熱電能電界変調法による SnO_2 薄膜トランジスタのチャネル厚さ分析

Electric Field Thermopower Modulation Analyses of the Channel Thickness for SnO_2 Thin Film Transistors

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Transparent amorphous oxide semiconductors (TAOSs) based transparent thin-film transistors (TTFTs) with high field-effect mobility (μ_{FE}) are essential devices for advanced flat panel displays. Among TAOSs, amorphous (a-) SnO_2 has several advantages against current a-$InGaZnO_4$ (μ_{FE} is ~10 cm^2 V^{-1} s^{-1}[1]) such as higher μ_{FE} >100 cm^2 V^{-1} s^{-1}[2] and being indium-free. However, due to the strong gas sensing characteristics of SnO_2, the further research and application of SnO_2 TFT have been limited. Recently, we clarified the operation mechanism of a-SnO_2 TTFT by field thermopower modulation analyses[3]. The result showed that a 1.7 ± 0.4 nm-thick effective conducting channel formed at the interface between gate insulator and conducting channel with a 2.5-nm-thick depletion layer from the top surface in a 4.2-nm-thick bottom-gate top-contact type a-SnO_2 TTFT without any surface passivation. To further clarify the operating mechanism of a-SnO_2 TTFT, we measured the electric field modulated thermopower of the a-SnO_2 TTFTs with different thicknesses.

The resultant a-SnO_2 TTFTs showed a decreased I_{ON}/I_{OFF} as increased the thickness of the SnO_2 conducting channel **(FIG. a)**. The 4.2 nm-thick SnO_2 TTFT[3] shows the best I_{ON}/I_{OFF} performance. All the a-SnO_2 TTFTs showed an almost linear relationship in the S−log n_s plot **(FIG. b)**, similar to that of S−log n_{3D}, indicating that the E−k relation at the bottom of the conduction band is parabolically shaped and the t_{eff} can be extracted as n_s/n_{3D}. The $t_{eff} \equiv n_s/n_{3D}$ of the conducting a-SnO_2 channel increased with the thickness of the SnO_2 conducting channel **(FIG. c)**. The 4.2 nm-thick SnO_2 TTFT[3] shows the smallest t_{eff} with the best I_{ON}/I_{OFF} performance. From the thickness of the a-SnO_2 film and the t_{eff}, the carrier depletion depth at the top surface was concluded to be around 3−4 nm of the a-SnO_2 film, which shows a similar depletion length as reported data[4]. The present results may provide the fundamental design concept of a-SnO_2 TTFT device.

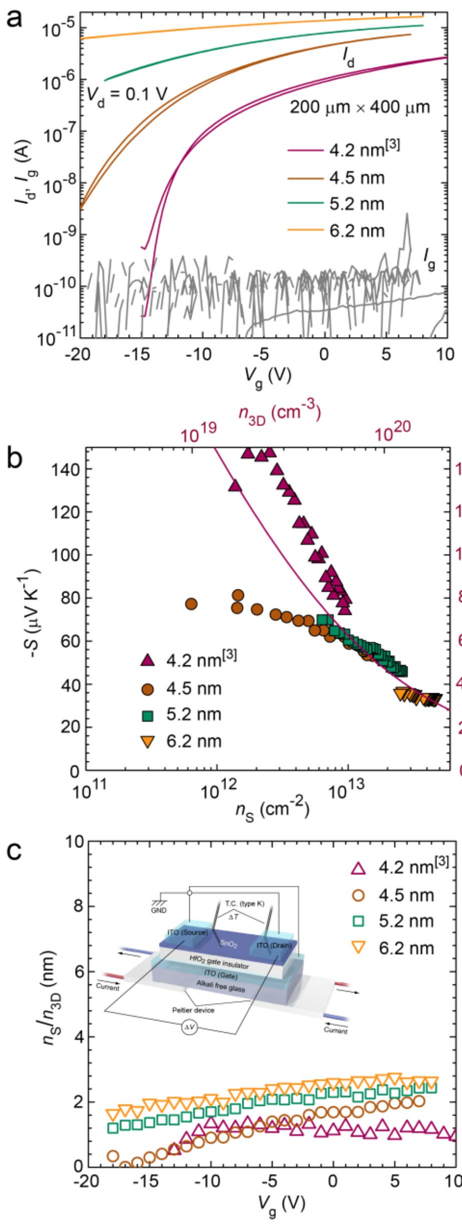

FIG. Electric field thermopower modulation analyses of the bottom-gate top-contact a-SnO_2 TTFT. (a) Transfer characteristic (I_d−V_g) curve at V_d = +0.1 V. (b) Change in S as a function of the sheet carrier concentration (n_s). (c) The effective thickness (t_{eff}), which is defined as n_s/n_{3D}, as a function of V_g.

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