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Evolution of correlated electron behavior from the surface to the bulk in $\mathbf{Sr}_x\mathbf{Ca}_{1-x}\mathbf{VO}_3$[1]

JUDE LAVEROCK, Boston University

Understanding correlated electron behaviour remains one of the most important, and challenging, problems in modern condensed matter physics. In correlated electron systems, the interaction between electrons is of the order of, or larger than, the electron kinetic energy, and the concept of a well-defined quasiparticle is restricted to a narrow region of energies near the Fermi level, beyond which our strict understanding of a quasiparticle with a defined dispersion relation, easily accessible through band theory, breaks down. In the last few decades, the discovery of unusual and promising behavior in strongly correlated materials has yielded effects as diverse as high temperature superconductivity, colossal magnetoresistance and multiferroics. Indeed, the functionalisation of strongly correlated materials, either in bulk crystalline form or as artificial layered heterostructures, is fast emerging as one of the most promising avenues for future advanced technologies, and key to unlocking the potential of such designed materials is a firm grasp of how electron correlations evolve at surfaces and interfaces. Here, we investigate $Sr_xCa_{1-x}VO_3$ as a prototypical example of a strongly correlated material, exhibiting both strong Hubbard subbands and appreciable quasiparticle peaks. Using a variety of ultraviolet, soft, and hard x-ray spectroscopies, we present a detailed depth-sensitive study of the evolution in the effects of electron correlations from the sample surface to its bulk. Our results illustrate the intrinsic enhancement of the effects of electron correlations at the surface, which has important implications for the designed properties at the interface of heterostructures. Strong incoherent subbands are found to lie $\sim$ 20% closer in energy to the coherent features in the most surface-sensitive measurements, accompanied by a $\sim$ 10% narrowing in the overall bandwidth. Secondly, we demonstrate that resonant soft x-ray emission spectroscopy is a sensitive probe of correlated electron behavior, capable of providing complementary information to photoemission spectroscopy from a truly bulk perspective.

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