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Heterogeneity in magnetic complex oxides[1]

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Heterogeneity of quantum materials on the nanoscale can result from the spontaneous formation of regions with distinct atomic, electronic and/or magnetic order, and indicates coexistence of competing quantum phases. In complex oxides, the subtle interplay of lattice, charge, orbital, and spin degrees of freedom gives rise to especially rich phase diagrams. For example, coexisting conducting and insulating phases can occur near metal-insulator transitions, colossal magnetoresistance can emerge where ferromagnetic and antiferromagnetic domains compete, and charge-ordered and superconducting regions are present simultaneously in materials exhibiting high-temperature superconductivity. Additionally, externally applied fields (electric, magnetic, or strain) or other external excitations (light or heat) can tip the energy balance towards one phase, or support heterogeneity and phase coexistence and provide the means to perturb and tailor quantum heterogeneity at the nanoscale. Engineering nanomaterials, with structural, electronic and magnetic characteristics beyond what is found in bulk materials, is possible today through the technique of thin film epitaxy, effectively a method of 'spray painting' atoms on single crystalline substrates to create precisely customized layered structures with atomic arrangements defined by the underlying substrate. Charge transfer and spin polarization across interfaces as well as imprinting nanoscale heterogeneity between adjacent layers lead to intriguing and important new phenomena testing our understanding of basic physics and creating new functionalities. Moreover, the abrupt change of orientation of an order parameter between nanoscale domains can lead to unique phases that are localized at domain walls, including conducting domain walls in insulating ferroelectrics, and ferromagnetic domain walls in antiferromagnets. Here we present our recent results on tailoring the electronic anisotropy of multiferroic heterostructures by imprinting the $BiFeO_3$ domain pattern in an adjacent $La_{0.7}Sr_{0.3}MnO_3$ layer, understanding the metal-insulator transition in strained VO_2 thin films and identifying a three-dimensional quasi-long-range electronic supermodulation in $YBa_2Cu_3O_{7-x}/La_{0.7}Ca_{0.3}MnO_3$ heterostructures.

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