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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Amorphous oxide semiconductors (AOSs) have brought a lot of amazing properties to optoelectronics including flat-panel displays, smart windows, electrochromic and flexible electronic. Because of their high tunability on electrical and chemical properties, possibility of commercialization on these compounds is promising. As matter of fact, the most well-known Indium-Gallium-Zinc Oxide (a-IGZO) has already been utilized in modern display technology. However, development of their application not only on display but also on more-complex functionality electronics has been slowed down due to following conventional issues: (i) difficulty in simultaneously achieving instability-free and high mobility AOSs thin film transistor (TFT), (ii) lack of high performance p-type semiconductor by easy processability. To solve above difficulties, I firstly aimed at the fundamental problems of mobility-stability trade-off relationship and clarified that charges transferring from surface impurity such as carbon-related impurity to high mobility AOSs TFT takes place easily due to readily charges receiving of deep conduction band nature for high mobility AOSs. Secondly, by taking the advantages from both 3D ($FASnI_3$) and 2D (PEA_2SnI_4) tin iodide perovskite attracting a lot of attention recently due to delocalized nature of their valence band maximum, I proposed a unique core-shell structure composed by 3D and 2D tin iodide perovskite to obtain desirable p-type switching property. Since 3D microcrystals are well isolated by 2D film, the threshold voltage of core-shell tin iodide perovskite TFT is mainly governed by 2D film. This means that high carrier concentration of 3D tin iodide perovskite can be overcome. Additionally, 3D microcrystals can well bridge between 2D film, which can relief the discontinuity raised by organic spacer of 2D system. As a result, this thesis demonstrates the pathway for achieving high mobility AOSs with high stability and high performance logic circuit powered up by AOS and tin iodide perovskite.

In chapter two, 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 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.

In chapter three, 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, increasing in carrier concentration caused by donation from surface impurities rather than carriers trapping was further confirmed for the origin of threshold voltage variation of a-ITZO TFT by comparing device simulation and experimental results. Since carrier generation model resulting in negative bias instability has been well proved and explained, conduction band minimum (CBM, electron affinity) level which affects energy barrier between CBM and energy states formed by impurities was systematically measured. 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.

In chapter four, 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 tin iodide perovskite. It is understood that 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 $FASnI_3$. However, 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.

In conclusion, in this thesis, I overcame two main challenges which AOSs face currently by providing detail explanation and deciphering the nature of AOSs and tin iodide perovskite. I believed that this thesis can not only contribute to display technology but also extend the application of AOSs.