How to overcome the oxide barrier

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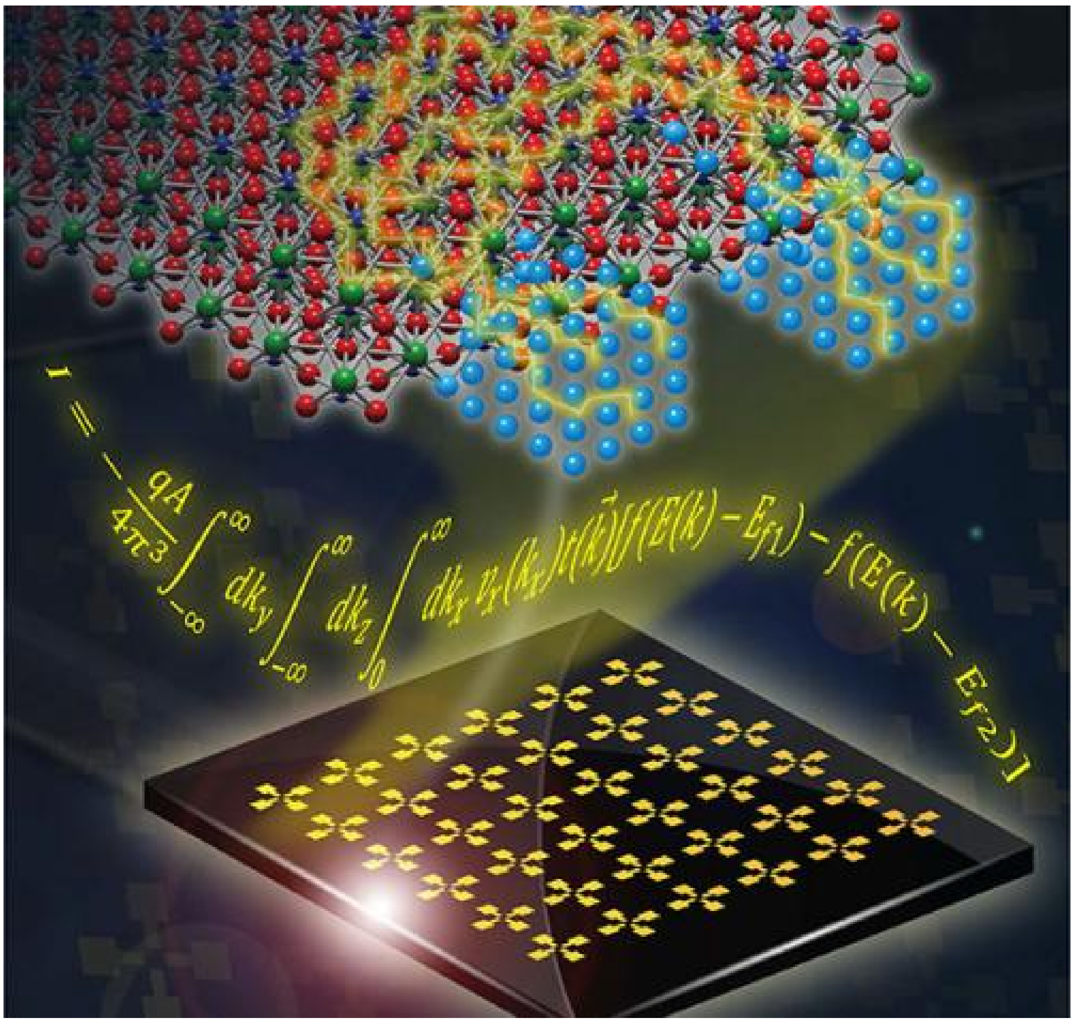

Atomistic diagram for crystalline chromium metal (light blue) on strontium titanate(top), an equation that describes the transport process (middle), and an array of metal contacts on a strontium titanate wafer (bottom). Chambers et al.: Ultra-low Contact Resistance at an Epitaxial Metal/Oxide Heterojunction through Interstitial Site Doping. Advanced Materials. 2013. Credit: Wiley-VCH Verlag GmbH & Co. KGaA

(Phys.org) —Researchers at Pacific Northwest National Laboratory have uncovered the characteristics of a low-resistance electrical contact to strontium titanate, $SrTiO_3$, an important prototypical oxide semiconductor. Oxides are likely to be important materials in next-generation electronic devices, and they need to be extremely small. Getting electrical signals into and out of oxide semiconductors is hard because a large energy barrier typically develops at the junction with metal contacts. Metal contacts are required to get electricity into and out of a semiconductor device in much the same way that jumper cables are needed to transfer power from a healthy car battery to a dead battery. This work shows how to eliminate this barrier while keeping the contact area extremely small, at the nanometer level.

Whether it be for advanced defense systems or consumer products, we as a nation are always looking for better performance and new features from our communications technologies. Yet, the limits of what can be achieved with conventional semiconductors, such as silicon, are clearly on the horizon. This work represents an important advance in the use of oxides, which by their very physical nature enable new electronic functionalities to be envisaged and implemented.

Crystalline films of chromium metal were deposited onto single-crystal surfaces of strontium titanate in ultrahigh vacuum using molecular beam epitaxy. The resulting heterojunctions, which are where two dissimilar materials come into contact, were characterized with scanning transmission electron microscopy, electron energy loss spectroscopy, ultraviolet and x-ray photoelectron spectroscopy, and first-principles theoretical modeling based on density functional theory. Earlier work by the same PNNL researchers had shown that the electrical resistance of this junction is as low as has ever been measured, but the reasons for this result were not known.

Other low-resistance metalizations are known, but forming them involves a somewhat messy mix of metals and what is effectively localized melting at the junction. This approach is not useful for nanoscale devices because of lateral spreading resulting from alloying at the junction.

Detailed investigation showed that the equivalent of 1 or 2 atomic layers of chromium diffuse into the strontium titanate, occupy interstitial sites, and anchor the remainder of the film to the oxide, resulting in strong adhesion. The in-diffused chromium atoms also transfer electrons to titanium atoms in the top few atomic planes, effectively removing the energy barrier that would otherwise be present if this diffusion and charge transfer had not occurred, and converting the surface of the strontium titanate into a metal. The resulting junction is thus a "metal/metal" rather than a "metal/semiconductor" interface. But, unlike other metal/oxide interfaces with low contact resistance, this junction is structurally and compositionally well defined and nearly atomically abrupt.

Electronics in general and computers in particular represent major energy consumption across the globe. This work shows how power dissipation can be reduced in the operation of a device using an oxide semiconductor as an active ingredient. The next step is to use crystalline chromium as an electrical contact in more advanced multi-layer structures that might be useful not only in oxide electronics, but also in oxide-based solar cells. Other future work involves searching for other metals that have the same useful properties as chromium for this purpose.

More information: Chambers, S. et al. 2013. Ultra-low Contact Resistance at an Epitaxial Metal/Oxide Heterojunction through Interstitial Site Doping. *Advanced Materials*. Online in advance of print. onlinelibrary.wiley.com/doi/10 … a.201301030/abstract

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