Highlights

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Large Polarons as Key Quasiparticles in $SrTiO_3$ and $SrTiO_3$-Based Heterostructures

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Quasiparticles in metals and semiconductors are formed through the interactions of electrons (holes) with the elementary excitations of the solid, like phonons and magnons. Here, by using titanium L-edge resonant inelastic x-ray scattering (RIXS) with unprecedent energy resolution we demonstrate that the quasiparticles in bulk $SrTiO_3$ and related heterostructures are large polarons formed by the coupling of itinerant carriers to optical phonons. RIXS spectra on different samples, from barely undoped $SrTiO_3$ to strongly metallic heterostructures, show low (25-30 meV), mid (50-60 meV) and high energy (90-100 meV, LO3) optical phonons excitations and, at a higher energy (125-135 meV), an intra-t_{2g} d-d excitation accompanied by the emission of an LO3 optical phonon, which represents a hallmark of large polarons in STO and LAO/STO bilayers. Furthermore, from the analysis of the RIXS cross section, we find that the electron-phonon coupling constant of the LO3 phonon mode decreases with the carrier density as consequence of the screening of the large-polaron self-induced polarization [1].

Beside confirming earlier signatures by ARPES at the surface of STO [2], in LAO/STO [3] and in FeSe/STO bilayers [4], our study demonstrates more generally the emergence of large polaron physics in both bi- and three-dimensional titanates. Finally, it emerges that polarons are observed also in nominally undoped STO, with a coupling constant well below the value expected for small polarons formation. Consequently, we can infer that even at the very low doping level, as that induced by residual defects or by long living photodoped carriers, $3d^1$ electrons are dressed by long-range polar lattice distortions, as theoretically predicted in other wide band gap materials like LiF [5]. Future investigations and theoretical modeling of the normal and superconducting state of STO and STO-based heterostructures will have to take in consideration the central role of large polarons in these materials

References

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