Quantum coherence possible in incommensurate electronic systems

November 2 2006

Researchers at the University of Illinois at Urbana-Champaign have demonstrated that quantum coherence is possible in electronic systems that are incommensurate, thereby removing one obstacle in the development of quantum devices.

Electronic effects in thin films and at interfaces lie at the heart of modern solid-state electronic technology. As device dimensions shrink toward the nanoscale, quantum coherence and interference phenomena become increasingly important.

"At quantum dimensions, quantum mechanics says device components will couple together and act in a concerted manner, where everything affects everything else," said Tai-Chang Chiang, a professor of physics and a researcher at the university's Frederick Seitz Materials Research Laboratory. "Most scientists assume that electronic layers must be commensurate, so electrons will flow without being diverted or scattered."

In fact, however, most material interfaces are incommensurate as a result of differences in crystal sizes, symmetries or atomic spacing. Random scattering of electrons was thought to destroy quantum coherence in such systems at the nanoscale.

Now, by studying electron fringe structure in silver films on highly doped silicon substrates, Chiang and his research group show that even when electronic layers are incommensurate, they can still be coherent.

The researchers report their findings in the Nov. 3 issue of the journal *Science*.

In work performed at the Synchrotron Radiation Center at the University of Wisconsin at Madison, the researchers grew atomically uniform silver films on highly doped n-type silicon substrates. Then they used a technique called angle-resolved photoemission to examine the fine-structured electronic fringes.

Although the silver films and silicon substrates are lattice mismatched and incommensurate, the wave functions are compatible and can be matched over the interface plane, Chiang said. The resulting state is coherent throughout the entire system.

The fringes the scientists recorded correspond to electronic states extending over the silver film as a quantum well and reaching into the silicon substrate as a quantum slope, with the two parts coherently coupled through an incommensurate interface structure.

"An important conclusion drawn from the present study is that coherent wave function engineering, as is traditionally carried out in lattice-matched epitaxial systems, is possible for incommensurate systems," the researchers wrote, "which can substantially broaden the selection of materials useful for coherent device architecture."

Source: University of Illinois at Urbana-Champaign