Graduate School of Science and Technology Doctoral Thesis Abstract

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Student ID	2121441	Submission date	2024/06/30 (yyyy/mm/dd)
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Title	High performance schottky contact-controlled transistors for new TFT application (新しい TFT 応用に向けたショットキー接触制御トランジスタの高性能化)		

Chapter 1 Introduction

Schottky contact-controlled devices have proven that fast saturation with stable output characteristics is achievable by replacing the Ohmic source with a Schottky source in traditional thin-film transistors (TFTs). This Schottky contact creates a resistive barrier in the active layer under the source contact, which results in an artificial pinch-off and better saturation characteristics than TFTs. Due to this artificial pinch-off of the resistive barrier, the source-gated transistor (SGT) reaches saturation at a much lower drain voltage than TFTs. These improved saturation characteristics are achieved with minimal changes to the standard TFT device, requiring only the substitution of the Ohmic source contact with a Schottky source contact. Despite the benefits of SGT devices, their low output current nature limits their application in high-current applications, such as display. This dissertation is focused on improving the output current of Schottky contact-controlled transistors by modification of source contact to be comparable with TFTs.

Chapter 2 Optimizing a-IGZO source-gated transistor current by structure alteration via TCAD simulation and experiment

This chapter investigates the change in structural parameters, including channel thickness, channel length, and source-channel overlap (SC) to increase the output current of SGT devices with TCAD simulation, as shown in Figure 1. The change in SC will affect the current injection mechanism of SGT device, primarily the current injection from bulk of source contact. As SC increases, this area of current injection becomes larger, allowing the source contact to inject more carriers, resulting in higher current. Experimental results confirmed that a high current SGT device with fast saturation characteristics is obtainable with an SC of 210 μm, channel thickness of 20 nm, and channel length of 5 μm. It was confirmed that the linear relationship between output current and drain voltage, which is the characteristics of current injection from bulk of source contact.

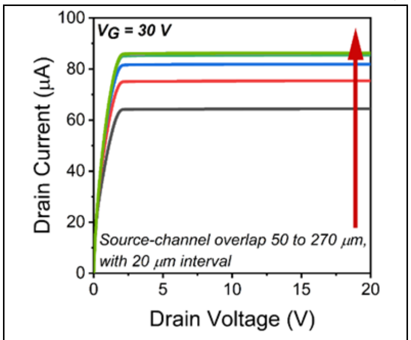

Figure 1. Output curves of simulated SGTs varying SC.

Chapter 3 Optimizing a-IGZO double-work function transistor (DWF) via structure alteration for output current improvement through TCAD and experiment

This chapter utilized the double work function concept, which involves both Schottky and Ohmic source. By replacing Schottky contact at source edge with Ohmic, this double-work function transistor (DWF) can provide high output current with low saturation voltage, as the Ohmic contact could inject more carriers than Schottky contact. By varying the Schottky source length (SSL), characteristics of DWF can be modified to suit different applications, as shown in Figure 2. This device trades off some saturation characteristics for a high current. Experimental results support the simulation, showing that a DWF with SSL of 5 μm could provide high current while maintaining SGT characteristics.

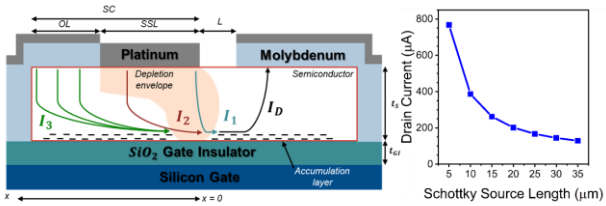

Figure 2. Diagram of DWF (left) and relationship of output current and SSL (right)

Chapter 4 Optimizing a-IGZO advanced-double work function transistor (a-DWF) via structure alteration for output current improvement through TCAD and experiment

This chapter further improves the current level of the DWF device by adding an Ohmic contact at the channel edge. This Ohmic contact operates similarly to a normal TFT device, injecting significantly more carriers than the Schottky contact. The high output current is due to the presence of Ohmic contact and recessed Schottky contact. The recessed Schottky contact forms a less effective resistive barrier, allowing the Mode I_3 to inject more carriers than in SGT and DWF device, as shown in Figure 3. Experimental results support the simulation, showing that an a-DWF SSL of 5 μm OSL of 5 μm has potential as an alternative structure for SGT device while provide high output current. Additionally, an a-DWF SSL of 10 μm OSL of 10 μm, which provides a high output current at only one third of TFT dev ice, is appealing as an alternative structure of TFT device.

