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High Performance Oxide and Iodide TFTs and CMOS

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Thesis outline

Chapter 1. "General Introduction"

This chapter described a brief background on amorphous metal oxide (AOS) and conventional p-type semiconductor. Current issues of high mobility AOS and conventional p-type semiconductor were also pointed out. Based on these issues, motivations and objectives of this thesis were addressed.

Chapter 2. "Unintended Carbon-Related Impurity and Negative Bias Instability in High-Mobility AOS-TFTs"

The major origin which leads to negative bias instability of InSnZnOx (a-ITZO), a representative of high mobility AOS, was examined. It is identified that CO-related surface impurities strongly correlate with negative bias instability of a-ITZO. From the thermal desorption spectroscopic (TDS) results, lithograph process (chemical reaction between photoresist and a-ITZO) was revealed to be the specific step for CO-related surface impurities incorporation. Additionally, similarity can be drawn between gas sensing mechanism of post-transition metal oxides (i.e., SnO_2, In_2O_3, and ZnO) and the degradation of a-ITZO thin film transistor (TFT) caused by CO-related surface impurity, which states that carrier injection/removal between the surface adsorbate and the conduction band of metal oxide can be manipulated by Femi-level change under gate bias. Based on this finding, an effective treatment was proposed to eliminate CO-related impurities and realized a-ITZO TFT with high mobility (~50 cm^2/Vs) and high stability.

Chapter 3. "Origin and Solution of Mobility-Stability Trade-Off in Oxide Thin-Film Transistors"

Based on the results of chapter 2, an extended study was conducted to understand why only high mobility AOSs are sensitive to surface carbon-related impurities. To decipher this empirical mobility-stability trade-off phenomenon, following methodology were further conducted: (i) device simulation on bilayer structure TFT (ii) systematical measurement on conduction band minimum (CBM, electron affinity) level for different AOSs system. From above simulation and experimental results, increasing in carrier concentration caused by donation from surface impurities rather than carriers trapping was clearly confirmed for the origin of threshold voltage variation of a-ITZO TFT. Moreover, it is clarified that large conduction band dispersion (high electron mobility) always comes with deep conduction band level. This means that charges on the energy states formed by the impurities experience smaller activation energy for becoming free carriers in high mobility AOS system, and thus results in high sensitivity of high mobility AOS TFT against surface impurities under external forces. Based on this understanding of the mobility-stability trade off and finding effective elimination way of CO-related impurities, high mobility and high stability was achieved even for a-ITZO TFT (mobility of 70 cm^2/Vs) with higher indium content.

Chapter 4. "Realization of High-Performance P-Type TFT by Utilizing Crystallographic Dimensionality of Metal Iodide Semiconductor"

Since a critical issue arising from mobility-stability trade-off relation in high mobility AOSs (i.e., a-ITZO) have been solved, next challenge was to realize easy processable high performance p-type semiconductor for extended application of AOSs (e.g., a-IGZO) such as integrated circuit. In order to build up the integrated circuit by AOSs, the basic building block, inverter, is important. This means that a p-type TFT comparable to n-type AOS TFT is required. For the requirement of equivalent p-type TFT, both threshold voltage and mobility are needed be similar to its counterpart. According to this prerequisite, a strategy for acquiring high performance p-type TFT was proposed based on combination of 2D PEA_2SnI_4 and 3D $FASnI_3$. Although both 2D PEA_2SnI_4 and 3D $FASnI_3$ have their own drawbacks on TFT application such as grain boundary issue for 2D PEA_2SnI_4 and uncontrollable high hole concentration for 3D $FASnI_3$, a good synergy effect can be achieved when these two systems are combined to form the unique core/shell structure. Basically, the core composed by 3D ($FASnI_3$) can be well isolated by the shell composed by 2D or quasi 2D (PEA_2SnI_4 or $PEA_2FA_1Sn_2I_7$). By utilizing this unique structure, uncontrollable threshold voltage of 3D perovskite TFT and poor hole transportation property of 2D perovskite TFT can be overcome successfully. As a result, high performance p-type TFT with mobility of 25 cm^2/Vs was realized. Due to the equivalency of electrical properties between 2D/3D perovskite TFT and a-IGZO TFT, the inverter with high voltage gain (voltage gain ~200 VV^{-1} at V_{dd}=20 V) was subsequently obtained.

Chapter 5. "General Conclusion"

In the last chapter, I concluded the overall contribution and provided suggestion for future research direction.