高介電鈦酸鍶鋇薄膜電容元件之電漿蝕刻特性研究

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摘 要

鈦酸鍶鋇(BST)薄膜，因其獨特的電性與物理結構，目前應用極為廣泛，本論文主要探討其應用於動態隨機存取記憶體的電容特性，由於此材料目前在薄膜電容元件中，其漏電流將仍有待改善且縮小元件製程亦為目前積體化重要的關鍵技術之一，因此本論文將使用感應式耦合電漿 (ICP) 技術進行鈦酸鍶鋇表面處理來改善薄膜的電特性，並對其蝕刻機制與電漿導致的傷害進行研究。由於此研究關係到許多電漿基本特性的探討，所以本論文也以Langmuir探針電漿檢測系統對一些常用的電漿製程參數進行探討。 於電漿處理部分，我們使用NH3電漿針對鈦酸鍶鋇薄膜作處理，探討其在 Pt/BST/Pt電容結構的漏電流與電性，研究結果發現經過NH3電漿處理的鈦酸鍶鋇薄膜在供應電壓1.5伏時，其漏電流可從10-7(A/cm2)下降至10-9(A/cm2)等級，這漏電流的改善，發現主要是由於氮原子的填入而減少薄膜氧空缺所貢獻的，經由X-ray 光電子頻譜儀 (XPS) 的量測證實，經電漿處理過的鈦酸鍶鋇薄膜將會有N 1s 的峰值出現，然而其薄膜的介電特性可能會因電漿導致的空間電荷或離子撞擊而降低介電常數，經由原子力電子顯微鏡的觀察，可發現經電漿處理過鈦酸鍶鋇薄膜表面型態將會改變，因此在電漿處理中，必須對漏電流與介電常數作一取捨。 於蝕刻方面，我們使用Cl2/CF4、Cl2/SF6、Cl2/Ar混合氣體針對腔體壓力、ICP功率、下電極射頻 (RF) 功率等參數進行探討，並使用熱化學熱平衡模擬軟體 (Thermo data) 針對氣體配方對BST的熱化學平衡反應進行模擬，進而提供蝕刻的研究參考。CF4和SF6兩種蝕刻氣體被發現會抑制蝕刻，猜測可能為沉積與蝕刻進行競賽的行為所致。在使用不同的Cl2/Ar的混合氣體比時，化學輔助蝕刻的行為將被發現，且經由掃描式電子顯微鏡與原子力電子顯微鏡的觀察，發現在Ar/Cl2的混合氣體下，加入30% Cl2 、ICP功率800 W、RF功率100 W 和腔體壓力5 mTorr時，將可得到一個平滑(粗糙度約1.8 nm)且沒有的殘留物的表面。為了要更確定蝕刻的機制，我們使用X-ray光電子頻譜儀對鈦酸鍶鋇薄膜的表面反應特性進行研究，研究的結果發現，鋇原子將主要靠化學輔助物理(BaClx為可能產物)進行去除，對於去除鍶原子，物理性的撞擊將比化學性的氯蝕刻更有效率，而鈦則主要靠化學反應進行去除(TiClx為可能產物)，以上蝕刻的結果證實與化學熱平衡模擬計算的結果相符。 然而在蝕刻時，可能會因一些電漿傷害而改變薄膜電容的特性，所以本論文以Pt/BST/Pt的電容結構針對漏電流與介電常數的變化探討其電漿導致傷害的機制，並對其電性恢復的方法進行研究。研究結果發現電漿會造成漏電流提高與介電損失，其中RF功率的提高可能為主要的影響因子。最後對於電漿傷害的元件，在經由氧氣600°C的熱處理後發現其可有效率的恢復元件電性，其漏電流在1.5 V的偏壓下可小於3×10-7 (A/cm2)，而其相對二氧化矽的厚度約3.5 nm.

關鍵詞 : 鈦酸鍶鋇 ; 高介電材料 ; 薄膜電容 ; 感應式耦合電漿 ; 蝕刻 ; 電漿導致傷害

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