The Influence of Poly-Si Morphology with Excimer Laser Optics System

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Abstract
In this study, we investigate the characteristic of the poly-Si grain and morphology influenced by XeCl excimer laser system. The stable laser beam source is basic requested; the irradiation beam through optical lens module is more important which limit the grain size smaller than 0.5 μm. The homogenization lens designs control the poly-Si grain size; so we hardly get enlarge grain size by one laser irradiation scan.

1. Introduction
Low temperature polycrystalline silicon (LTPS) thin film transistors (TFTs) are necessary to create high performance liquid crystal displays (LCD) and organic light emitting diode displays (OLED). To crystallize amorphous silicon (a-Si) film into polycrystalline silicon (poly-Si) films for the fabrication of TFTs, laser annealing techniques are commonly used for high quality poly-Si fabrication on low cost glass substrate [1-3], due to the low temperature of the process. Compare to the conventional a-Si TFTs, the mobility of both p-type and n-type poly-Si TFTs is approaching 100 times of a-Si TFTs, another benefit of LTPS was the cost reduction with integrated driver circuit on the LCD panels and realizes system on penal. By using CMOS circuit [4-5] or PMOS circuit [6-7] can achieve panel with integrated driver and active matrix organic light emitting diodes display.

In this case, excimer lasers have been applied as laser source [8-9]. There are several different excimer laser types, one of the popular excimer laser is LAMBDA STEEL series made by LAMBDA PHYSIK company. The poly-Si grain size of poly-Si film recrystallized by cxcimer laser annealing (ELA) may not large enough; the poly-Si grain size is less than 0.5 μm typically. Although we adjust the laser irradiation energy and scan speed but it seems hard to enlarge the grain size more than 0.5 μm. Besides, the position of poly-Si grains is random arrangement. As we know optical system plays an important role in ELA system. Laser beam go through and be adjusted by optical lens then irradiate a-Si film to form poly-Si grains. The most important function of optical lens is to homogenize and change laser beam size. In this paper we will focus on the laser irradiation beam shape, homogenization lens and poly-Si grain arrangement in the film.

2. Experimental
The conventional low temperature polycrystalline silicon process-flow was adopted in this work. The buffer layer SiO2 (2500Å) / SiN (500Å) and 50 nm thickness a-Si:H films were deposited by plasma enhanced chemical vapor deposition (PECVD). The dehydrogenation process at 470ºC and 6 min prior to the ELA. The 308 nm XeCl excimer laser is irradiated on the a-Si film at 300 Hz and at room temperature under N2 environment approximately 1 atm. The irradiation time is 23 ns at full width at half maximum (FWHM). The energy density is 250 to 400 mJ/cm^2. The overlap ratio of irradiation beam is 95%. The long axis irradiation beam homogenous is 2σ □2.5 %, the short axis irradiation beam homogenous is 2σ□4%, respectively. After laser irradiation on a-Si film, secco etching is performed before observing the poly-Si surface by SEM to clarify the film morphology

3. Result and discussion
The morphology of the new ploy-Si grain arrangement and conventional ones are shown in Fig.1. The conventional arrangement of poly-Si grains is random spread in the film after laser annealing. Now we obtain the very regular sequence poly-Si recrystallization. The regular arrangement poly-Si is not only local but also large area spread, it looks like array in the poly-Si film and the average grain size is 0.3μm.

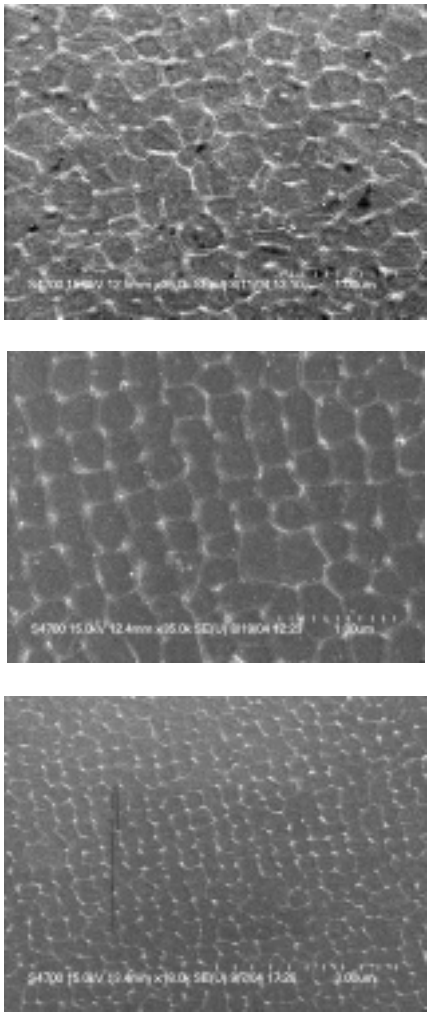

Fig.1.SEM micrograph (after Secco-etching the sample) (a).The conventional poly-Si surface morphology (b) the new poly-Si surface morphology (c) more large image area from (b).

