Chapter 1

Introduction

1.1 Characterization of Low Temperature Poly Silicon

Recently the poly-crystalline Silicon thin film transistor (poly-Silicon TFTS) was employed by the active devices in driver circuits of active matrix liquid crystal display (AM-LCD) and active matrix organic light emitting diode display (AM-OLED) all applications need the uniform film and larger poly-silicon grain size where it should be fabricated on the glass under the fabrication temperature was less than 550°C [1]. To attain this requirement, the laser annealing [2] and thermal annealing crystallization had been investigated. We reported the different laser annealing [3] and presented the uniform film for self-alignment grain structure. Compared to conventional amorphous Si:H (a-Si:H) TFTs, LTPS TFTs technology provides better device performance, such as high carrier mobility. As a result, the requirement of system-on-glass (SOG) [4] can be proposed by using the LTPS TFTs.

Many methods of crystallization technologies for fabrication high-quality poly-silicon thin film had been widely studied. Solid phase crystallization (SPC) [5] of α-silicon was a simple and effective method to form microns grain-sized poly-Si thin film. Many intra-grain defects such as microtwins and stacking faults were existed within the microns grains. In addition, the longer crystallization time makes it unacceptable for mass production.

Excimer laser annealing crystallization (ELA) [6] was the most promising method to fabricate high-quality poly-silicon thin film on glass substrate. A significant driving force for laser-crystallized poly-silicon had been its utilization as an active layer in thin-film transistors for large area liquid matrix displays. Poly-silicon thin film with large-sized grains and excellent crystallinity could be obtained by suitable laser irradiation conditions. However, due to the narrow process window, the uniformity of the device characteristics becomes an important issue. As a result, several grain-controlled engineering [7] had been extensively demonstrated to broaden the process window of ELA technology.

Owing to the low melting point of glass substrate, several key processes, such as thin film crystallization, gate dielectric deposition, and dopants activation, should be carried out at low temperature. The thin film crystallization and dopant activation could be performed even at room temperature by excimer laser irradiation. Low temperature gate oxide deposition was commonly achieved by plasma enhanced chemical vapor deposition (PECVD) system. Moreover, low-temperature direct oxidation of poly-silicon thin film had been extensively adopted as the method for fabricating thinner and high quality gate dielectric for the future LTPS TFTs. The high-density plasma (HDP) oxidation [8] was thought to be the potential candidate due to it was low process temperature and good long-term reliability.

According to the LTPS technology development trend, reduced process thermal budget, improved defect-passivation throughput, higher manufacturing yield, and lower cost were extremely in demand. For device electrical characteristics, higher carrier mobility and lower leakage current were needed to accomplish high performance LTPS TFTs. In addition, good uniformity and high reliability were the two most important issues for the next generation LTPS TFTs technology.

1.2 Prior Clean Process with Laser Crystallization Technique

Surface clean process had widely application in semiconductor and TFT's LCD processes. The clean process was included the HF clean, O3 clean, H2O2 clean and UV exposure clean, all of these function could eliminate surface oxide and particle to improve the better contact with other layers. So the normal clean process of LTPS TFTs was HF + O3 +HF. In many laser irradiations investigation was shown to reserve the heating of laser energy and retard the super cooling taking place before the onset of solidification due to homogeneous nucleation. So the surface oxidative treatment for reserving the heating of laser energy was studied in this thesis.

Different crystallization laser system will be used to fabricate the LTPS TFTs. The excimer laser and continuing wave laser was compared with their parameter, the specifications of excimer laser were wavelength 308nm, repetition rate 300Hz, maximum power 300W and beam size 310*0.4mm^2. The specifications of continuing wave laser were wavelength 532nm, repetition rate< 5MHz, beam size 2.25*2.25πmm^2, maximum power 10W. Owing to the continuous energy and directional solidification were caused by continuing wave laser scanning and slow cooling rate of melting silicon [9].

1.3 Motivation

In this thesis, owing to the carrier mobility enhancement, many means were applied in low-temperature polycrystalline thin film transistors to improve the device performance. In the first part, pre treatment processes of polycrystalline silicon thin films were fabricated by excimer laser annealing to be explored. In the second part, different crystallization ambiance would be improved the thresholds voltage to be studied. In the last part, different crystallization technology of continuing wave laser crystallization was applied to fabricate high performance low-temperature poly-silicon TFTs.

