Multimodal encapsulation of p-SnOx to engineer the carrier density for thin film transistor applications

Dong Hun Lee[1], Yuxuan Zhang[1], Kwangsoo No[2], Han Wook Song[3], and Sunghwan Lee[1,*]

1School of Engineering Technology, Purdue University, West Lafayette, IN 47907, USA

2Department of Materials Science and Engineering, KAIST, Daejeon 34141, Republic of Korea

3Center for Mass and Related Quantities, Korea Research Institute of Standard and Science, Daejeon 34113, Republic of Korea

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*Corresponding authors: sunghlee@purdue.edu

Abstract

It has been challenging to synthesize p-type SnO_x ($1 \leq x < 2$) and engineer the electrical properties such as carrier density and mobility due to the narrow processing window and the localized oxygen 2p orbitals near the valence band.

We recently reported on the processing of p-type SnOx and an oxide-based p-n heterostructures, demonstrating high on/off rectification ratio (>10^3), small turn-on voltage (<0.5 V), and low saturation current (~1×10^{-10} A)[1]. In order to further understand the p-type oxide and engineer the properties for various electronic device applications, it is important to identify (or establish) the dominating doping and transport mechanisms. The low dopability in p-type SnOx, of which the causation is also closely related to the narrow processing window, needs to be mitigated so that the electrical properties of the material are to be adequately engineered [2, 3].

Herein, we report on the multifunctional encapsulation of p-SnO_x to limit the surface adsorption of oxygen and selectively permeate hydrogen into the p-SnO_x channel for thin film transistor (TFT) applications. Time-of-flight secondary ion mass spectrometry measurements identified that ultra-thin SiO_2 as a multifunctional encapsulation layer effectively suppressed the oxygen adsorption on the back channel surface of p-SnO_x and augmented hydrogen density across the entire thickness of the channel. Encapsulated p-SnO_x-based TFTs demonstrated much-enhanced channel conductance modulation in response to the gate bias applied, featuring higher on-state current and lower off-state current. The relevance between the TFT performance and the effects of oxygen suppression and hydrogen permeation is discussed in regard to the intrinsic and extrinsic doping mechanisms. These results are supported by density-functional-theory calculations.

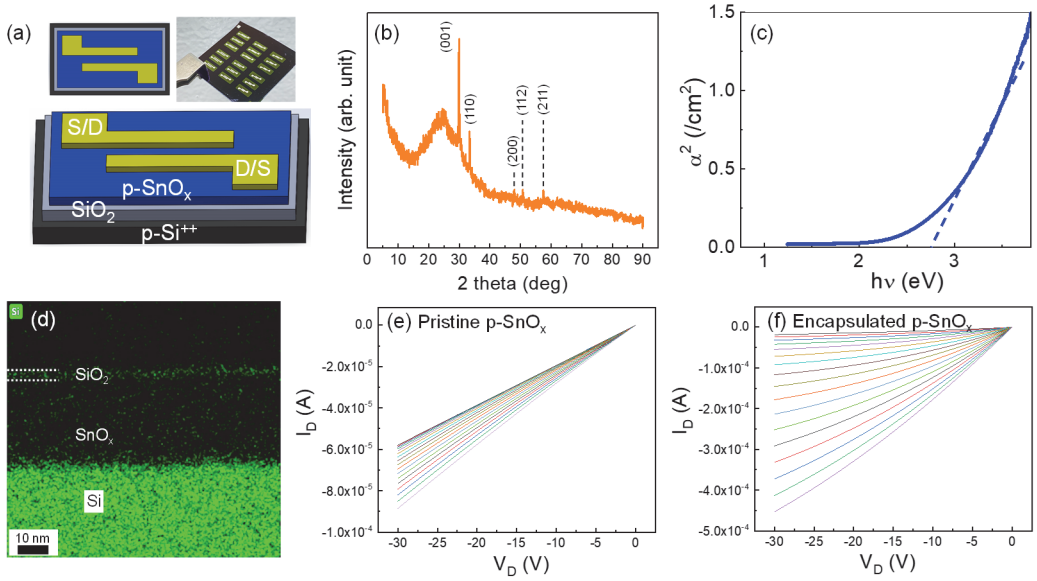

Figure 1. p-SnO_x-based TFTs with pristine p-SnO_x and SiO_2 encapsulated p-SnO_x channels

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