The Study of Sequential Lateral Solidification Process as a Function of Laser Intensity

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Abstract

We report the suitable SLS (sequential lateral solidification) as a function of laser intensity. Precursor film is changed from 50nm to 100nm and is deposited on glass substrate by PECVD. We can find the suitable SLS length by changing the mask size. In this paper, we present the well-defined grain growth conditions as a function of laser intensity.

1. Introduction

Integration of peripheral circuits on glass substrate and exclusion of silicon based driver chips are the main advantages of poly-Si TFT-LCD s in comparison to a-Si TFT-LCDs. During last ten years, many research groups[1] have studied the poly-Si films, which have advantages of high resolution, low power consumption, light-weight, and aperture ratio on the glass substrate. In order to drive the active matrix organic electroluminiscent device (AM-OELD)[2] by electric current, poly-Si TFT is essentially required. Therefore, the demand of poly-Si TFT is increased. Although the mobility of a-Si TFT have been reported under 1cm^2/Vs, the mobility of poly-Si TFT have been reported under 200cm^2/Vs as a function of process. It means that the high mobility of poly-Si TFT is able to fabricate small size TFT with increase in brightness and integrate the driver IC inside panel. The mobility of poly-Si is highly influenced by grain size, length and shape. But, nucleation site or agglomeration deteriorates the mobility of poly-Si films. To improve the mobility, we studied with the approved laser intensity without nucleation or agglomeration using a SLS (sequential lateral solidification) process. SLS technology [3] is different from directly irradiated ELA. The grains are grown up step-by-step by laser beam irradiation for two times on the selective area using a mask. It is very promising method that has a comfortable large area process, higher process window intensity of about 200mJ/cm^2 in opposition to 20mJ/cm^2 in case of ELA. We changed the excimer laser intensity to determine the energy density value having a good crystalline growth of constant precursor thickness. In this paper, we will present the SLS growth properties of poly-Si as a function of laser intensity.

2. Experimental

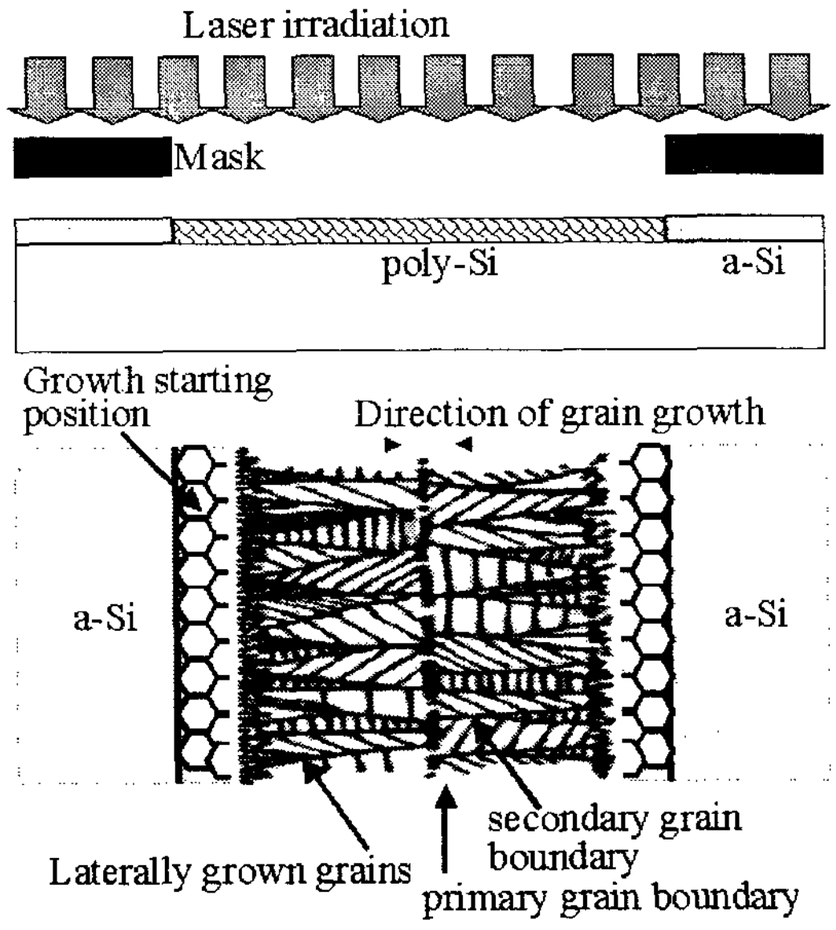

Figure 1 SLS process schematic diagrams for poly-Si crystallization.

