金屬誘發側向結晶應用於低溫多晶矽薄膜電晶體

-結晶成長之熱力學、動力學及電晶體元件效能

學生：胡國仁　　　　　　　　　　　　指導教授：吳耀銓博士

國立交通大學材料科學與工程研究所博士班

摘　　　要

金屬誘發結晶方式可以用來降低非晶矽結晶的溫度，而其中以 Pd 及 Ni 金屬被最廣泛的使用。但由於鍍覆金屬的方式必須使用高真空設備的濺鍍機，對大面積的玻璃基板來說，相當耗時且昂貴，因此在本論文中利用無電鍍方式鍍覆 Pd 在非晶矽上進行誘發結晶的研究，此無電鍍的方式簡單且方便，適合用於製作大面積的顯示器。然而，我們利用無電鍍鈀結晶的多晶矽膜來製作低溫多晶矽的薄膜電晶體（LTPS TFT）時，發現有大量的 Pd silicide 殘留在多晶矽膜中，所以造成元件的效能變差。因此本論文中提出利用兩階段退火的方式得到適量的 Pd silicide 進行誘發結晶，而利用此兩階段退火的方式也讓 TFT 元件特性獲得明顯的提升。

另外，針對氧對NILC成長結晶影響進行研究。結果發現氧的退火氣氛不會影響NILC結晶長度及成長速率。而且Ni膜中的氧存在也不會降低NILC結晶速率。但是，結晶的孕核階段會受影響，需花四小時的時間成核，這是因為 NiO需要時間還原成Ni金屬後才會與矽反應形成$NiSi_2$而進行誘發結晶。

而為了提升Ni誘發結晶的結晶品質，因此提出利用混和結晶技術進行結晶品質的改善，混和結晶技術即利用金屬誘發結晶技術搭配準分子雷射結晶技術以得到高品質的大晶粒。首先是利用Ni金屬將非晶矽轉變成結晶，之後再利用準分子雷射進行二次結晶的動作。從此研究中發現，隨著不同的雷射能量密度而提出兩個NILC-ELA多晶矽膜的結晶機制：(A)非晶矽（a-Si）熔融；及(B)非晶矽/多晶矽(a-Si/poly-Si)熔融。在a-Si熔融時，其結晶形狀和NILC poly-Si的針狀結晶一樣。而在a-Si/poly-Si熔融區時，多晶矽晶粒的形狀和尺寸與NILC的針狀結晶非常不同。在此a-Si/poly-Si熔融區依雷射能量大小又被分成(1)幾何合併(geometrical coalescence)區及（2）完全熔融區。在幾何合併區時，由於NILC結晶晶粒有<111>的優選方向，因此晶粒彼此的角度相差很小，而造成有幾何合併的行為產生，在此區晶粒異常成長至600nm的大晶粒。而當雷射能量大到讓NILC多晶矽膜完全熔融時，此時多晶矽晶粒的形成是以均質成核的方式進行成核成長，因此晶粒較小。而在其電性上的比較來說，以幾何合併區域得到的多晶矽品質最好，而且在電性上的表現也較穩定。

最近，在塑膠基板上製作高效能的薄膜電晶體正被廣泛的研究中。可撓曲顯示器是下一世代顯示器發展的主力，由於其重量輕、體積小、便於攜帶且成本低等優點，已可漸漸取代傳統製作在玻璃基板上的顯示器。然而受限於塑膠基板的耐熱溫度，在塑膠基板上進行高品質的多晶矽TFT的製作非常的困難。因此提出利用一次轉移及二次轉移技術，在塑膠基板上製作高品質的多晶矽TFT。

最後，提出Si過濾基板的方式進行Ni誘發結晶的研究。而且利用兩階段退火來進行結晶的製程，此結晶技術可以縮短製程時間，並且得到由平行<111>方向的次晶粒所組成的高品質的大晶粒，晶粒大小約30μm。

