The Simplified LDD Process of LTPS TFT on PI Substrate

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Abstract

Traditional LTPS TFT needs additional LDD process to decrease leakage current. However the fabrication process is no suitable for PI substrate. Additional laser multi-irradiation will damage the poly-Si to cause the TFT electrical degrade. Therefore we propose the simplified process to activate the N^+ and N^- at the same time.

1. Introduction

Low temperature poly-Si films have attracted extensive studies due to their outstanding property for thin films transistors fabricated on glass substrates. Recently, the LTPS TFT process on inexpensive plastic received more attention for the applications of flexible displays and electronics [1,2]. For plastic substrate, the process temperature should even lower than that for a glass substrate. The limitation of process temperature for polyimide (PI) substrate is about 280^0C (Tg).Therefore, the LTPS TFTs process of low temperature ($<200^0$C) has much difficult to execute on PI. The obvious existence of high leakage current for LTPS TFT on PI will to emerge the important of LDD process. The traditional a-Si:H thin film was deposited by PECVD includes a large number of hydrogen. The multi-steps laser dehydrogenated process is requirement for LTPS on PI. However, the additional laser irradiation for LDD process will cause the damage of poly-Si and worsen the uniformity of TFTs. Therefore we propose the new simplify LTPS process for plastic substrate to avoid excess laser irradiation. The another advantage is to shorten the process time. The schematic diagram of simplify LDD process for PI substrate was shown in Figure 1.

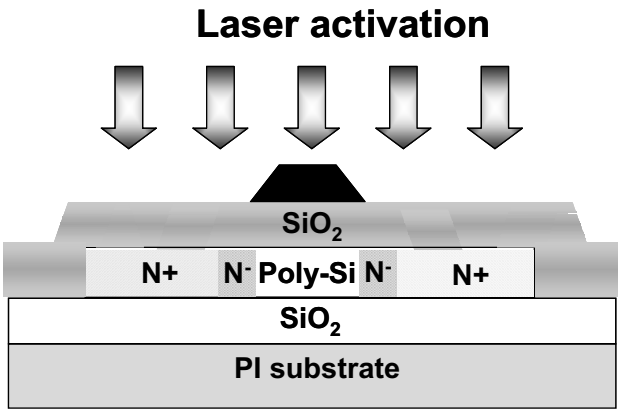


Figure 1 The schematic diagram of poly-Si TFT by laser activation

2. Experimental

Figure 1 shows the schematic cross-sectional view of sample structure used to crystallize by laser. The substrate used in this study is polyimide (PI). Before deposition of the a-Si layer, the 1um thick SiO2 film, was deposited as thermal barrier during laser crystallization between the PI substrate and the Si film. The SiO2 and a-Si layer were deposited by low-temperature (200^0C) Plasma Enhanced Chemical Vapor Deposition (PECVD) method respectively. The crystallization was carried out at room temperature. a-Si:H films were irradiated by a XeCl excimer laser (Lambda Physik 670, λ~308 nm) at room temperature. A step-by-step excimer laser irradiation process was employed for the dehydrogenation and crystallization step. Then the LTPS process was executed. The microstructure of crystallized films was observed with a Scanning Electron Microscopy (SEM). The Secco Etching method was performed before SEM. The microstructure of poly-Si was observed by TEM. The

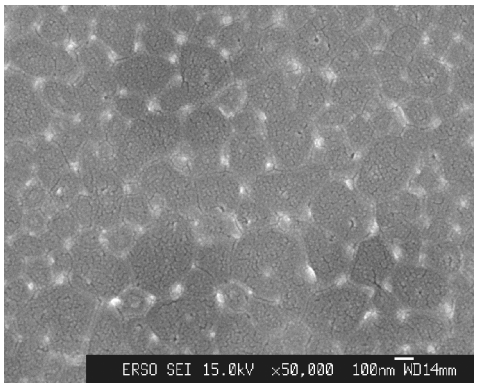
surface roughness of poly-Si was measured by using Atomic Force Microscopy.

3. Results and discussion

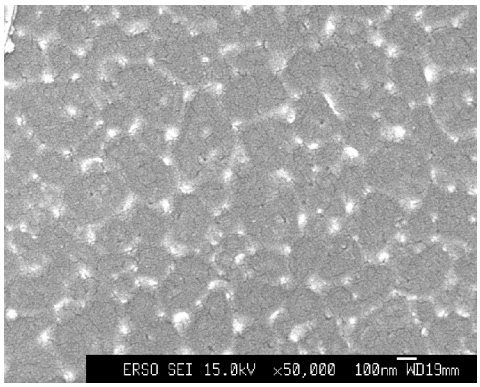
a-Si film was deposited by PECVD at low temperature(<200^{0}C)contains excessive hydrogen. Therefore, the energy density of the excimer laser irradiation was increased with step by step [3]. Through this step-by-step increase in the energy density of the excimer laser irradiation, dehydrogenation was carried out simultaneously with crystallization. Figure 2 shows the grain structure of poly-Si on glass and PI respectively. The average grain size is about 0.3um. The grain size and morphology is not different between Glass substrate and PI substrate. However, from Figure 2 we can find some pinholes on the surface of poly-Si film. This pinhole formation is due to the hydrogen out diffusion from a-Si at the dehydrogenation and crystallization process.

