# Scientists reveal how a novel ceramic achieves directional conduction

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An international team led by University College London scientists at the London Centre for Nanotechnology has unravelled the properties of a novel ceramic material that could help pave the way for new designs of electronic devices and applications.

Working with researchers from the Swiss Federal Institute of Technology (ETH), Zurich, the University of Tokyo and Lucent Technologies, USA, they reveal in a Letter to Nature that the complex material, which is an oxide of manganese, functions as a self-assembled or 'natural' layered integrated circuit. By conducting electricity only in certain directions, it opens up the possibility of constructing thin metal layers, or racetracks, insulated from other layers only a few atoms away.

Currently, the race for increasingly small and more powerful devices has relied on two-dimensional integrated circuits, where functional elements such as transistors are engineered via planar patterning of the electrical properties of a semiconductor. Packing more functionalities into tiny electronic devices has until now been achieved by reducing the lateral size of each component, but a new realm of opportunity opens with the ability of building three-dimensional structures.

Professor Gabriel Aeppli, Director of the London Centre for Nanotechnology and co-author of the study, explains: "There is an issue of how you deal with leakage between layers when you pack circuits into three dimensions. Our work with the Tokyo-Lucent groups shows that you can have many layers with little or no leakage between them. This is because we're not dealing with ordinary electrons, but with larger objects, consisting of electrons bound to magnetic and other disturbances of the atomic fabric of the material, which can't travel across the barriers between layers."

The flow of electricity in modern electronic devices relies on the fact that electrons move readily in certain solids, such as metals like copper, and are blocked from moving in insulators such as quartz. In ordinary solids, electrons move similarly in all three dimensions, therefore if a material is metallic along one direction, it will be metallic in all directions. The ceramic – a manganese oxide alloy with the chemical formula La1.6Sr1.4Mn2O7 – has fascinated scientists for a decade due to the extraordinary sensitivity of its electrical properties to magnets placed near it. Most interesting was the discovery by the University of Tokyo group that even quite small magnets can switch electrical currents in the same way in this ceramic as in much more expensive, individually fabricated electronic devices of the type being tested for advanced magnetic data storage.

Using one of the classic tools of nanotechnology, the scanning tunnelling microscope, Dr Henrik Rønnow (ETH) and Dr Christoph Renner (LCN and UCL) swept a tiny metallic tip with sub-atomic accuracy over the surface of the ceramic to sense its topographic and electronic properties at spatial resolution of less than the diameter of a single atom. The data showed that this ceramic behaves like a perfect metal along the planes parallel to the surface and like an insulator along the direction perpendicular to the surface.

The results also revealed the first snap-shot of a possible culprit for this unusual electronic behaviour. In conventional solids, charge is carried by simple electrons, but in such ceramics, it is shuttled around by more complex objects, known as polarons, which consist of electrons bound to a magnetic disturbance as well as local displacements of atoms away from their ordinary positions.

Source: University College London