The theory of poly-Si recrystallization by laser annealing had been investigated very details[10]. In laser irradiation process, some a-Si is not be melted by laser irradiation at the a-Si / SiOx interface, this is so called near complete melting region. The non-melt a-Si becomes the poly-Si nucleus seed. As time goes by, cooling temperature will cause melting a-Si recrystallize to form large grain size poly-Si, Fig. 2-3. But here we protest of the poly-Si nucleus site, if the nuclear position is at non-melt a-Si / SiOx interface, the nuclear site must be random spared on a-Si / SiOx interface, and the ply-Si grains grow should not be uniform like Fig.1 (a). But in Fig.1 (b), poly-Si grain is regular arrangement in poly-Si film, it means that the nuclear position in a-Si / SiOx interface is not random formation. There must be some reason that we do not find out.

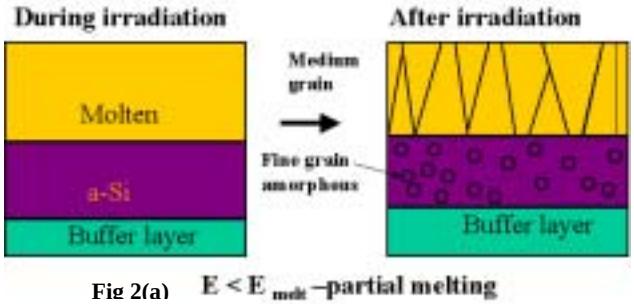

Fig 2(a) $E < E_{melt}$ –partial melting

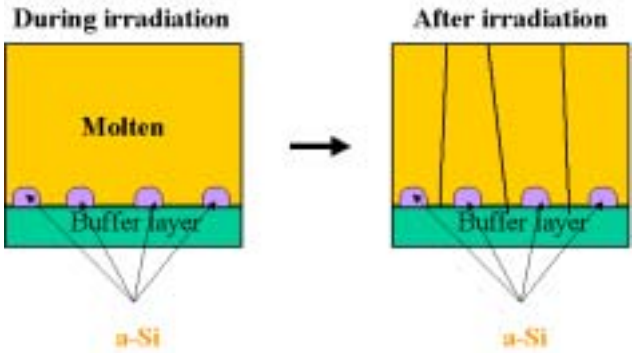

Fig 2(b) $E = E_{melt}$ – near melt through

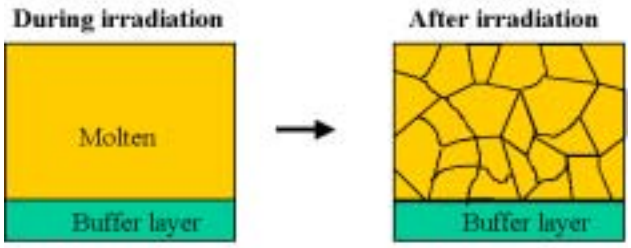

Fig 2(c) $E > E_{melt}$ – full melt through

Fig.2.When laser energy density(ED) small than near complete melt energy, only partial a-Si melting and grain size is small. When ED is equal to near complete melt energy, grain size will be large. When ED is large than near complete melt energy, grain size will be small again.

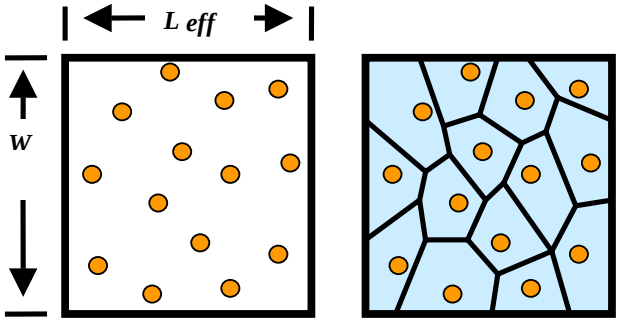

Fig.3.When ED= near complete melt energy, only small amount nuclear site will be formatted and the nuclear position is random appeared.

According to the phenomenon that mention above, optical system of ELA provide a good way to explain nuclear site is regular arrangement in a-Si / SiOx interface. First, review the ELA optic lens[11]. Laser beam outgoing from laser source, laser energy is not uniform in beam area. For adjust laser beam uniformity the homogenization lens is used. One pair of homogenization lens consist horizontal and vertical lens. Laser energy is homogenized by horizontal and vertical lens respectively. After homogenization, laser energy density will be uniform in whole area, shown in Fig. 4. Further observation the homogenizer lens, each direction lens consists of several small convex, shown in Fig. 5.

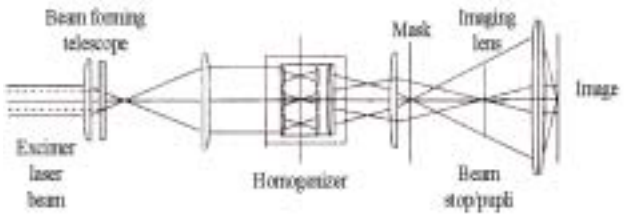

Fig.4.Homogenizer lens adjust laser energy density become uniformity.

