High-mobility two-dimensional electron gas with quantized states in polar-discontinuity doped $LaInO_3/BaSnO_3$ heterostructure grown by molecular beam epitaxy

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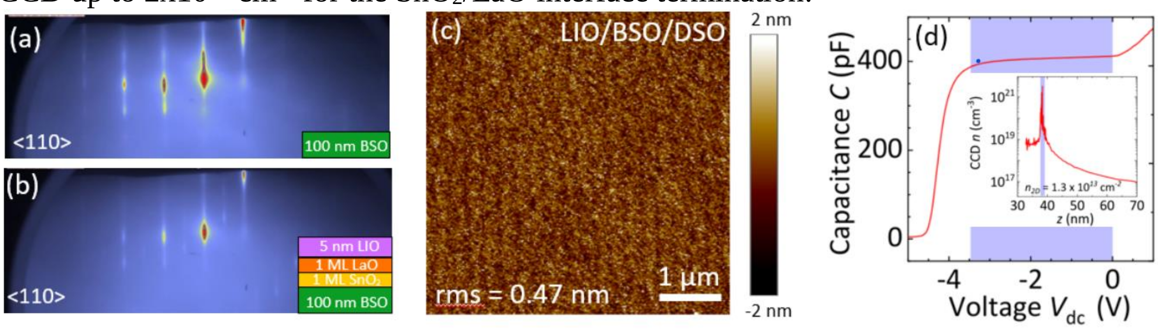
Transistor applications of semiconducting oxides require, both high room-temperature electron mobilities (μ_{RT}) and high charge carrier densities (CCDs), ideally realized with a two-dimensional electron gas (2DEG). So far, prototype oxide 2DEG systems have either high μ_{RT} but limited CCD such as modulation-doped $(Al_xGa_{1-x})_2O_3/Ga_2O_3$, or a high CCD but low μ_{RT} such as the polar-discontinuity doped $LaAlO_3/SrTiO_3$ interface. Interfacing the more suitable, wide-bandgap, nonpolar semiconductor $BaSnO_3$ (BSO), having high bulk μ_{RT} (up to 320 cm^2/Vs), with polar $LaInO_3$ (LIO) is predicted to create and confine a 2DEG with CCD up to $2x10^{14}$ cm^{-2} for the SnO_2/LaO interface termination.



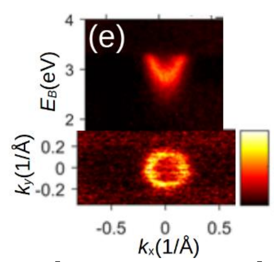


Fig.1: RHEED images of (a) 100 nm thick BSO layer and (b) a 5 nm-thick LIO layer on top of BSO with SnO_2/LaO interface design. (c) AFM image of the grown BSO/LIO heterostructure on $DyScO_3$ substrate. (d) CV measurement confirming charge accumulation layer at the BSO/LIO interface. Inset: Corresponding CCD depth profile. (e) Parabolic dispersion and in-plane Fermi surface map of a 1.2 nm LIO-on-BSO heterostructure measured by ARPES, confirming quantization of the 2DEG.

We demonstrate the adsorption-controlled growth of the LIO[1] on BSO heterostructure by molecular beam epitaxy using a shutter sequence to control the SnO_2/LaO interface termination. The films were analyzed by reflection high-energy electron diffraction (RHEED) [Figs. 1(a) and 1(b)], x-ray diffraction, atomic force microscopy (AFM) [Fig. 1(c)]. The interface structure is investigated by cross-sectional transmission-electron microscopy. The formation of the quantized 2DEG at their interface is confirmed by capacitance-voltage (CV) [Fig. 1(d)] and angular-resolved photo-electron spectroscopy (ARPES) [Fig. 1(e)]. Van der Pauw-Hall measurements confirm CCD>$10^{13}cm^{-2}$ and μ_{RT}>$100cm^2/Vs$.

[1] G. Hoffmann et al., Phys. Rev. Mater. **7**, 084606 (2023).

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