Exploring novel phenomena in artificial oxide heterostructures

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Perovskite oxide compounds, with the chemical formula ABO_3, display a very large diversity of physical phenomena, including magnetism, ferroelectricity, colossal magnetoresistance and superconductivity, among many others. Their simple structure allows them to be stacked on top of each other using state-of-the-art deposition techniques, combining their properties to create new multifunctional materials. Additionally, the interactions between the different degrees of freedom at the interfaces of these systems can lead to completely new phenomena that are not present in the bulk constituent materials. This opens endless possibilities for exploring new phenomena and engineering new functionalities [1]. Finally, as well as these artificially engineered interfaces, perovskite oxides can exhibit naturally occurring interfaces, such as ferroelectric domain walls, nanoscale sheets with equally fascinating properties that are not present in the bulk materials [2].

In this talk, I will discuss on how we focus on assembling synthetic materials in epitaxial oxide structures, and searching for novel properties and functionalities in these materials. Firstly, I will show how in $PbTiO_3$-$SrRuO_3$ ferroelectric-metal superlattices, the combination of electrostatic boundary conditions [3] and epitaxial strain creates a three-dimensional ordering of nanoscale ferroelectric domains, leading to a supercrystal phase [4]. This domain structure causes local deformations of the ferroelectric layers and therefore imposes giant curvatures and strain gradients on the metallic $SrRuO_3$ layers, presenting a new paradigm for engineering correlated materials with tailored modulated structural and electronic properties.

For the last part of my talk, I will discuss how the recent discovery of superconductivity in hole-doped infinite-layer nickelate films ($RNiO_2$, where R is a rare earth cation) [5] has motivated us to search for ways to electron-dope the perovskite nickelate family ($RNiO_3$). I will show how we succeed in electron doping these systems using A-site substitution with a novel type of dopant, and I will discuss the implications of this doping in the search for superconductivity in these materials, as well as the decade-long search for multiferroic behaviour in the $RNiO_3$ family.

References

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