To study the microstructure of poly-Si, the low temperature poly-Si was observed by means of a transmission electron microscope (TEM). Figure 3 shows the microstructure of poly-Si with different laser energy density. The grain size increased with the laser energy. When the energy reached 350mJ/cm^2, Si films were in the near-complete-melting regime. In this regime, the width of poly-Si grains dramatically increased to 600nm.

.Figure 4 shows surface roughness of poly-Si as a function of laser energy density for ELA. From Figure 4 we can found that the dehydrogenation of step by step and crystalline process is not increasing the roughness of poly-Si on PI.

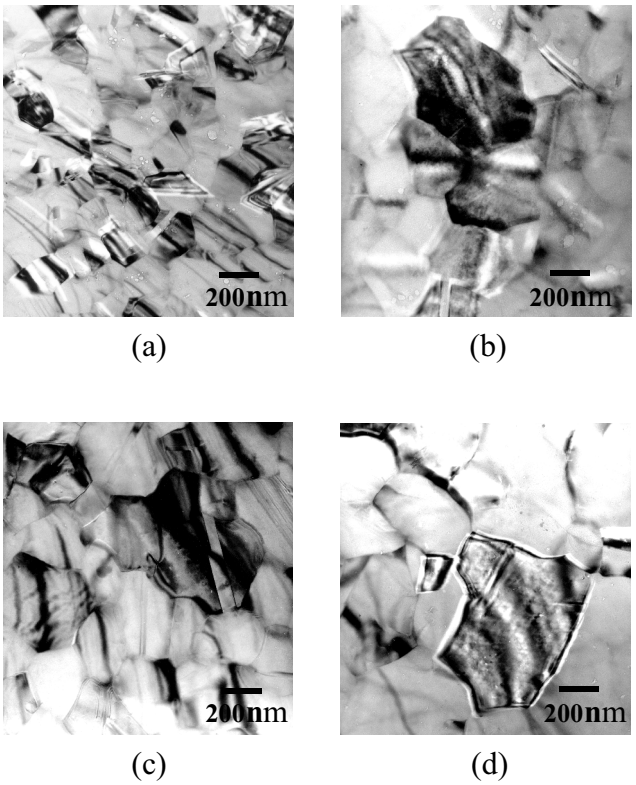


(a)



(b)

Figure 2 SEM images of 50 nm poly-Si film on (a) glass and (b) PI with laser energy density of 340 mJ/cm^2



(a) (b)

(c) (d)

Figure 3 Plane view of poly-Si film fabricated by ELA for dehydrogenation and crystallization with various laser energy density (a) 320mJ/cm^2 (b) 330mJ/cm^2 (c) 340mJ/cm^2 (d) 350mJ/cm^2

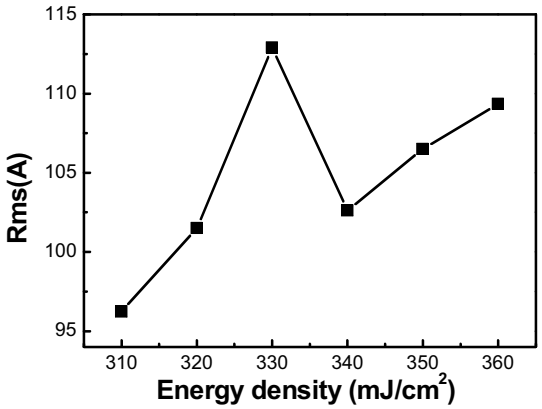
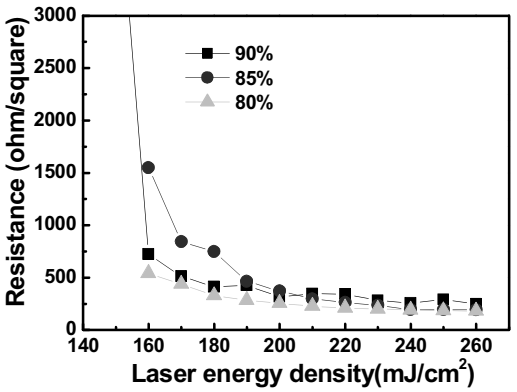
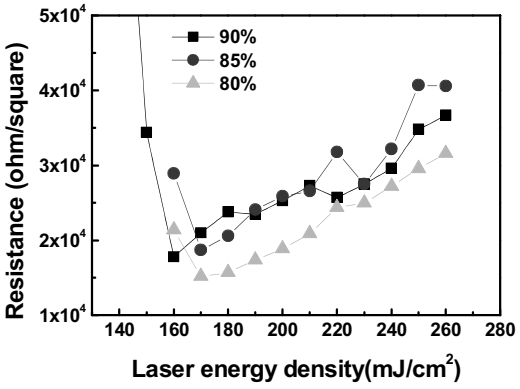


Figure 4 Surface roughness as a function of laser energy density for ELA.

