Amorphous p-Channel Tellurium Oxide Transistors

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Abstract

This presentation discusses high-performance p-type oxide semiconductors for thin-film transistors (TFTs). It highlights selenium-alloyed tellurium in a tellurium sub-oxide matrix, demonstrating stable p-channel TFTs with high mobility (10~15 cm²/V·s), on/off ratios (10^6–10^7), and long-term stability, driven by delocalized valence bands and selenium alloying for enhanced transport.

1. Introduction

Amorphous semiconductors offer cost-effectiveness, uniformity, and scalability over polycrystalline counterparts. However, conventional amorphous silicon (a-Si) delivers poor electrical properties and doping capabilities, necessitating new materials. High-mobility amorphous n-type oxide has advanced and commercialized new-generation displays, memories, and optoelectronic devices. To advance next-generation CMOS technology and low-power electronics, a comparable p-type counterpart is required. Conventional oxides exhibit intrinsically poor p-type properties and doping capability due to localized valence band maxima (VBM) from anisotropic oxygen orbitals. Despite decades of efforts to develop alternative materials, significant challenges persist, and none have shown promise for commercialization.

Current efforts utilize p-type poly-Si combined with n-type oxides for advanced electronics fabrication; however, the crystalline structure and the high-temperature complex processing limit the high-intensity integration [1]. Recent development of amorphous p-type Te-based oxide (a-TeO_x) by our group and others offer new opportunities [2,3]. The dispersive VBM from the high-mobility Te percolation channel within the amorphous TeO_2 matrix enables high hole mobility and stability in an amorphous state. This new material design makes replacing commercial a-Si with all-oxide CMOS technology feasible [4]. (*Nat. Electron.* 7, 328, 2024).

The next step in advancing commercial applications is the development of large-scale functional all-oxide CMOS integrated circuits (ICs) in an industry-compatible manner. This requires key scientific insights and effective strategies for modulating the conduction channel to meet various integration needs, which remain largely unexplored in amorphous p-type semiconductors. Meanwhile, as a potential semiconductor, developing high-efficiency hole doping capabilities is crucial—capabilities that are not demonstrated in conventional a-Si and other oxides.

This study aims to address these challenges by uncovering key insights and strategies for flexible, tunable hole transport pathways and doping in amorphous p-type oxides, while also achieving the first large-scale all-oxide CMOS ICs. Through comprehensive experimental and theoretical analysis, we introduce selenium alloying in a-TeO_x, facilitating hole transport in a semiconducting channel of p-type transistors. In the presentation, we discuss the effect of Se alloying details in the tellurium suboxide matrix and also introduce new dopant to reduce process temperature of the p-type oxide film for a channel of TFTs .

5. Conclusion

In conclusion, we demonstrated high-performance amorphous p-channel TFTs using TeOx:Se semiconductors via scalable thermal evaporation. This approach outperforms other p-type amorphous semiconductors, offering excellent electrical performance, stability, scalability, and processability. The fabrication is compatible with industry standards, advancing the commercialization of cost-effective, large-area, flexible complementary devices.

References

[1] *Hikmet Celiker, Wim Dehaene, Kris Myny, Nature* 629, 335, 2024
[2] *A.Liu, et. al. Nature* 629, 798, 2024
[3] *Y. Meng, et. al. Nat. Commun.* 15, 4440, 2024
[4] S. Thomas, *Nat. Electron.* 7, 328, 2024.

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