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New Thin Film Transistor with Poly-Si Active Layer Consisting of Enlarged Grain Structure

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1. Introduction

Polycrystalline silicon thin film transistors (poly-Si TFTs) fabricated by excimer laser annealing are promising for active matrix liquid crystal displays (AMLCD's)[1,2]. The electrical characteristics of poly-Si TFTs are dependent on the grain size and defect density of poly-Si film[3]. A considerable attention has been paid to increase the grain size and arrange a specific location of grain boundary in poly-Si film through an effective laser recrystallization of amorphous silicon (a-Si) film[4,5].

In this paper, we have proposed and fabricated a new poly-Si TFT with a active layer which is selectively crystallized by employing a grid-shaped masking window. During the laser irradiation through the specific masking window opened in a narrow grid shape (1~2 μm), the liquid silicon nucleates at the a-Si interface and solidification occurs in a perpendicular direction, so that the grains may be enlarged until both the grains grown from both edges reach in the middle. The residual amorphous regions are also recrystallized by the additional laser irradiation without the masking window.

2. Experiment

We fabricated the masking window by simple method. 1000Å thick poly-Si layer was deposited and patterned in a square array with precise distance and size on quartz substrate which is transparent to XeCl excimer laser (λ =308nm). XeCl excimer laser was irradiated on a-Si laser with the masking window as shown in figure 1. The poly-Si patterns on masking window transmit the laser radiation selectively to a-Si layer.

A-Si layers for acive layer was deposited with plasma enhanced chemical vapor deposition (PECVD) and its thickness was 800Å. The XeCl excimer laser crystallization was performed at an energy density of 350mJ/cm^2. We fabricated a TFT by conventional process, using 1000Å thick TEOS (tetra ethyl ortho silicate) gate oxide and 2000Å thick molybdenum gate electrode. After the gate electrode and oxide patterning, we employed ion shower doping for source/drain formation, which does not require any post-annealing. After contact metallization and hydrogenation, we finished the fabrication. For comparison, we also made poly-Si TFTs using the conventional laser annealing technique without the masking window.

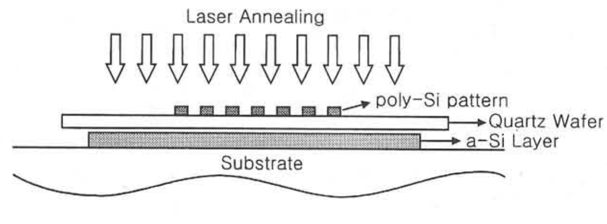


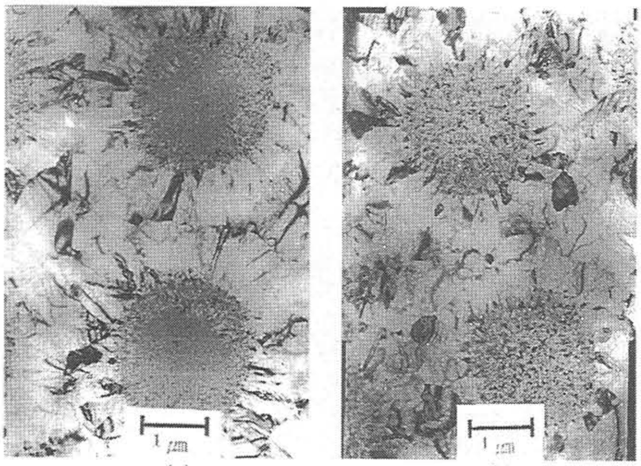
Fig 1. Schematic feature of the proposed laser annealing method

3. Results and Discussion

We investigated the poly-Si grain structure recrystallized by our method with transmission electron microscopy (TEM). 800Å thick a-Si films were deposited with plasma enhanced chemical vapor deposition (PECVD) at 250℃ and dehydrogenation was carried out at 400℃ for 2hours. The energy density of XeCl excimer laser(λ =308nm) was 350mJ/cm^2. In our system, this energy level melts 800Å thick a-Si layer completely to the bottom of layer. The substrate temperature was maintained at 200℃. Figure 2 shows the plane view TEM (transmission electron microscopy) image of poly-Si film recrystallized by our method. In figure 2 (a), we can see the overall feature of selectively crystallized poly-Si film. The a-Si regions are allocated in ordered array determined by laser blocking patterns and poly-Si regions can be recognized by the unique grain structure. The shape of residual a-Si region is rather circular. This is because the angle of square pattern was smoothened during the photolithography and etch step. Most of all, the several large and elongated poly-Si grains are outstanding. They spread out from the residual a-Si regions, which looks like a sunflower. The elongated poly-Si grains grown from both the opposite sides encounter in the mid-region and the length of each grain is nearly 1 μm, which is half the distance between masking patterns in the masking window. This result indicates that our specific laser-masking window successfully obtained the lateral growth of grains and the ordered arrangement of grain boundaries. Further increase of grain size is also possible through enlarging the distance of masking patterns and optimizing laser energy density as long as the lateral growth reaches.

