Thermopower modulation clarification of the operating mechanism in wide bandgap $BaSnO_3$–$SrSnO_3$ solid-solution based thin film transistors

RIES-Hokkaido Univ.[1], IST-Hokkaido Univ.[2],
°A. V. Sanchela[1], M. Wei[2], H. J. Cho[1,2], and H. Ohta[1,2]
E-mail: anup.sanchela@es.hokudai.ac.jp

Transparent oxide semiconductor (TOS) with large bandgap (E_g ~4 eV) based thin-film transistors (TFTs) showing both high carrier mobility and UV-visible transparency has attracted increasing attention as a promising component for the next generation optoelectronics. Among TOSs, $BaSnO_3$–$SrSnO_3$ solid-solutions (E_g = 3.5–4.2 eV) are good candidates because the single crystal shows very high mobility. However, the TFT performance has not been optimized due to the lack of fundamental knowledge especially the effective thickness (t_{eff}) and the carrier effective mass (m^*). Here we demonstrate that the electric field thermopower (S) modulation method address this problem by combining with the standard volume carrier concentration (n_{3D}) dependence of S measurements.

Figure 1a shows the sheet carrier concentration dependences of the thermopower. The degenerate/non-degenerate threshold is located at S = −244 μV K^{-1}. In the degenerate region, the slope of the S–n_{2D} relationship is −198 μV K^{-1} $decade^{-1}$ (dotted lines), indicating parabolic E–k relationship. In order to analyze the effective thickness of the TFT channel, we calculated the S–n_{3D} relationship with varied carrier effective mass (m^*) from 0.1 m_0 to 1 m_0 (**Fig. 1b**). In the degenerate region, the calculated values well reproduce the observed values (m^* = 0.4 m_0 for x = 0, 0.2 m_0 for x = 0.5). The difference would be due to the increase of E_g and latter would be due to the enhancement of overlap population of neighboring Sn 5s orbitals.

By comparing the electric field accumulated sheet carrier concentration (n_{2D}) and n_{3D} at same S, we clarified that the t_{eff} ($\equiv n_{2D}/n_{3D}$) of the conducting channel becomes thicker with increasing Sr concentration, whereas the m^* becomes lighter. Schematic carrier accumulation of the x = 0 and x = 0.5 $Ba_{1-x}Sr_xSnO_3$ TFTs. The effective channel thickness (n_{2D}/n_{3D}) of x = 0 sample is ~1 nm, whereas x = 0.5 sample is ~32 nm (**Fig. 1c, d**).

The present analyses technique is epoch-making to experimentally clarify the t_{eff} and m^*, and essentially important to realize advanced TOS-based TFTs showing both high optical transparency and high mobility.

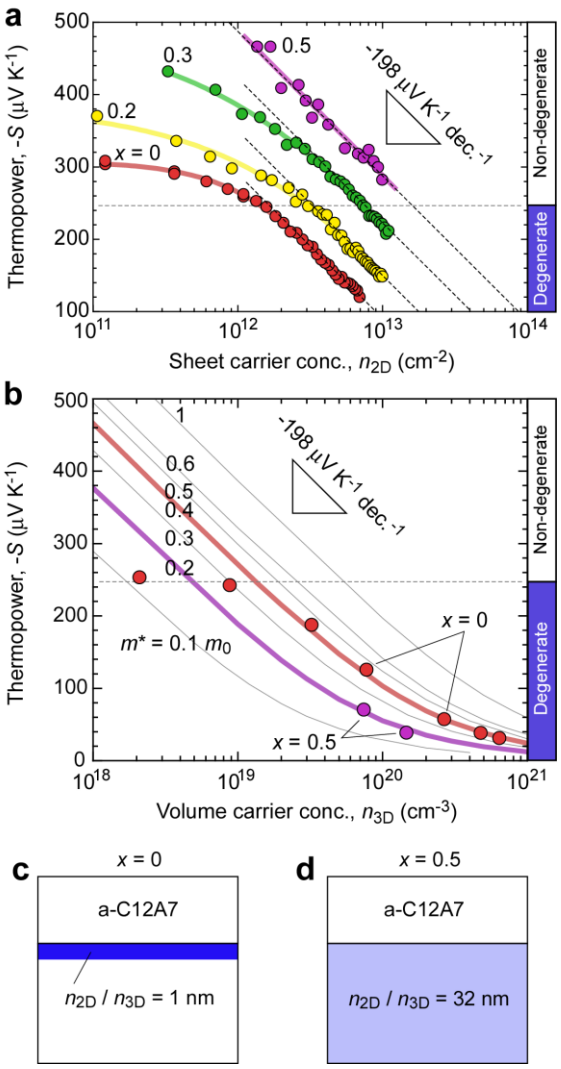

FIG. Electric field thermopower modulation analysis of the $Ba_{1-x}Sr_xSnO_3$ TFTs. a. Sheet carrier concentration dependences of the thermopower. **b**. Volume carrier concentration (n_{3D}) dependence of the thermopower. **c, d.** Schematic carrier accumulation of the x = 0 and x = 0.5 $Ba_{1-x}Sr_xSnO_3$ TFTs.