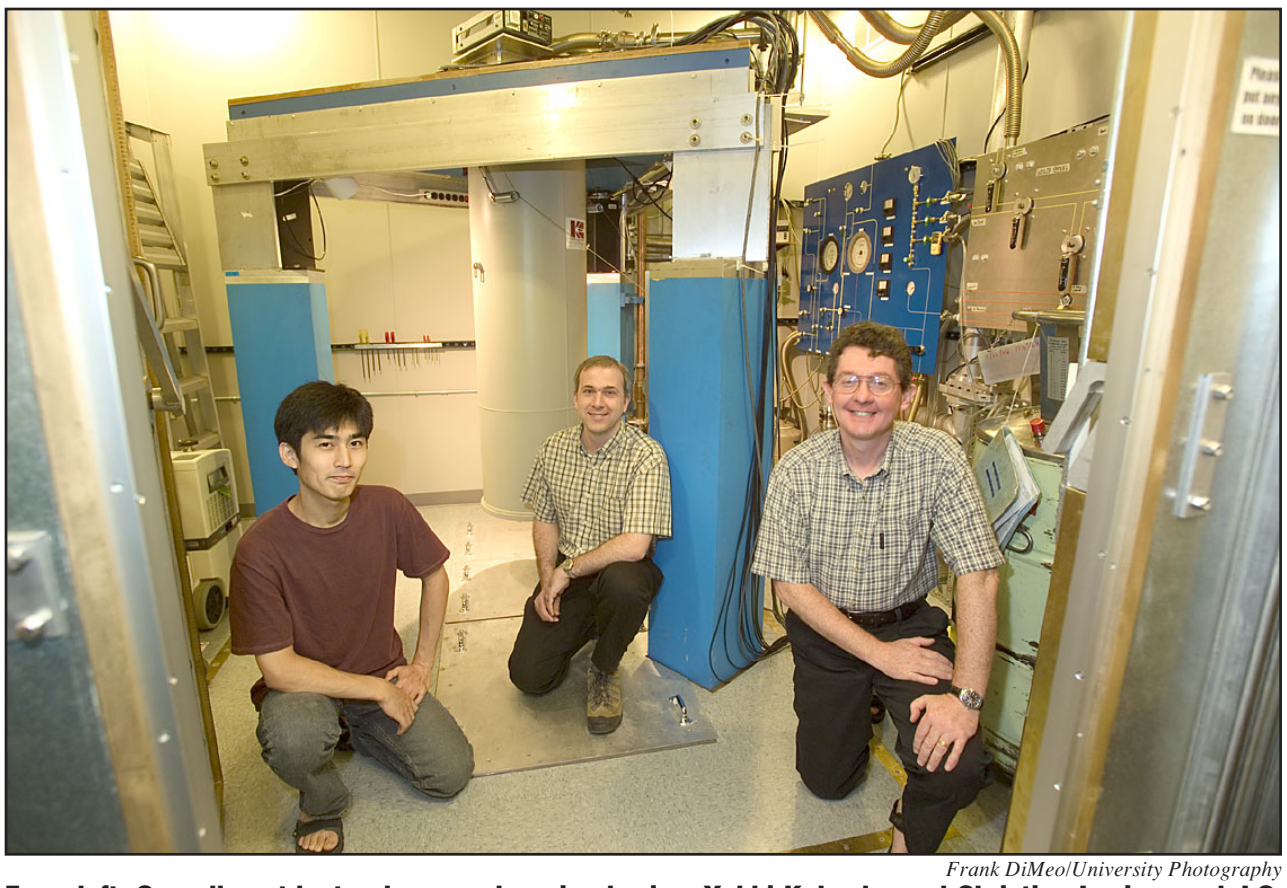
Davis, Hidenori Takagi, professor of physics at the University of Tokyo, and co-workers describe the observations in the Aug. 26 issue of the journal *Nature*. An article about the work also is scheduled to appear in the September issue of *Physics Today*.