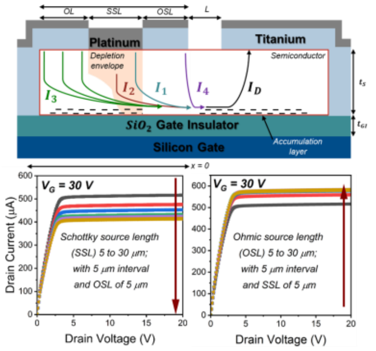

Figure 3. Diagram of a-DWF (top), relationship of output current and SSL (left), and OSL (right)

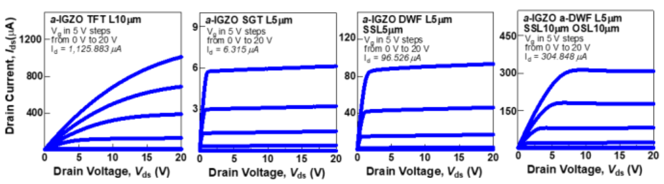

Figure 3. Output curves of fabricated TFT (left), SGT (middle left), DWF (middle right), and a-DWF (right)

Chapter 5 Conclusion

In conclusion, this dissertation demonstrated the versatility of Schottky contact-controlled devices. By modifying the source contact, specific device characteristics can be tailored. Replacing part of the Schottky source contact with an Ohmic source in DWF devices increases output current, though saturation occurs later than in conventional SGT devices. While offering lower output current than TFTs, Schottky contact devices provide fast saturation with stable output current. Fine-tuning their electrical properties will expand their application range, allowing for a trading between current level and saturation characteristics for each application, making them a compelling alternative to TFTs.

論文審査結果の要旨

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Schottky接触制御型トランジスタ（SGT）は、従来の薄膜トランジスタ（TFT）においてオーミックソースをSchottkyソースに置き換えることで、迅速な飽和と安定した出力特性を実現する可能性を示している。本博士論文では、Schottky接触制御型トランジスタの出力電流を改善し、TFTに匹敵する性能を持たせるためのソース接触の改良に焦点を当てた。本研究では、SGTデバイスの構造パラメータの最適化と、出力電流を向上させながら望ましい特性を維持するためのダブルワークファンクション（DWF）コンセプトの導入を行った。実験結果とTCADシミュレーションは、構造を変更することで、高電流と迅速な飽和特性を備えたSGTデバイスを実現できることを確認しており、これにより、従来のTFTに代わる魅力的なデバイスを提案した。
また、Schottky接触制御型デバイスの多用途性と可能性について議論した。研究は、ソース接触を微調整することで、出力電流レベルと飽和特性のバランスをとることができることを示しており、これによりこれらのデバイスの適用範囲が拡大する。SGTはTFTよりも低い出力電流を提供するが、その迅速な飽和と安定した出力特性は、これらの特性が重要なアプリケーションにおいて魅力的な代替手段となる。
本論文は、DWFコンセプトをさらに進化させたアドバンストダブルワークファンクショントランジスタ（a-DWF）を導入し、チャンネルエッジにオーミック接触を追加することで、DWFデバイスの性能を大幅に向上させた。この改良により、改良型Schottky接触とオーミック接触の組み合わせが可能となり、出力電流が大幅に増加した。
また、この研究はデバイス構造と材料の最適化に関する新たな知見を提供し、高性能トランジスタの開発に大きく貢献している。特に、DWFアプローチを通じて強化されたSchottky接触制御型トランジスタは、将来のTFT応用において大きな可能性を持つことが示唆されている。さらに、本研究は次世代の薄膜トランジスタ回路の実現に向けて有益な手法を提供しており、審査員はこの論文が博士（工学）として十分に価値があると評価している。