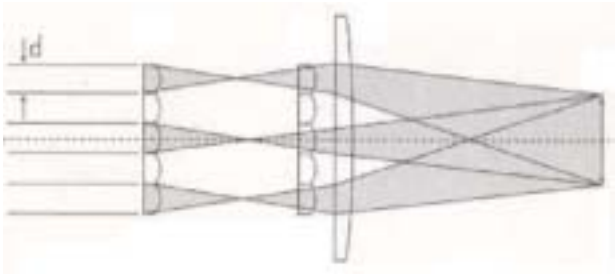

Fig.5.Homogenizer lens consist of several convex. Laser beam will be projected by convex at plane D.

According to Fig.5, we suppose laser energy density is not real uniform at plane D. Consider each adjacent 2 convex, laser energy density is higher at convex center and lower at 2 convex adjacent point. In microcosmic region at plane D, laser energy density will be a little bit lower at some fixed projection line than other area. Combine horizontal and vertical lens effect, the lowermost energy density position is located horizontal and vertical projection cross-spots, and the spots arrange as array, shown in Fig. 6.

According to the homogenizer lens effect, let's reconsider the poly-Si grain regular arrangement phenomenon. When laser irradiation on a-Si film, these lowermost energy density spots will not cause a-Si film fully melt and remain non-melt a-Si seeds on a-Si / SiOx interface. Then poly-Si grain growth when film temperature is cooling down. Grain will continue growth until adjacent grain boundary touch to each other. Besides, grain growth rate is almost the same so that the grain size and shape is similar in all laser irradiation area; average grain size is 0.3 μm, shown in Fig.7.

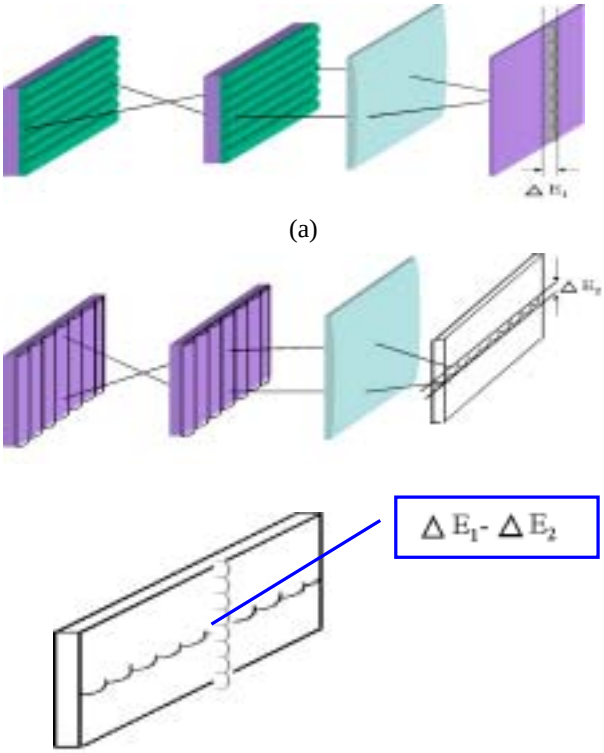

Fig. 6 (a) Horizontal homogenizer lens cause the vertical low energy density line (ΔE1). (b) Vertical homogenizer lens cause the horizontal low energy density line (ΔE2). (c) The lowermost energy density spots (ΔE1-ΔE2) arrange as an array on plane D.

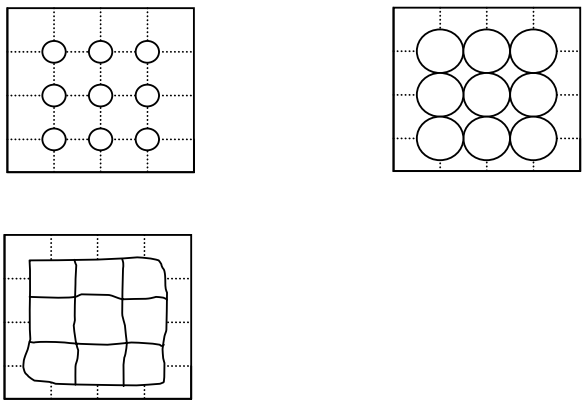

Fig.7.The schematic of poly-Si grain growth Dotted line is lower energy density position. (a) Small circle shows seeds position on a-Si / SiOx interface. (b) Disc-like shape of Poly-Si grain growth as a-Si film temperature cooling down.. (c) Final grain shape when grain boundary contacts to each other.

Based on the poly-Si recrystallization experiment and the inference of homogenizer lens affection from nuclear position. The a-Si / SiOx interface nuclear site is controlled by laser beam homogenization result. It provides a significant phenomenon, poly-Si grain size cannot enlarge by using near-complete melting way if laser irradiation only one time and did not do any other additional process after a-Si formation and before ELA irradiation duration.

4 Conclusion

We have proposed the relationship between poly-Si seed position and ELA homogener lens. Poly-Si grain size is small and non-uniformity when laser irradiation energy density is higher or lower than near complete melting temperature. But the energy density is exactly at near complete melting range, homogenization beam will limit seed positions for only once laser recrystallization scan. So the different way to enlarge poly-Si grain size must be improved.

7. References

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