"In at least in one cuprate high-temperature superconducting material that phase is an electronic crystal," Davis reported. "We don't understand what we've found, but we have moved into unknown territory that everyone has wanted to explore. Many people have believed that to understand high-temperature superconductivity we have to look in this territory."

A superconductor is a material capable of conducting electricity with virtually no resistance. Modified crystals of copper oxide, known as cuprates, can become superconductors at temperatures up to about 150 Kelvin (-123 degrees Celsius or -253 degrees Fahrenheit) when they are doped with other atoms that create "holes" in the crystal structure where electrons would ordinarily be. These superconductors are widely used in industry, although there is still no clear explanation of how they work. Their superconducting behavior begins when about 10 percent of the electrons have been removed, but for over a decade physicists have been puzzled by what happens when somewhat fewer electrons are removed: the material conducts electricity, but just barely, and in theory it shouldn't conduct at all.

Davis has now been able to observe this phase with a specially modified STM that measures, in effect, the quantum wave functions of the electrons in a sample.

The famous Heisenberg uncertainty principle says that we can never tell exactly where an electron is. Rather than thinking of electrons orbiting the nuclei of atoms like little planets, scientists today imagine "clouds" of electrons somewhere in the vicinity. An STM uses a needle so fine that its tip consists of just one atom, scanning across a small surface and measuring current flow between the surface and the tip. Conventional STMs scan with enough precision to image individual atoms. Davis has increased the scanning precision to a point where he can resolve details smaller than atoms. His new instrument, located in the basement of the Clark Hall of Science on the Cornell campus, is so sensitive that it has been built in a room mounted on heavy concrete pillars and isolated by air springs. For these experiments, it scans a sample and reads the probability that electrons are in certain locations, based on current flow through the STM tip.



Frank DiMeo/University Photography

From left, Cornell postdoctoral researchers in physics, Yuhki Kohsaka and Christian Lupien, and J.C. Séamus Davis, professor of physics, are flanked in Clark Hall by the massive supports of a modified scanning tunneling microscope, so sensitive that it can resolve details smaller than atoms, Aug. 2.

Davis's team studied a copper oxide containing calcium and chlorine that was doped by replacing some of the calcium atoms with sodium to remove, in various samples, from 8 to 12 percent of the electrons. The material was cooled to about 100 milliKelvins, or a hundredth of a degree above absolute zero.

What they found was that the electrons in the sample arranged themselves in tiny squares, all in turn arranged in a neat checkerboard pattern. The same pattern was found at the highest level of doping tested, where the material begins to become superconducting. Whether or not it continues at higher levels remains to be seen, Davis said.

The discovery only leads to more questions. Theoretically, Davis said, this arrangement should not conduct electricity at all, because the electrons are locked into their crystal-like pattern. "It's always been a mystery: How do you get from an insulator through a tiny change to a superconductor?" he said. "Having empirical knowledge of what this phase is may help us to get from here to there."

The *Nature* paper is titled "Discovery of a 'Checkerboard' Electronic Crystal State in Lightly Hole-Doped Ca2-xNaxCuO2Cl2." Along with Davis and Takagi, co-authors include Cornell postdoctoral researchers Christian Lupien and Yuki Kohsaka; Dung-Hai Lee, University of California-Berkeley professor of physics; and Tetsuo Hanaguri of the RIKEN Institute in Japan. The cuprate material used in the experiments was prepared by Kohsaka at the University of Tokyo in collaboration with the scientists who developed it in 1995, Masaki Azuma and Mikio Takano of Kyoto University.

CU researcher: Half of all Americans will use food stamps during adulthood

By Susan Lang

Hirschl

To be worry-free about having enough food is not the norm in the United States, says a Cornell sociologist.

"Rather, the need to use food stamps is a common American experience that at least half of all Americans between the ages of 20 and 65 will face," said Thomas A. Hirschl, professor of development sociology, who has completed a study of food-stamp use.

