

研究藉由多閘極製程改善成長於矽基板上之氮化鋁鎵/氮化鎵高 速電子遷移率電晶體元件之線性度

研究生：黃冠寧

指導教授：張翼 博士

國立交通大學材料科學與工程學系

摘要

近年來無線通訊系統的快速發展，使得影音通話，高畫質影音的無線傳輸得以在日成生活中實現。然而在大量的使用者情況下，可用的頻寬已經過度的擁擠，為了要減少在高價位射頻頻譜上的花費，必須在最小的頻寬下擁有最大的資訊傳輸量。此時就必須靠複雜調變技術來達成高速率傳輸的目的，例如四相移相鍵控技術，但是此調變技術又會導致動態訊號的產生，進而造成訊號失真，因此在射頻功率放大器中，元件線性度成為無線通訊系中一項非常重要的參數。由於三五族氮化鎵材料具有高電子遷移率、高載子濃度、高功率截止頻率和高崩潰電場的特性，因此三五族氮化鎵高電子遷移率電晶體在無線傳輸方面的應用展現極大的潛力。

本實驗中，成功的製作出八十奈米閘極線寬的氮化鎵高電子移動率電晶體，並且進一步利用創新的多閘極技術，使元件在線性度上有顯著的改善。在單閘極八十奈米閘極

的氮化鎵高電子遷移率電晶體中，元件展現出高飽和電流，高轉導性和高電流增截止頻率特性。但是因為短通道效應，造成元件有較高的漏電流，此一現象經過討論是可以進一步藉由閘極蝕刻技術來改善短通道效應和抑制閘極漏電流。

然而，在八十奈米閘極線寬下，由於高電場的因素，使得速度過衝效應很容易產生。在此實驗中，成功的製造出多閘極元件，在實驗數據的分析與資料的佐證下，發現多閘極可以有效的改善高電場現象，讓電子在多閘極區域下，有著較穩定的電子速度，進一步抑制速度過衝效應，使元件可以在較大的 V_{GS} 範圍下， I_{DS} 有著穩定的上升率，並且維持平穩的轉導值，有效的改善元件線性度，同時具有奈米極線寬元件的特性。經過量測得到元件的三階交叉點在三閘極結構下，可達 30.5dBm 的最高值。此外，此研究中還比較了在不同閘極操作偏壓下，多閘極與單閘極的三階交叉點表現，利用分析 I_{DS} 對 V_{GS} 的關係式，成功解釋多閘極可以在較大的 I_{DSS} 範圍下，有著高三階交叉點。由上述分析可知，多閘極技術可以有效的提升元件線性度特性。由此可知，在未來多閘極氮化鎵高電子遷移率電晶體可有效地應用在無線通訊系統中的射頻功率放大器。

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Study of Device Linearity Improvement for the 80-nm AlGaIn/GaN HEMTs on Silicon Substrate by Using Multi-Gate Process

Student: Kuan-Ning Huang

Advisor: Dr. Edward Yi Chang

Department of Material Science and Engineering

National Chiao Tung University

Abstract

In this study, the 80 nm gate length AlGaIn/GaN High Electron Mobility Transistors were successfully fabricated. Moreover, by using the innovative multi-gate technique, the linearity of devices has significant improvement. In the 80nm gate length AlGaIn/GaN HEMTs, the devices possessed high saturation current, high transconductance and high current-gain cut-off frequency. However, the short channel effect led to the high leakage current. After the discussion, this phenomenon could be improved by using the gate recess technique to suppress the short channel effect and gate leakage current.

Nevertheless, due to the high electric field under the gate domain, the electron over shoot effect could be observed in 80 nm gate length devices. In this study, the multi-gate devices were successfully fabricated. By the experiment data analysis and paper evidence, it could be found that multi-gate effectively reduced the high electric field. It made the electron possessed a stable electron velocity under the gate domain and further to suppress the velocity

overshoot effect. The multi-gate devices could stably increase the drain current and maintain the transconductance value under a larger gate bias region; furthermore, multi-gate devices possessed the electrical characteristic as same as the nanometer gate length device. After the measurement, the maximum third order intermodulation point (IP3) of 30.54 dBm could be achieved in the triple-gate devices. It shown that multi gate could effectively improve the linearity of devices. In addition, the third order intermodulation points of the multi-gate and single gate device under the different gate bias are also compared in this study. By analyzing the function of I_{DS} versus V_{GS} , It could successfully demonstrated that the multi-gate device have the higher IP3 in the larger I_{DSS} % region. Therefore, it could be known that multi gate technique could effectively improve the linearity performance.

In the future, the multi-gate AlGaIn/GaN HEMTs have the great potential to be the RF power amplifier applied in the modern wireless communication system.

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GaN Material Properties and High Electron Mobility Transistor

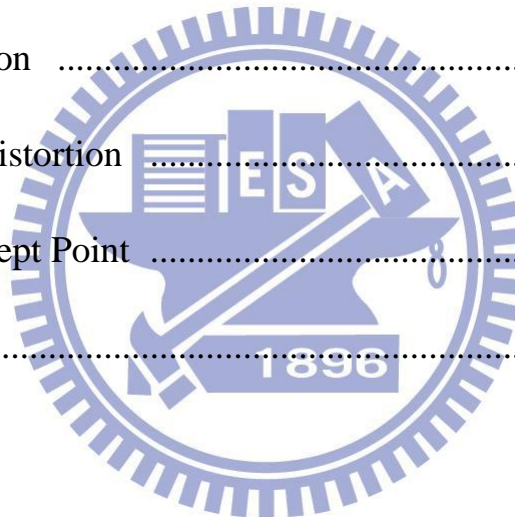
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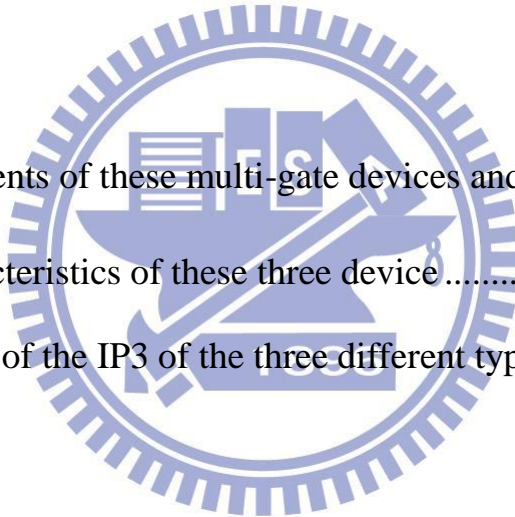
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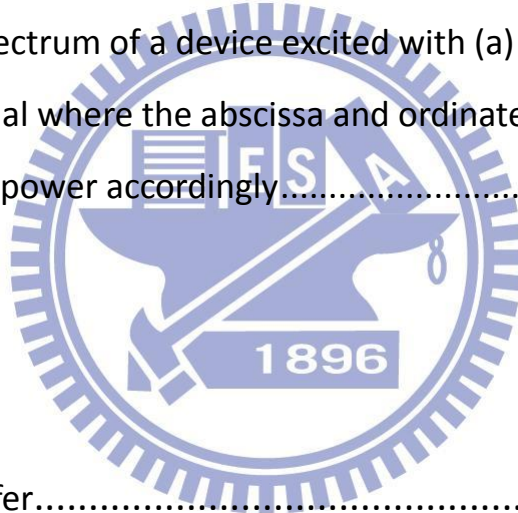
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