Generation of tailored magnetic materials

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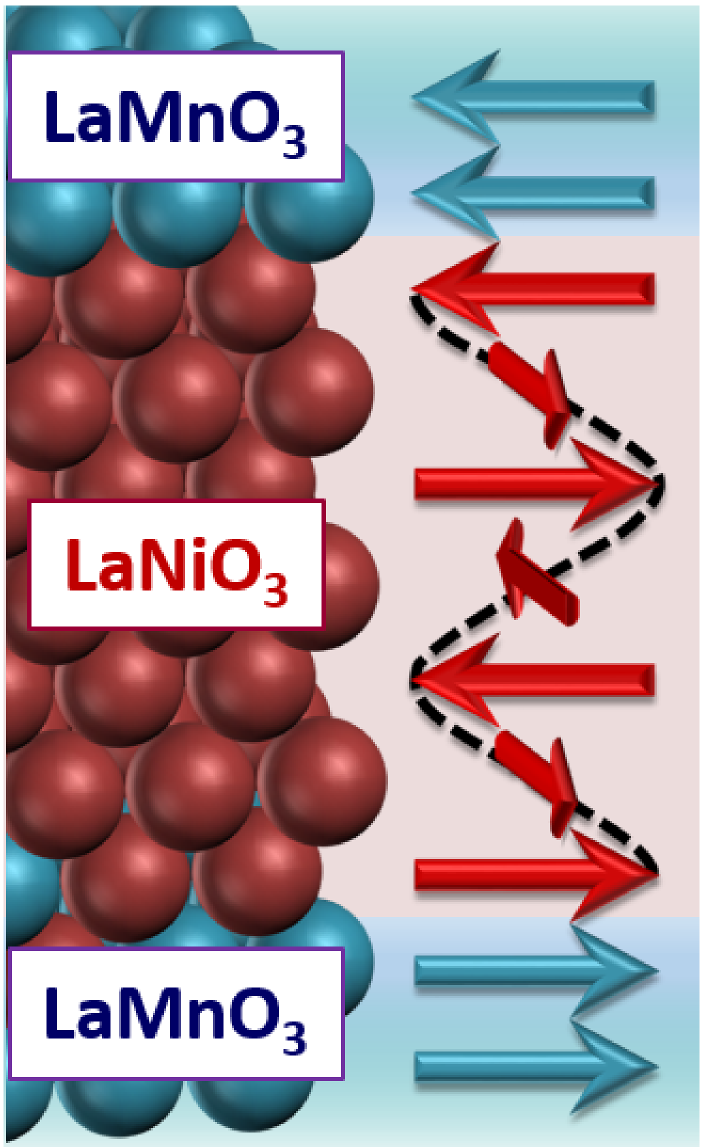

Artist view of the manipulation of the magnetic properties achieved in the oxide materials LaNiO3 and LaMnO3 when few atomic layers of each material are grown one on top of the other successively. In this case, LaNiO3, which initially was conducting and non-magnetic, is found to become insulating and magnetic when in contact with LaMnO3. Credit: © Marta Gibert Gutierrez - UNIGE

New technologies require growing precision in the intrinsic properties of the materials used. To meet increasingly specific requirements, physicists are interested in a generation of artificial materials, the properties of which can be controlled. Researchers at the University of Geneva (UNIGE), Switzerland, in collaboration with French and English teams, have succeeded in manipulating the properties of two oxides that make up this artificial material. The researchers modified the magnetic properties, which can be either ferromagnetic or antiferromagnetic; that is, with or without net magnetic moment. The scientists have demonstrated, in their study published in *Nature Communications*, that they can control the magnetism in this type of material and that they could, in the near future, offer tailored materials for new technologies.

When two materials are in contact, they interact in different ways, and sometimes exchange electrons. But what happens when one stacks up ultrathin layers on the order of one nanometer? "We have combined two materials, $LaNiO_3$, a metallic paramagnet (without magnetic order), and $LaMnO_3$, an insulating antiferromagnet, by alternating a layer of the first, then of the second, etc. We then observed what the influence of interactions at the interfaces was and we noticed a profound change in the intrinsic properties of the two materials," said Jean-Marc Triscone, professor at the department of quantum matter physics in the faculty of science at UNIGE.

$LaNiO_3$ and $LaMnO_3$ have the same cubic crystalline structure, and thus the researchers can stack the elemental unit cells of these compounds—that is, the small "cubes" made of just a few atoms—by using state-of-the-art technology. Then, they create an artificial structure with a perfect alignment of the unit cells. To do this, the physicists deposit one unit cell after the other on a substrate—a small, heated crystal tile. The layers are very thin and their nanometer thickness is controlled precisely at the unit cell.

Goldsmith precision

"In order to realise a perfect structure on the crystal tile, we had to find the exact temperature and pressure conditions required to grow the materials one on top of the other. Then we investigated the properties of the interfaces depending on the number of layers stacked," explained Marta Gibert, researcher in physics at UNIGE and first author of the study. "Measurements of the physical properties then revealed that the properties of $LaNiO_3$ are very different when in contact with $LaMnO_3$. From being a metal without magnetic order, it becomes not only magnetic but also insulating. Moreover, the overall properties of the artificial material depend on the individual thickness of the layer of each material and they can also change as a function of the chosen thickness," she said.

Thanks to this discovery, the researchers are therefore able to control the magnetic state of these materials—a track to build artificial tailored materials according to specific needs in the future. Such control of the magnetic interactions could be used to develop future magnetic memory technology, allowing the high dissipation energy of current processors to be reduced.

This research is not limited to magnetic materials, but it is also of interest for materials that are simultaneously magnetic and ferroelectric, suggesting new memory technology or even superconducting materials working at higher temperatures—a dream which may be not so distant.

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