Race and education, Hirschl said, have dramatic links to food stamp use: More than 85 percent of African Americans will use food stamps some time between the ages of 20 and 65, compared with 37 percent of white Americans; about 64 percent of adults with less than 12 years of education will use food stamps, compared with 38 percent of adults with 12 or more years of education.

The study, co-authored with Mark R. Rank, professor of social work at the George Warren Brown School of Social Work at Washington University, will be published in the December 2004 issue of the *Journal of Nutrition Education and Behavior*. The findings were presented at the Society for Nutrition Education annual meeting in Philadelphia in July of this year.

Looking at the two extremes, the researchers found that about one-quarter of white males with 12 or more years of education will use food stamps, while more than 90 percent of black females with less than 12 years of education will use food stamps some time between ages 20 and 65.

"We also find that while the use of food stamps is often brief, of those who have used food stamps once, about three-quarters will use them again in a different year," said Hirschl. "These findings are in sharp contrast to the belief that the use of the nation's food nutrition safety net is something that happens to someone else and is atypical of the American experience. Rather, they indicate that Americans have a substantial need and use of food stamps, and they suggest a significant risk of food insecurity across the life course." Food insecurity is defined as when the availability of nutritious and safe foods or the ability to acquire foods in socially acceptable ways is limited or uncertain.

The researchers merged 30 waves (1968 to 1997) of the nationally representative Panel Study of Income Dynamics data set to analyze 260,000 "person years" of information on food stamp use, defined as an individual in a household receiving food stamps sometime during the year.

"The patterns that emerged from our analysis are particularly troubling in light of the fact that food insecurity, along with hunger, have been shown to be closely related to various health problems, including an increased risk in the development of chronic diseases, impairment of psychological and cognitive functioning among children and a greater likelihood of self-reporting health status as poor," reported Hirschl and Rank. "The fact that at least four out of 10 Americans will experience food insecurity at some point during their adulthood would appear to represent a significant public health cause for concern."

The findings show that many Americans rely on food stamps to help them through periods of economic turmoil. "Yet ironically, the food nutrition safety net that was designed to help alleviate food insecurity and hunger has been under attack in recent years and is threatened by proposals to reduce and restrict enrollment," said Hirschl.

The research was supported by a U.S. Department of Agriculture-funded research development grant administered through the Northwestern University/University of Chicago Joint Center for Poverty Research.

Study: Mom's money skills and mental health predict family's food adequacy

By Susan Lang

Even when poor rural families receive food stamps from the U.S. Department of Agriculture, many still do not have enough food, according to a new study by nutritionists at Cornell and their colleagues from several other land-grant universities.

The researchers found that about half of the families in their study used food stamps, and half of these families said they did not have enough to eat.

Important factors affecting whether poor rural families have enough to eat, the researchers say, are a mother's financial management skills, her depressive symptoms and her difficulty in paying medical bills.

"Because using food stamps has such a stigma in the United States, particularly in rural areas, only those families who are the worst off tend to use food stamps," explained Christine Olson, professor of nutritional sciences at Cornell and the lead author of the study, which is published in the current issue of *Family Economics and Nutrition Review* (Vol. 16, No. 1). "However, using food stamps is not enough to raise the standard of living among these very poor families to a point where they are no longer food insecure."

The study found that about half of the rural low-income families studied were "food insecure," defined as the limited or uncertain availability of nutritionally adequate and safe food. Olson and her co-authors interviewed 316 low-income families with children in 24 rural counties in 14 states. They found that after controlling for income and financial resources, one of the most significant factors in predicting whether a family was food insecure was how many food and financial skills the mother used. The more skills she used, such as managing bills, making a budget, stretching foods and preparing meals, the less likely she was to have a food-insecure household.

"This study is important because it's the first to show how important the food and financial skills and the health of

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