Tuning the electronic structure of LuSb via epitaxial synthesis

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Observation of extreme magnetoresistance (XMR) in rare-earth monopnictides has raised enormous interest in understanding the role of its electronic structure. I present first demonstration of epitaxial synthesis of LuSb thin films on GaSb (001) substrates. Combining the techniques of molecular-beam epitaxy, low-temperature transport, angle-resolved photoemission spectroscopy, and hybrid density functional theory, we have unveiled the bandstructure of LuSb, where electron-hole compensation is identified as a mechanism responsible for XMR. In contrast to bulk single crystal analogues, quasi-two-dimensional behavior is observed in our thin films for both electron and holelike carriers, indicative of dimensional confinement of the electronic states. Introduction of defects through growth parameter tuning results in the appearance of quantum interference effects at low temperatures, which has allowed us to identify the dominant inelastic scattering processes and elucidate the role of spin-orbit coupling [1]. Furthermore, by fabricating ultra-thin films I show that it is possible to controllably create an imbalance in the band fillings of electron and hole-like carriers in this otherwise compensated semimetal. Moreover, magnetoresistance behavior can also be tuned by application of bi-axial strain by synthesizing thin films of LuSb on lattice mis-matched substrates. Our work demonstrates the efficacy of epitaxial synthesis of rare-earth monopnictides to control its electronic structure and thereby, its physical properties.

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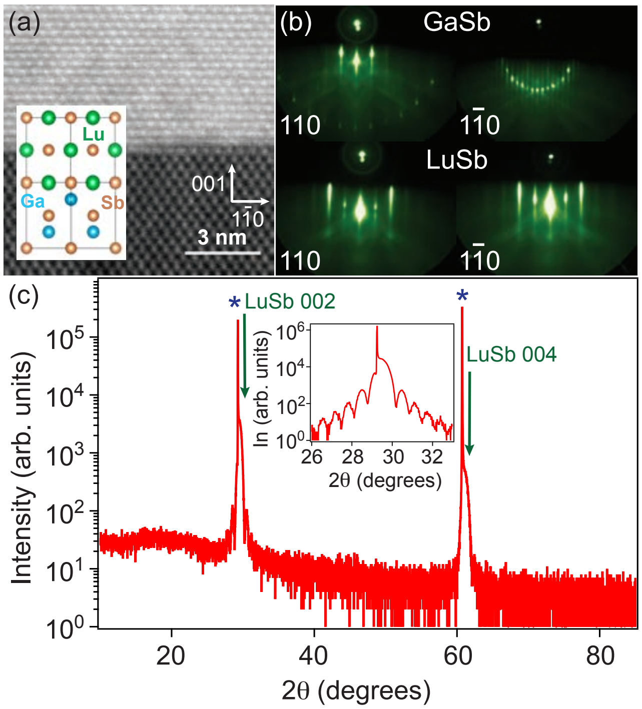

Figure 1: Structural characterization of LuSb/GaSb (001) thin films. (a) HAADF-STEM image along the [110] zone axis. Inset shows the schematic of a proposed atomic arrangement across the GaSb-LuSb interface when viewed along the [110] direction. (b) RHEED images recorded after completion of growths of GaSb and LuSb epitaxial layers both along the [110] and [1$\bar{1}$0] azimuths. (c) Out-of-plane θ – 2θ XRD scan establish that our thin film is single phase. Substrate peaks are marked by asterisks. Inset shows thickness fringes around the (002) LuSb Bragg peak.

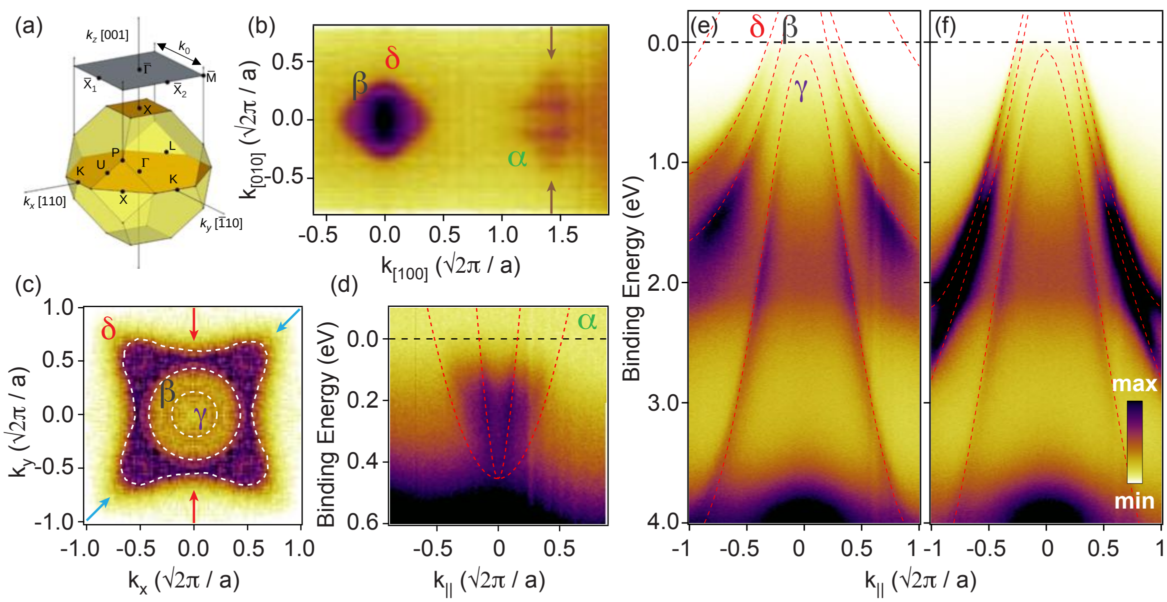

Figure 2: ARPES spectra of LuSb/GaSb (001) thin films. (a) Bulk three-dimensional Brillouin zone of LuSb and its surface projection showing high-symmetry points. (b) Two-dimensional Fermi surface map near the bulk Γ point showing both holelike (β, δ) and electronlike (α) Fermi surface sheets. (c) Two-dimensional map near the bulk Γ point at a binding energy of 0.495eV illustrating anisotropy of the δ pocket. (d) *E*-*k* spectral map along $\bar{\Gamma}$-$\bar{M}$-$\bar{\Gamma}$ as indicated by brown arrows in panel (b). *E*-*k* spectral maps along (e) $\bar{M}$-$\bar{\Gamma}$-$\bar{M}$-and (f) $\bar{X}$-$\bar{\Gamma}$-$\bar{X}$ indicated by blue and red arrows in (c), respectively. Red dotted lines are calculated band dispersions from DFT.