Materials scientists watch electrons 'melt'

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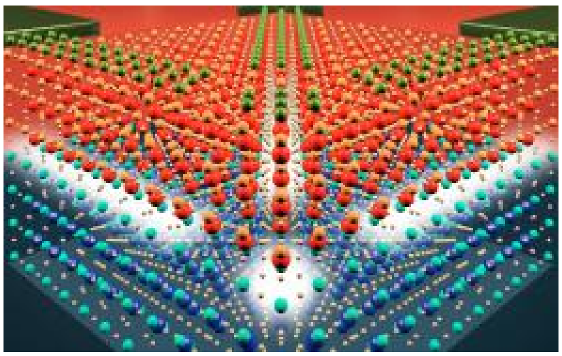

Electrons in a grid pattern. Credit: University of Pittsburgh

(PhysOrg.com) -- When a skier rushes down a ski slope or a skater glides across an ice rink, a very thin melted layer of liquid water forms on the surface of the ice crystals, which allows for a smooth glide instead of a rough skid. In a recent experiment, scientists have discovered that the interface between the surface and bulk electronic structures of certain crystalline materials can act in much the same way.

Materials scientists often face the challenge of finding ways to move electrons across interfaces and through a material, according to John Mitchell, a chemist at the U.S. Department of Energy's Argonne National Laboratory. However, the organization of the crystalline surface of a material does not always correlate with the organization of the electronic states below. In fact, in the boundary layer between the surface and the bulk can be quite rough.

"You can think about the fidelity of an interface chemically—how well the atoms are arranged, or how neatly and properly they're distributed," Mitchell said. "Below that, however, there's a second level of organization, which is electronic fidelity."

While the crystal structure of the material can look nearly perfectly organized over large length scales, researchers at Argonne and Brookhaven National Laboratory showed a dividing line of "roughness" between the crystal surface and the bulk. "The electronic structure there is not perfect; instead, it's disturbed. That has implications for how electrons might transport within that layer or across that surface. We tried to explore how this rough intermediary layer evolves as a function of temperature compared to the bulk of the crystal. Looking towards future devices, structures and new materials, we'd like to think about this in a three-dimensional way, moving not just in a plane but across different interfaces," he added. "How well you're going to communicate information across interfaces depends on how well organized they are."

Using surface X-ray scattering techniques at Sector 6-ID of Argonne's Advanced Photon Source, the research team studied the electronic order of an oxide material just below the temperature at which it would begin to "melt"—that is, to become electronically disorganized—in the bulk. "You want to operate in a temperature window just below this bulk ordering temperature because that's where you get the biggest bang for your buck in terms of signal, but the potential problem we're seeing here is that it's exactly in this regime that the electronic surface might be in its worst condition."

"It's the same principle that we see in ice skating, just shrunk down much smaller," Mitchell added. "The electronic surface pre-melted while the bulk remained frozen."

According to Mitchell, the findings have important implications for future electronic devices that require well-defined electronic interfaces. This could be particularly true for nanoscale devices, whose performance is dominated by their surface electronic behavior. "The challenge is to figure out how to engineer these materials to try to make this surface a little more electronically robust," he said.

Provided by Argonne National Laboratory

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