Emerging new properties at oxide interfaces

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In many ionic materials, including the oxides, surfaces created along specific directions can become electrically charged. By the same token, such electronic charging, or 'polarisation', can also occur at the interface of two connecting materials.

Theoretically, this could lead to the build-up of an ever increasing voltage in the materials in certain systems, a situation known as a 'polarity catastrophe'. Certainly this cannot occur in practical systems, for energy sake, and Nature deals with this situation by reconstructing the electronic configuration of the interface via a shifting of charges across the interface, or by structural reconstructions, namely, the displacement of atoms.

With oxide materials, a unique consequence of these reconstructions is that it provides a means to create novel electronic phases, stabilised by the interface, and which cannot exist in the bulk.

Dr. Ariando from the National University of Singapore's (NUS) Department of Physics and NUS Nanoscience and Nanotechnology-NanoCore, along with his co-workers, showed that at this interface, a remarkable combination of strong diamagnetism (superconductor like), paramagnetism and ferromagnetism can co-exist with the quasi two-dimensional electron gas when prepared under a more oxidising condition.

Past studies had shown that two-dimensional conducting planes, in the form of quasi two-dimensional electron gas, could emerge between otherwise non-magnetic insulating oxide, Lanthanum Aluminate ($LaAlO_3$) and Strontium Titanate ($SrTiO_3$).

Interestingly, Dr. Ariando's team had also shown that the ferromagnetic phase was stable even above room temperature and the diamagnetism below a relatively high temperature of 60 K.

Industrial applications

The results also indicate that the free surface of $SrTiO_3$ could well be responsible for all these fascinating phenomena. The $SrTiO_3$ resembles Silicon. This will have a significant impact on industry since Silicon has been used in semiconductor technology – silicon has been the workhorse for oxide-based devices and electronics.

These multiple electronic and magnetic phases at oxide interfaces could yield interesting technological applications. That a variety of magnetic states can be produced close to the surface ($_3$ or the interface of $LaAlO_3$ /$SrTiO_3$, be it change in oxygen pressure or magnetic field, proves that this is a very active interface, and that it can yield strong responses to external stimuli.

One could well consider building novel sensors out of these interfaces that could be used as, say, oxygen sensors, or even magnetic sensors. Still, where these applications are concerned, there is a need to further understand these phenomena and optimise the device configuration.

The research of Dr. Ariando and his co-workers in the oxide interface field is reminiscent of the times when two-dimensional electron gas in the semiconductor heterostructures first became available, and the quantum Hall effect and fractional quantum Hall effect were discovered, both resulting in Nobel prizes.

The physics of the oxide material systems is however richer, involving much stronger interaction between the electrons, mutually and within the crystal lattice. There is great interest in exploring these interfaces in the quest for new nano-electronic devices.

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