國立交通大學

理學院應用科技學程

碩士論文

整合型溝渠式功率接面場效電晶體與蕭特基阻障二極體

Power Trench Junction Field Effect Transistor Integrated with Schottky Barrier Diode

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摘　　要

現今在電源供應之開關應用方面，以功率式金氧半導體場效電晶體為主要產品。為了追求更高的轉換效率與操作頻率，採用同步壓降轉換器設計可以達到此要求。然而，對同步壓降轉換器之下橋開關元件而言，仍然有一些缺點仍需要克服，譬如物理限制的元件通道導通電阻、以及來自於本身具有的 PN 二極體在遲滯期間的造成的高功率損失。

本篇研究首先提出一個新穎的元件結構，以整合型的溝渠式接面場效電晶體與蕭特基二極體來改善上述之缺點。本設計可提供另一個吸引人的方法來實現同步壓降轉換器之下橋開關元件。

從模擬的結果得知，較大的接面場效電晶體間距與蕭特基二極體之主動區平台寬度會得到較高的通道截止電壓，以及在不變動通道截止電下的條件下，會得到較低的汲極與源極之間崩潰電壓。另一方面，較大的通道寬度會得到較小的通道導通電阻。而蕭特基二極體的平台寬度與二極體的反向回復

特性無顯著相關性。至於磊晶層方面，低摻雜的磊晶層濃度會造成低的通道截止電壓；磊晶層的電阻率與汲極與源極之間崩潰電壓成反比，與通道導通電阻成正比。

此新穎之結構可做成超高主動區元件密度、可具競爭的導通電阻、期望的崩潰電壓、極好的低反向漏電流、以及低的順偏電位壓降。從整體的特性比較中可得知，對直流轉直流轉換器之應用，本元件結構可做為好的元件開關取代方案。

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ABSTRACT

Nowadays, Power MOSFETs are dominant products of switching converters in the application field of power supply. For high power conversion efficiency and high frequency operating consideration, adopting synchronous buck converter (SBC) design would meet this requirement. However, for the low-side switch device of SBC, there are still some drawback characteristics such as physical limit of on-state resistance of channel, high power loss during the dead time due to the inherent PN body diode etc.

In this study, a novel structure of power trench junction field effect transistor (JFET) integrated with Schottky barrier diode (SBD) is the first time being proposed. This design provides a new alternative solution for the low side switch

of synchronous buck converter.

From the simulation result, we find the larger pitch size of JFET and mesa width of SBD causing higher pinch-off voltage, lower breakdown voltage of drain to source if it was under the same pinch-off voltage. On the other hand, it would result in lower specific on-resistance due to the larger channel width. There is no significant correlation between different mesa widths of Schottky diode and reverse recovery characteristics of diode. The lighter epitaxial doping concentration would get the lower pinch-off voltage. The lower resistively of epitaxial layer is in inverse proportional to breakdown voltage, but is in proportional to on-state resistance of drain to source.

This novel structure is achievable for ultra high cell density, competitive on-state resistance, desirable breakdown voltage, excellent low reverse leakage level and lower forward voltage drop. The overall characteristic comparison shows it is a good candidate for switch device of DC-DC convertor application.

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Table of Contents

Figure Captions

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Table Captions