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An Area-efficient Robust Read Embedded Resistive RAM (ReRAM) Macros Using Temperature-Aware Current-Mode Read Scheme

具溫度警覺之高密度高讀取效能之內嵌式電阻式記憶體

隊伍名稱

記憶體小尖兵 / Memory Warriors

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作品摘要

近年來，手持式消費性電子產品、智慧型車用電子與新興智慧型醫療產業需要大量內嵌式非揮發性記憶體做程式的儲存。而產品要達到高效能與快速回應的目標，對於執行程式將有高速讀取的需求。高效能消費型電子產品功能常需要做大量的程式運算、智慧型車用電子於不同環境下，常需要做快速反應的控制程式序列做不同的操作、新興生醫電子需要做到及時生物檢測與自動化醫療，過程中會做大量資料辨識與程序控制，這些產品對於高速程式讀取都有高度要求。藉由非揮發性內嵌式記憶體與微控制單元（MCU）整合，可成功大大提高MCU之高速資料處理速度，進而達到對於手持性電子產品、智慧型車用電子以及智慧型醫療的需求。

目前傳統的內嵌式記憶體都使用快閃記憶體，然而快閃記憶體（Flash memory）有讀取與寫入速度慢，寫入操作無法直接寫入（需要erase、program操作）並需要高電壓與高寫入電流，製程縮小至奈米等級之後，快閃記憶體在微縮尺寸上遇到了困難與挑戰等缺點，因此開發新型態非揮發性記憶體是必需且迫切的。電阻式記憶體（RRAM）為公認相當具有潛力取代快閃記憶體，如給予適當的寫入驅動電流，其可達到快速直接寫入、低寫入電壓與低功耗、具有快速讀取度、寫入阻值均勻穩定並可在長時間儲存後擁有穩定而不漂移的阻值等優點。

電阻式記憶體目前面臨兩個主要的挑戰:

1. 滿足寫入驅動電流的要求並減小驅動電晶體的面積來提高密度
2. 加大讀取電流提高資料讀取良率與讀取速度的同時避免讀取干擾

在此次作品中，我們使用了與CMOS製程相容的創新之寄生BJT元件，可節省4.5倍以上的面積。但BJT驅動能力對溫度具有較高的敏感度，若是以傳統箝制電路將位元線電壓固定，在高溫時即可能因溫度升高而造成讀取干擾的問題。而若是以預留邊限（margin）改變箝制電壓使傳統箝制電路在高溫時不會讀取干擾，則在低溫時讀取電流將下降並影響良率。

因此我們提出具溫度警覺位元線偏壓讀取機制（Temperature-Aware Bit-line Bias Scheme）來解決BJT溫度變異的問題。此機制在低溫下可提高4.7倍的細胞電流，配合具溫度警覺之加速機制可提高1.6倍的讀取速度。

我們分別以0.18微米與65奈米製程實作1Mb與2Mb的BJT RRAM記憶體測試晶片。量測結果其讀取速度可達到4.2ns and 4.7ns, 為目前全世界Mb等級RRAM晶片中最快的速度表現。

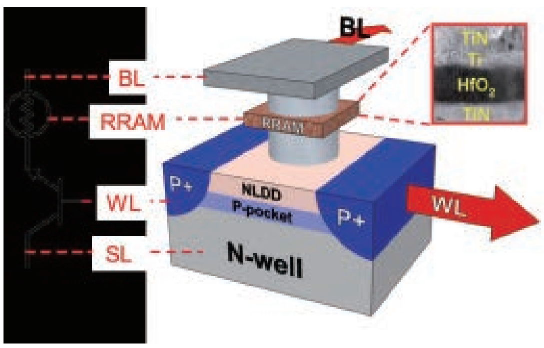

圖1 > BJT RRAM元件剖面示意圖

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研究領域

奈米與下世代記憶體電路設計，低功耗低電壓電路、3D-IC 電路、憶阻器電路。

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研究領域

記憶體元件、功率元件、CMOS 元件。

Abstract

Recently, handheld consumer electric products, smart car electric products and smart medical industry require a lot of non-volatile embedded memory for code storage. To achieve high program performance and instant responding need, the products read the program code out from memory fast. Handheld consumer electric products often process a lot of data calculation. The smart car electric products have to read different control process codes quickly to do fast rely in different conditions. In the emerging biomedical industry, the instant bio-detection and automatic medical care and reply are required. These processes also require large data recognizing and process control. By combining the non-volatile embedded memory and micro controller unit (MCU), we can largely increase the data process speed of MCU and meet the requirements of the handheld consumer electric products, smart car electric products and smart medical industry.

The mainstream non-volatile memory is FLASH. However, the Flash has disadvantages like slow write speed, high write voltage, high write current, slow read speed and it can’t do the write operation directly(It requires an erase operation before a write operation.). Also the flash memory meets many challenge and difficulty in nanometer process scaling. Therefore, developing new type of non-volatile memory is necessary and important. Among those emerging non-volatile memory, people believed that RRAM is a very promising candidate. When the RRAM is operated with appropriate write current, it would have the features like direct write operation, rapid write time, low write voltage, low write power, high speed read, stable resistance value and long retention time.

However, RRAM memory is facing two major challenges:

1. Meet the driving current need and reduce MOS area to improve memory density.
2. Enlarge the sensing current to increase yield, access time and avoid read disturbance at the same time.

In this work, we used a CMOS process compatible BJT device to drive RRAM cell. In this way, we can save 4.5 times of area reduction. However, the BJT driving capability is quite sensitive to temperature. If we use traditional bias circuit to bias BL voltage, the read disturbance would occur at high temperature. On the other hand, the read current would reduce and influence yield at low temperature. To solve the problem, we propose a Temperature-Aware Bit-line Bias Scheme (TABBS) to solve the temperature variation problem on BJT. This scheme can increase 4.7 times of cell current at low temperature and increase 1.6 times of read access time.

We implement a 1Mb BJT RRAM memory test chip in 0.18 um process and 2Mb BJT RRAM memory test chip in 65nm process separately. From the measurement result, the read access time and reach as fast as 4.2ns. It's the fastest access speed in Mb scale RRAM chip in the world.