For our experiments, we controlled the thickness of a-Si layer from 30nm to 100nm. Precursor film of a-Si is deposited at 350℃ using a mixture of SiH_4 and H_2 by PECVD process on the glass of dimensions, 300mm×400mm. The crystallization system consists of an excimer laser operation at 308 nm (XeCl). A schematic diagram of the process is shown in figure 1. The UV mask plays an important role to define the melting area. We used the rectangular masks from 3/1 to 8/2(unmasked length (μm)/ masked length (μm)). The excimer laser irradiates the sample at an energy density sufficient to induce complete melting of the unmasked areas of the films. UV mask is located above a-Si layer as shown the figure 1. The mask pattern has bright and dark areas. Laser beam is irradiated through open area but is protected by closed area. The complete process was carried out under ambient conditions and room temperature. To certificate the nucleation sites, we etched the crystallized samples using a Secco. solution.[4]

3. Results and discussion

Figure 2 shows the SLS length as a function of laser intensity. As the laser intensity increases SLS length also increases. Each of intensities has a limitation of grain growth. In case of 800mJ/cm^2, nucleation sites to the mask sizes of 5/1, 5.5/1 were not observed. But, these were observed to the mask size above 6/1 in the same site. It means that the length of grain growth is controlled by the laser intensity. From the figure 3, we could observe SLS length as a function of energy density. The suitable mask size is summarized in the Table 1. This result exhibits that SLS length without nucleation is determined by mask size.

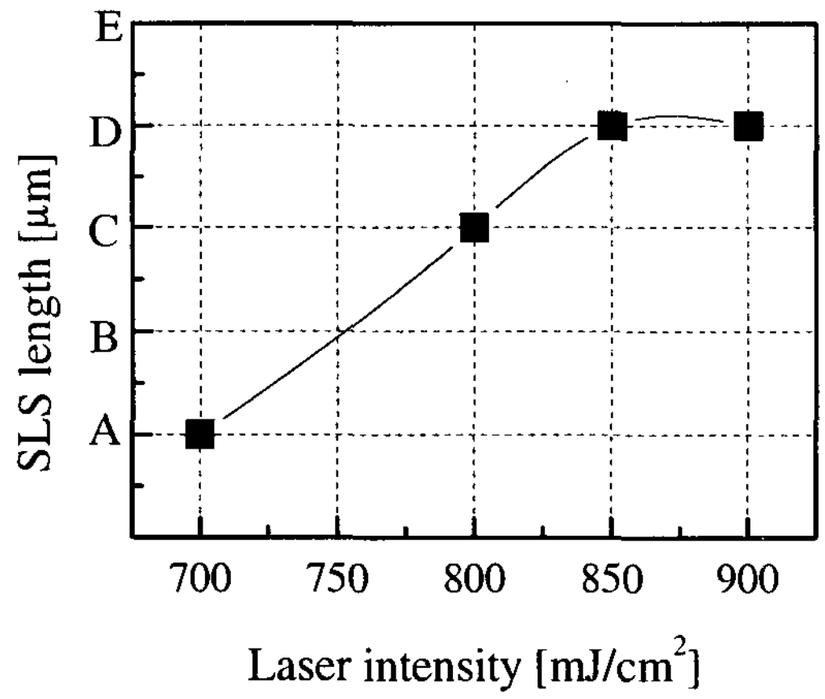

Figure 2 SLS length as a function of laser intensity.