1.3.1 Pre Treatment Processes of Amorphous Silicon Thin Film

LTPS TFTs fabricated by excimer laser annealing (ELA) of α-silicon thin films that was used different pre treatment processes. From the results of material analysis and device characterization, the relation between electrical characteristics of LTPS TFTs and pre treatment processes conditions with laser annealing conditions had been identified. It was found that caused the surface oxidation of α-silicon thin films by pre treatment process and laser energy density had a deep influence on the resulting poly-silicon grain structure and electrical characteristics of LTPS TFTs. It was included the different methods of pre treatment process, the first method was surface cleaning with O3 water which concentration was 20ppm, the second method was surface cleaning with H2O2 water which concentration was 30%, the third method was surface cleaning with UV light exposure which wave length was 254um, and all of these methods could advance the surface oxidation of α-silicon thin films, it had the difference at long time or short time treatment. When surface of α-silicon thin films was completely oxidized by pre treatment process then treated by ELA.

1.3.2 Crystallization in Different Laser Annealing Condition

The variation parameter of excimer laser was included the laser frequency 0~300Hz, laser energy 850~1000mJ, laser energy density 330~480mJ/cm^2, scan pitch 0.004~0.1mm and scan speed 1~30mm/sec. The poly-crystallization was influenced by different frequency and energy conditions would be studied. In different ambiance of ELA crystallization had different efficiency, before mention the process of ELA crystallization had ambiance of N2 gas [3], now the different concentration of low O2 was utilized in ELA crystallization ambiance. From the results of material analysis, the LTPS thin films fabricated by ELA crystallization in ambiance of low O2 concentration had surface roughness like before mention process, the maximums surface roughness was about 80nm and average surface roughness was about 9nm, but the shape had some difference, the LTPS thin films surface roughness of low O2 concentration status had the shape like the cylinder in which the position was grain boundary and potential barrier was larger than grain area. The cylinder top surface were close to the gate bottom, when gate applied the forward bias, it would enhance the high electric file near the gate then induced the average thresholds voltage degradation. LTPS TFT's fabricated by

ELA crystallization in ambiance of low O2 concentration had lower threshold voltages than N2 ambient condition, the threshold voltages of +2 and –2 V can be achieved for n-channel and p-channel ELA LTPS TFTs, respectively.

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1.3.3 Crystallization of Continuing Wave Laser Applications for Low Temperature Polycrystalline Thin Film Transistors

One solution was to substitute laser system with higher mobility for the poly-silicon active layer. At present, the most possible laser system was continuing wave laser. A novel crystallization technology of poly-silicon thin film would be fabricated by continuing wave laser. It had pumping system that utilized Nd-YVO4 (Yttrium Vanadate) crystal. This crystal had been growing in popularity because of it was high gain, low threshold, and high absorption coefficients at pumping wavelengths, which result from the excellent fit of the neodymium dopant in the crystal lattice. These advantages make Nd:YVO4 a better choice than Nd:YAG for low-power devices such as hand-held pointers, and others compact lasers.

1.4 Thesis Outline

Chapter 2 explores the mechanisms of pre treatment processes and excimer laser crystallization of amorphous silicon thin films. The material properties of poly crystallize silicon thin films were analyzed by SEM, AFM, and TEM. Several physical characterizations were performed to appraise the composition, crystallinity and grain structure of the ELA poly silicon thin film prepared with different pre treatment process conditions, including HF pre treatment clean, O3 water pre treatment clean, H2O2 pre treatment clean and UV exposure pre treatment clean. The electrical properties of ELA poly-silicon TFTs, including the field-effect mobility, the subthreshold swing, the threshold voltage, the off current and the on/off current ratio, were investigated.

Chapter 3 describes the low-temperature poly silicon thin film fabricated by excimer laser annealing in different condition for crystallization. To vary the laser frequency and energy of excimer laser were discussed. In the O2 ambiance of different concentration were also discussed. The material properties of poly crystallize silicon thin films were analyzed by SEM, AFM. The electrical properties of ELA poly-silicon TFTs, including the field-effect mobility, the subthreshold swing, the threshold voltage, the off current and the on/off current ratio were investigated.

Chapter 4 Crystallization of continuing wave laser applications for low-temperature polycrystalline thin film transistors. Crystallization of amorphous silicon (α-silicon) thin films utilized the wavelength 532nm of CW lasers with different power and scan speed. Many factors of influence for grain size were discussed. It included the scan system configuration, speed control in stage with different power during laser scanning; front and backside scan on substrate at different scanning speed. Meanwhile The LTPS thin films were fabricated by CW laser with grain size more than 3um, and the LTPS TFTs fabricated at large grain size area, the field effect mobility, the thresholds voltage, the subthreshold swing, the off current and the on/off current ratio for n-channel and p-channel LTPS TFTs, were investigated in this chapter.

Chapter 5, we drew the conclusions of the researches.