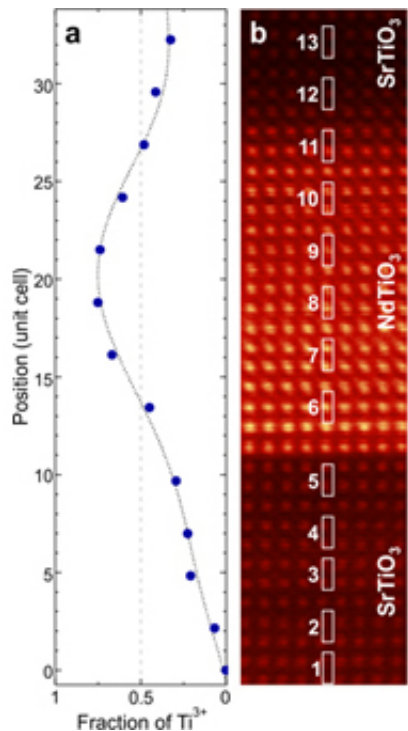


# Creating an electrical conduit using two insulators

January 14 2016



Scanning transmission electron micrograph (right) and Ti<sup>3+</sup> fraction [Ti<sup>3+</sup>/(Ti<sup>3+</sup>++Ti<sup>4+</sup>)] extracted from electron energy loss spectra (left) for a SrTiO<sub>3</sub>/NdTiO<sub>3</sub>/SrTiO<sub>3</sub> heterojunction. Electron transfer from NdTiO<sub>3</sub> to SrTiO<sub>3</sub> results in Ti<sup>4+</sup> in the former and Ti<sup>3+</sup> in the latter. The electrons transferred to the SrTiO<sub>3</sub> are itinerant and constitute the highest density quasi-2D electron gas ( $3 \times 10^{15} \text{ e-/cm}^2$ ) ever achieved in a semiconductor superlattice.

Revolutionary new electronic devices, such as those required for next-

generation computers, require new and novel material systems. Scientists at the University of Minnesota and Pacific Northwest National Laboratory showed that combining two oxide materials in one particular orientation gives rise to a densely packed sheet of highly mobile electrons. The sheet is created when bound electrons jump across the junction of a neodymium-based oxide,  $\text{NdTiO}_3$ , to a material based on strontium,  $\text{SrTiO}_3$ , and become free. The density of these electrons—the highest ever observed at the junction of two materials—paves the way for a new class of electronic devices.

New kinds of [electronic devices](#) that exhibit novel functionalities are constantly being sought after to expand our technology base. One such device, which cannot be fabricated with existing electronic materials, is a high-frequency plasmonic field effect transistor. This device can turn a larger electronic signal on and off very fast, something not achievable with traditional semiconductor materials, such as silicon. The interface between  $\text{NdTiO}_3$  and  $\text{SrTiO}_3$  constitutes such a pathway, even though neither oxide conducts electricity as a pure material.

By depositing alternating, ultra-thin layers of  $\text{NdTiO}_3$  and  $\text{SrTiO}_3$  on a crystalline surface, and investigating their properties experimentally and theoretically, the researchers demonstrated that a very high density of mobile electrons can be generated and confined within the  $\text{SrTiO}_3$  layers. The mobile electrons jump from the  $\text{NdTiO}_3$  layers, where they cannot easily move, into the  $\text{SrTiO}_3$  layers, where they are free to move.

Why do the electrons jump? A certain number must jump from  $\text{NdTiO}_3$  into  $\text{SrTiO}_3$  to stabilize the combined material system. The charges that stabilize the neodymium (Nd) and titanium (Ti) ions in  $\text{NdTiO}_3$  cannot be reached without electron rearrangement, and part of this rearrangement involves some electrons jumping across the junction into the adjacent  $\text{SrTiO}_3$  layers. However, when the  $\text{NdTiO}_3$  layer reaches a certain thickness, it becomes energetically favorable for additional

loosely bound electrons in the  $\text{NdTiO}_3$  layer to spill over into the adjacent  $\text{SrTiO}_3$  layer, like water running over a waterfall. Once this happens, the  $\text{SrTiO}_3$  layers become conducting channels with a high density of [mobile electrons](#).

**More information:** Peng Xu et al. Quasi 2D Ultrahigh Carrier Density in a Complex Oxide Broken-Gap Heterojunction, *Advanced Materials Interfaces* (2015). [DOI: 10.1002/admi.201500432](https://doi.org/10.1002/admi.201500432)

Provided by Pacific Northwest National Laboratory

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