Electronic Surface Melting

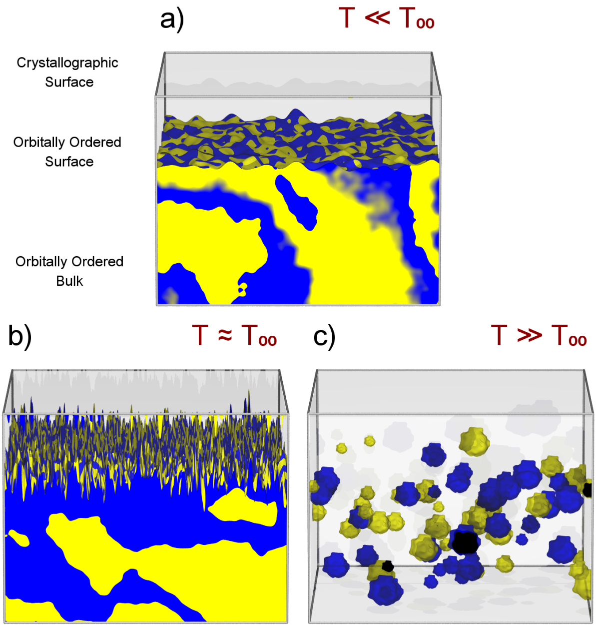
The performance of devices like transistors and memory chips depends on controlling the behavior of electrons at surfaces and interfaces of complex structures. For example, the performance of nanoscale devices is determined by the electronic behavior of their surfaces. Understanding the temperature dependence of electronic order at a surface can provide important insights into the nature of electronic interactions and in particular the relative strength of the surface and bulk interactions.

The Challenge

To understand what happens when ordered ensembles of electron orbitals melt and how this affects surface electronic behavior.

The Solution

A team of Argonne and Brookhaven researchers used X-ray scattering techniques (performed at Argonne's Advanced Photon Source) to observe electrons in oxide compounds.



Schematic representation of the crystallographic surface, the electron orbital surface, and the orbitally ordered bulk for temperatures below the bulk freezing temperature (a), near the bulk freezing temperature (b), and well above the bulk freezing temperature. The size of the blue and yellow regions represents schematically the correlation length of the orbital order in the bulk. The roughness of the orbital surface is shown as the height variation of the shaded (blue and yellow) surface and the in-place correlation length by the size of the shaded surface regions.

The Results

Ensembles of electrons freeze and melt in ways similar to ice. When heated, the surface of ice melts first, a phenomenon that allows skiers to glide across snow. Researchers found that the electronic orbitals of the tested oxides froze into ordered arrays (just like ice) and that the surface melted first, establishing electronic surface melting. This finding has important implications for electronic devices that require well-defined electronic interfaces. The electronic surface becomes increasingly rough and less well defined when melting and vanishes below the bulk ordering temperature. Materials with electronic surfaces that behave in this way could be problematic in devices operating at finite temperature.

> ***"Surface melting is a fundamental science problem with real implications for future generation electronics platforms. It is extremely important to understand the microscopic behavior of such models systems to be able to take the next step—control of interface electronic functionality,"*** **says John Mitchell, senior chemist.**