

A perverse transparent oxide semiconductor, La:BaSnO₃

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La-doped BaSnO₃ (LBSO) is one of the most promising transparent oxide semiconductors (TOSs) since its single crystal exhibits a high mobility of 320 cm² V⁻¹ s⁻¹.^[1] However, the electron mobility of LBSO thin films are less than 150 cm² V⁻¹ s⁻¹.^[2] Electron scatterings at threading dislocations caused by the film/substrate lattice mismatch are widely considered as the main origin of mobility suppression in LBSO films. Nevertheless, the mobility value of deposited LBSO epitaxial films still below 100 cm² V⁻¹ s⁻¹ even if BaSnO₃ single crystal substrates were used to minimize the lattice mismatch.^[3] In addition, the electron transport properties of LBSO films were not significantly affected by the lattice mismatch and exhibited a strong thickness dependence.^[4]

To clarify the mobility suppression in LBSO from a different perspective, we used ozone to create a highly oxidative environment during the LBSO film growth and examined the role of oxygen vacancies in the electron transport properties of LBSO. The results suggest that the electron mobility suppression in LBSO films is strongly related to oxygen deficient LBSO layers generated at the initial film growth stage, which may be attributed to the strong thickness dependence observed in our previous study.^[4] The oxygen deficiencies in LBSO hindered the activation of La ion and changed the valence state of nearby Sn from 4+ to 2+. Since the conduction band of LBSO consists of Sn 5s orbitals, oxygen vacancies locally filled Sn 5s orbitals and created discontinuities in the conduction band, which reduced the electron mobility (FIG.).^[5] This phenomenon is completely opposite from typical behaviors of n-type TOS, where oxygen vacancy formation improves the electron transport properties.

[1] H. J. Kim *et al.*, *Appl. Phys. Express* **5**, 061102 (2012).

[2] S. Raghavan *et al.*, *APL Mater.* **4**, 016106 (2016).

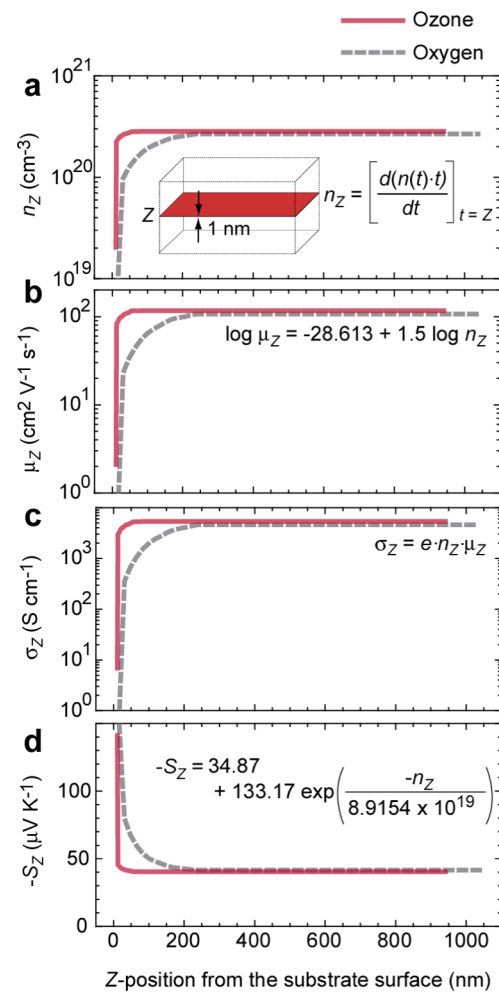


FIG. Calculated depth profile of (a) carrier electron concentration, (b) mobility, (c) electrical conductivity, and (d) thermopower in the 2%-La doped LBSO film grown under ozone and oxygen atmospheres. We assumed that the Sn²⁺ ions play as both charge compensation and ionized impurity.

[3] W-J.Lee *et al.*, *Appl. Phys. Lett.* **108**, 082105 (2016).

[4] A. V. Sanchela, M. Wei *et al.*, *Appl. Phys. Lett.* **112**, 232102 (2018).

[5] A. V. Sanchela, M. Wei *et al.*, submitted.