國立交通大學

電子工程學系 電子研究所

博士論文

集極相關製程及結構對於0.18微米世代之矽鍺異質接面雙極性電晶體直流及射頻效能影響的物理機制分析以及銅製程相容低介電常數材質之電性強化技術開發

A study and Analysis of the Impacts on the DC and RF characteristics of 0.18 μm SiGe HBT Resulting from the Collector Associated Processes and Doping Profiles and Copper Comparable Technology Development for Improving the Performance of the Low-K Material

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中華民國九十三年六月

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A Dissertation
Submitted to Institute of Electronics
College of Electrical Engineering and Computer Science
National Chiao Tung University
In Partial Fulfillment of Requirements
For the Degree of Doctor of Philosophy
In
Electronics Engineering
May 2004/4/24 Hsinchu, Twiwan, Republic of China

中華民國九十三年五月

集極相關製程及結構對於0.18微米世代之矽鍺異質接面雙極性電晶體直流及射頻效能影響的物理機制分析以及銅製程相容低介電常數材質之電性強化技術開發

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摘要

本論文主要內容是針對矽鍺異質接面雙極性電晶體（SiGe HBT）之直流及射頻行為與其原件之參雜分佈及製造過程之間的關係作深入的研究探討.

首先,本研究設計了一套估算電晶體 transit time 的方式此方式經過實際量測的結果驗證後證實具有一定的準確度.可以在元件設計階段，以製程參數為基礎，定性評估電晶體的高頻效能.除此之外，可解析 transit time 的各個組合成分比例，可以幫助元件設計者深入了解元件的特質，以最有效最省資源的方式發展.

其次,確立了 SiGe HBT 電晶體中集極參雜濃度對基極電阻的調變作用,並證實其物理機制.此外更進一步證實 SiGe HBT 的射頻行為中 f_T 及 f_{max} 的峰值不發生

在同一壓電流密度值上的這個現象,其背後的原因是基極電阻的調變作用所引起.除此之外,本研究亦提出這個現象對電路設計的影響及潛在困難,並提出建議.

再者,是針對深溝結構對 SiGe HBT 電晶體的直流及射頻特性的影響的研究.深溝結構是類比及射頻應用中常用的技術作為阻隔電路中訊號的洩漏.但是很少有研究針對深溝結構對元件的直流及射頻特性的影響提出報告.本研究發現， 深溝結構製程確實對直流及射頻特性有所調變,並對其相關物理機制及電性影響有深入的研究與探討.

此外,本研究中發展了一個以 NH_3 電漿處理低介電電材料的製程,能降低低介電材料在灰化的過程中所遭受的破壞.除此之外,這一個處理方式同時可抑制銅在低介電材料中的擴散.本方法是一個有效,經濟而且符合製程整合要素的方法.最後,本研究針對接面可變電容之直流及射頻特性對元件幾何的變化作分析.這部分研究結果將對訊號生電路的設計者有相當程度的參考價值

A study and Analysis of the Impacts on the DC and RF characteristics of 0.18 μm SiGe HBT Resulting from the Collector Associated Processes and Doping Profiles and Copper Comparable Technology Development for Improving the Performance of the Low-K Material

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Abstract

In this research, the impacts and corresponding physical origins on the DC and RF characteristics of modern silicon germanium hetero-junction bipolar transistor related to the collector processes and doping profile have been studied.

First, a new and efficient transit time estimation approach has been developed and identified. By using this approach, the components which consisted the transit time of the transistor and could be difficultly decoupled in the simulation way could be obtained based on the doping profiles of the device. Such approach did great help during the device development steps because of its simple, fairly accurate and

efficient. Besides, the device designer could optimize the doping profile according to pre-estimation of the transit time components for improving the capability of the devices. Furthermore, after analyzing, it was discovered that the collector doping profile could be more important as the vertical dimension of the device continuously shrinking.

Second, the physics associated with the modulation behavior of the current flux distribution in the pinch base region has been studied. It was found that Such current distribution modulation was directly related to the doping concentration level in the collector region. Besides, it was also found that such behavior could also alter the bias dependency of the base resistance r_B-I_C. Furthermore, such altered r_B-I_C behavior has also been proven in this research that it should attribute to the inconsistence of the current density levels on which the peak cutoff frequency and maximum oscillation frequency took place.

Third, the associated physical origins and impacts from the deep trench process on the DC and RF characteristics of the SiGe HBT was investigated. For identifying the physical mechanism, several work have been done including the process simulation and practical measurement. It was proven that the key indexes of the HBT devices for circuit design including the RF noise characteristics and two-tone performance could be impacted. Such impact could be suppressed by increasing the collector doping level.

Furthermore, a new-developed technology for improving the electric and physical performance of low-K material by NH_3 plasma pre-treatment has been reported. Finally, the DC and RF characteristics of the junction varactor respective to the geometry effect have been described which could be very valuable for the circuit designers in signal generation networks.

誌謝

首先我要對於我的指導教授 張國明博士致上我最崇高的敬意與謝意. 對於他多年來的指導與教誨, 使本人在學術研究上獲益良多, 同時也從老師身上學到許多待人處事的道理. 是我有生以來最寶貴的際遇.

另外我要感謝我的父母, 曾勝雄先生, 呂淑英女士的全力支持, 此外要感謝我的家人以及好友張美雯小姐在精神上的支持及鼓勵.

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