Figure 2 (b) is the image of the sample recrystallized by two step laser irradiation with and without masking window. The first laser irradiation with masking window was carried out at 350mJ/cm^2 and the second laser irradiation without masking window at 250 mJ/cm^2.

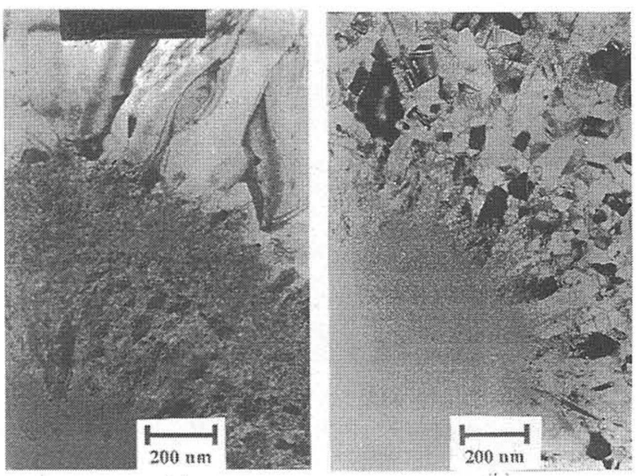
In this image, the a-Si regions shown in figure (a) was transformed to poly-Si by the second laser irradiation, however the enlarged poly-Si grains formed by the first laser irradiation was not changed. By this two step laser irradiation method, a-Si film can be completely recrystallized and the grain structure can also be orderly arranged.



(a) (b)

Fig. 2 TEM image of our selectively crystallized film

Figure 3 shows boundary region of a-Si and poly-Si. These figures show how the laser energy density affects the lateral growth mechanism. Figure 3 (a) is the image of the sample recrystallized at 350mJ/cm^2, which is above complete melting threshold. We can clearly see that the poly-Si grains grew from the a-Si edge. However we cannot find the elongated poly-Si grains and only small grains can be seen in figure 3 (b). This sample was recrystallized at 250mJ/cm^2, which is below the complete melting threshold. Incompletely melted a-Si was subjected to explosive nucleation and therefore the nucleation was not occurred at a-Si edge but at the bottom of molten a-Si bulk. Consequently the small grains which originated from the vertical growth were obtained. From these results, we can see that lateral growth takes place above complete melting condition.



(a) (b)

Fig. 3 TEM image of our selectively crystallized film

Figure 4 shows the electrical characteristics of TFTs employing poly-Si layer recrystallized by the proposed method. The proposed poly-Si TFTs show higher driving current than that of conventional one. Such excellent characteristics may be attributed to the ordered microstructure and enlarged grains of the active poly-Si film. We can also find that the driving currents vary with the size and gap of masking patterns. The size and gap of masking patterns directly related with the portion of enlarged poly-Si regions in the channel. In our experiment, the device crystallized with 2 μm/1 μm of masking pattern gap/size(a/b) shows the best electrical characteristics.

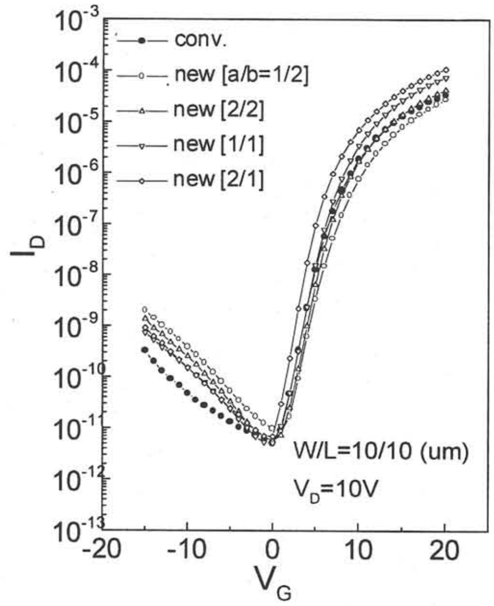


Fig. 4 The transfer characteristics of devices with the various active channel

4. Conclusion

We have fabricated a new poly-Si TFT with the selectively crystallized channel in grid shape. Employing a masking window, the active poly-Si layer was recrystallized in enlarged grains. The new poly-Si TFT showed the excellent electrical characteristics due to the improved grain structure.

References

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