Complex oxides become multifunctional at ultimate quantum limit

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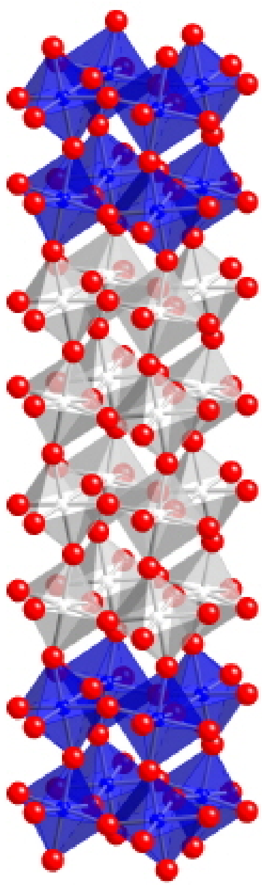

Illustration of a 4-unit-cell film of $NdNiO_3$ (white) confined by $LaAlO_3$ (blue) at the boundaries to make a quantum well structure.

(Phys.org)—A University of Arkansas physicist and his colleagues have examined the lower limits of novel materials called complex oxides and discovered that unlike conventional semiconductors the materials not only conduct electricity, but also develop unusual magnetic properties.

Jak Chakhalian, Jian Liu, Derek Meyers and Benjamin Gray of the University of Arkansas and John W. Freeland and Phillip Ryan of the Advanced Photon Source at Argonne National Laboratory present their ideas in Physical Review Letters.

"Contrary to what we have today in modern microelectronics devices based on silicon, here in a single quantum well, which is just four nanometers thick, we now have several functionalities in one device layer," said Chakhalian, professor of physics and holder of the Charles and Clydene Scharlau Chair in the J. William Fulbright College of Arts and Sciences. "Engineers can use this class of material to devise new multifunctional devices based on the electrons' spin."

The microelectronic materials – semiconductors—used in today's computers, have almost reached the lower limitation for size and functionality. Computers run on several semiconducting devices layered together in the very smallest of spaces, known as quantum wells, where nanoscale layers of a semiconducting material are sandwiched between two nanoscale layers of a non-conducting material. However, the researchers found that by using complex oxides with correlated electrons confined to quantum well geometry, they added a new dimension to the mix.

The new structure is based on the concept of correlated charge carriers, like those found in rust, or iron oxide. In rust, if one electron does something, all of the other electrons "know" about it. This phenomenon, called correlated electrons, does not exist in silicon-based materials that run today's computers, televisions, complex medical equipment,power cell phones and keep the electricity on in homes.

"In normal materials used today, electrons don't care about the movement of one another," Chakhalian said. "We can predict their properties almost on the 'back of an envelope' with the help of powerful computers." However, with correlated materials, the calculations for the movement of one electron involve tracking the interactions with billions of electrons, and this is beyond modern theory capabilities.

Chakhalian and his colleagues went down to four atomic layers of a correlated complex oxide material based on nickel and sandwiched it in between two layers of non-conducting oxide material based on aluminum. Unlike the semiconducting materials, the complex oxide structure revealed the unexpected presence of both electronic and magnetic properties.

These multiple properties in a single material may allow the semiconductor industry to push the limits of current conventional computers and develop multiple functions for a single device, possibly allowing everyday electronics to become smaller and faster than they are today.

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