Metal Induced Lateral Crystallization of a-Si for Low Temperature Polycrystalline Silicon Thin Film Transistor

-Growth Thermodynamic、Kinetics and Device Performance

Student：Guo-Ren Hu Advisors：Dr. YewChung Sermon Wu

Department of Material Science and Engineering
National Chiao Tung University

ABSTRACT

A metal-induced crystallization method can be used to decrease the crystallization temperature of amorphous silicon (a-Si). Pd and Ni are in widespread use. The metal layer was generally deposited by traditional Physical Vapor deposition (PVD) method. However, the metal layer deposited by PVD method was a time-consuming and high equipment cost process. In order to solve above problems, Pd metal was deposited on a-Si by an electroless plating method was proposed. The electroless plating method include the simple and convenient merits. In this study, electroless Pd plating induced crystallization of amorphous silicon (a-Si) thin films has been proposed for fabricating low temperature polycrystalline silicon thin film transistors (LTPS TFTs). However, the current crystallization process often leads to poor device performance due to the large amount of Pd silicide residues in the poly-Si thin films. It was found that the amount of Pd silicide increased with annealing time and temperature. In this study, a two-step annealing process was developed to obtain the appropriate amount of Pd silicide for inducing the crystallization of a-Si. The device characteristics were significantly improved by this two-step process.

Effects of oxygen on the growth of metal (Ni) induced lateral crystallization (NILC) of amorphous silicon have been investigated. It is found that the oxygen in the annealing ambient did not degrade the MILC length or growth rate. The oxygen existence in Ni film does not degrade the MILC growth rate either. However, it retards the nucleation of poly-Si for about 4 h. This is because that NiO needed an incubation period to be reduced to nickel metal for the subsequent mediated crystallization of a-Si process.

In order to further improve the crystalline quality of poly-Si and the performance of LTPS TFT, the hybrid processes are proposed. The hybrid processes are to combine the NILC and ELA process to produce high quality and large grain. The growth mechanism of a hybrid processes to crystallize amorphous silicon (a-Si) film was studied . In the process, a-Si was first converted to polycrystalline silicon (poly-Si) using Ni-metal-induced lateral crystallization (NILC), and then annealed with excimer laser (ELA). Two crystallization mechanisms were found on these NILC-ELA films: (A) a-Si melting, and (B) a-Si/poly-Si melting region. In a-Si melting region, the sizes and the shapes of the needle Si grains were similar to those of NILC poly-Si. In a-Si/poly-Si melting region, the shapes and sizes of poly-Si grains were quite different from those of NILC needlelike grains. Two crystallization regimes were found in a-Si/poly-Si melting region: (1) geometrical coalescence regime and (2) complete melting regime. In the geometrical coalescence regime, the width of grains dramatically increased to 600nm due to the geometrical coalescence of Si needle grains. However, in the complete melting regime, the NILC Si films melted completely. Small poly-Si grains were formed by homogeneous nucleation and growth. The compare of the characteristic of the TFT devices are also discussion in this study. It's found the grain in the geometrical coalescence regime have the better characteristic of TFT.

Recently, high performance thin film transistors (TFTs) on plastic substrate have been studied. Plastic display which have advantages of lighter weight, small thickness, high shock-resistant and good flexibility have much potential for replacements conventional display on glass. However, it’s the difficult process to fabricate the high performance TFT on the plastic substrate. The heat-resistant of plastic substrate is much lowest. Therefore, the transfer technology develop was needed. In this study, the once and double transfer technology was used to fabricate the high performance TFTs on plastic substrates.

Finally, TWO-STEP Ni-induced crystallization of amorphous silicon (Si) using a Si wafer as a filter was proposed for the first time. In the first step, sample stacks were preannealed at 500 for 2h to produce appropriate amounts of silicides and polycrystalline Si. The Si wafer filter was then removed and annealed at 550 for 12h. It was found that the average grain size was about 30μm. The grain was composed of parallel needle-like sub-grains that grew in <111> directions.