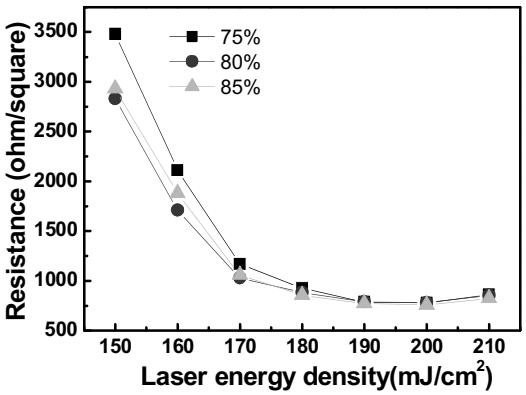
The temperature of dopant activation was limited due to the glass transition temperature of PI substrate. Therefore, the laser activation process is the only choice for activation of poly-Si. However the out diffusion of dopant is key issue for performance of LTPS TFTs [4]. Figure 5 (a) and (b) show the sheet resistance of N^+ and N^- with various laser energy density. The poly-Si was implanted with phosphors atoms at 1e15 atom/cm^2 and 10kev for N^+ and 5e13 at/cm^2 at 10 kev for N^-. From figure 5(a) we can found the 80% overlap is the better activation parameter for N^+. It's meaning the reconstruction of dopant with 80% overlap is more effective than other percentage of laser shot overlap. However the sheet resistance of N^- increases with the laser energy density (Figure 5(b)). The final sheet resistance also depends critically upon the microstructure of the pre-doped poly-Si films. This is especially obvious to n-type doping, for phosphors atoms are much heavier than boron atoms and tend to disrupt Si more serious [5]. Therefore, it is speculated that damage formation of poly-Si at higher laser energy density and higher percentage of laser shot overlap. Figure 5(c) shows the sheet resistance of P^+ with various laser energy densities. The poly-Si was implanted with Boron atoms at 2e15 atom/cm^2 and 70kev. It need higher laser energy density to reach the better efficiency of activation. It's due to the incorporation of oxygen atoms in the implanted region to retard the crystal reconstruction [5]. The oxygen atoms come from the gate oxide insulator during implantation process. Therefore the activation of P^+ need higher laser energy density to achieve the low sheet resistance.



(a)



(b)



(c)

Figure 5 Sheet resistance of (a) N^+ and (b) N^- (c)P^+ as a function of laser energy density and percentage of overlap

To verify the quality of poly-Si, in the first instance we fabricated p-channel LTPS top gate TFTs with TEOS oxide (380^0C). The process of p-channel TFT was executed at 200^0C except oxide. The transfer characteristic of p-channel LTPS top gate TFT are shown in Figure 6.The field-effect mobility and threshold voltage are 8cm^2/V.s and -4.61V separately. The subthreshold swing was as low as 0.582 V/dec. The characteristic of p-channel TFT is not perfect yet. We have to fine tune the process of p-channel TFT. in the future. The n-channel with LDD and p-channel TFT process on PI was realized as soon as possible.

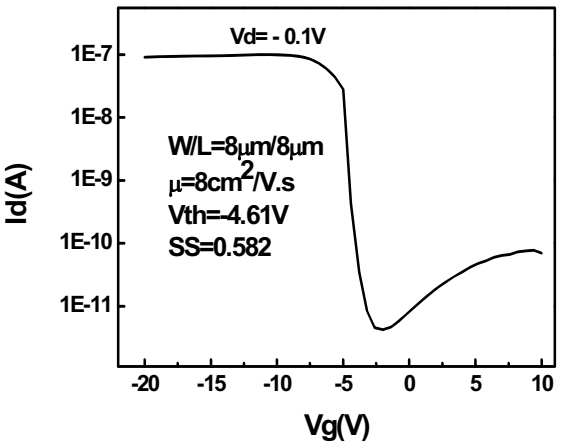


Figure 6 Electrical properties of p-channel LTPS TFT.

4. Summary

In this work, the crystallization of Si films on plastc substrate by laser irradiation was examined. The grain size of poly-Si is about 0.3um. The LTPS TFT process on flexible substrate is more complex than LTPS on glass especially for crystallization and doping activation. In addition to the LTPS TFT is hard to fabricate on flexible substrate due to the temperature limitation Therefore we propose the simplified LDD process for n-TFT on plastic substrate to avoid excess laser irradiation. The mobility of p-TFT is about 8cm^2/V.s and subthresholed slop is 0.582. From our results, the pinholes were found in the poly-Si film. It maybe degrade the performance of LTPS TFT at low temperature (200^0C). Certain characteristics, such as the mobility and off current, need to be improved in the future. The characteristic of n-TFT must establish as soon as possible.

Acknowledgements

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5. References

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