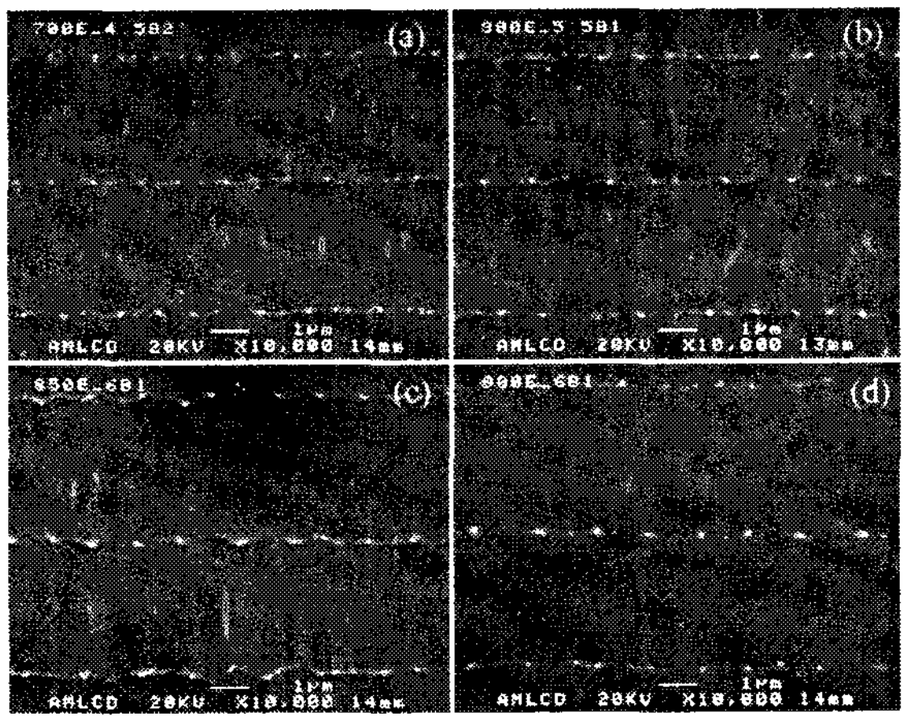

Figure 3 Surface views as a function of SLS length and laser intensities with precursor thickness of 50nm. It has not exhibited the nucleation site or agglomeration (a) 700mJ/cm^2, (b) 800mJ/cm^2, (c) 850mJ/cm^2, (d) 900mJ/cm^2.

Table 1 Suitable mask size as function of laser intensity. ◎, N mean the films without and with nucleation respectively.

μm / mJ/cm^2	A	B	C	D	E	F
700	◎	N	N			
800		◎	◎	N	N	
850			◎	◎	N	
900				◎	N	N

In our experiment, we fixed the mask size as 5.5/2μm, in the other words, open mask length of 5.5μm and closed mask length of 2μm. The regions of nucleation or agglomeration were observed by increasing the laser energy density as a function of precursor thickness for 2-shot irradiation. In those conditions, SLS length was calculated as 3.75μm for the 2-shot process. Figure 3 shows that the nucleation happened when the laser was of low energy density and agglomeration took place when irradiated with the laser of too high energy density. Therefore, we could find the energy density at which the nucleation or agglomeration does not take place. For the thinner precursor thickness, the probability of nucleation or agglomeration decreased with increase in energy density of the laser. On the other hand, if there is greater precursor thickness, it increases with increase in energy density. These conditions are very important

to define the active layer size in order to fabricate thin film transistor.

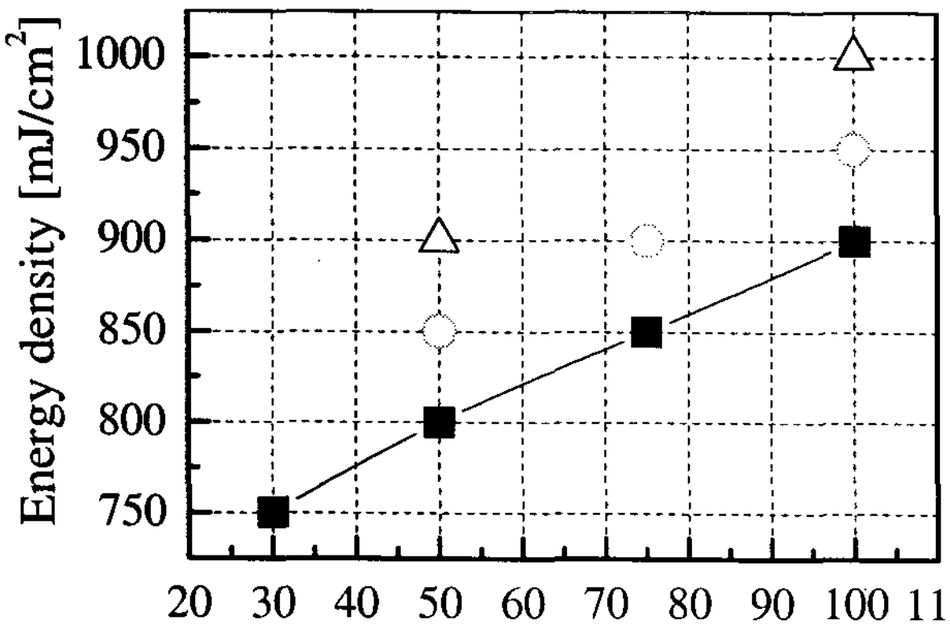

Figure 3 The energy density that does not include the nucleation and agglomeration sites as a function of precursor thickness.

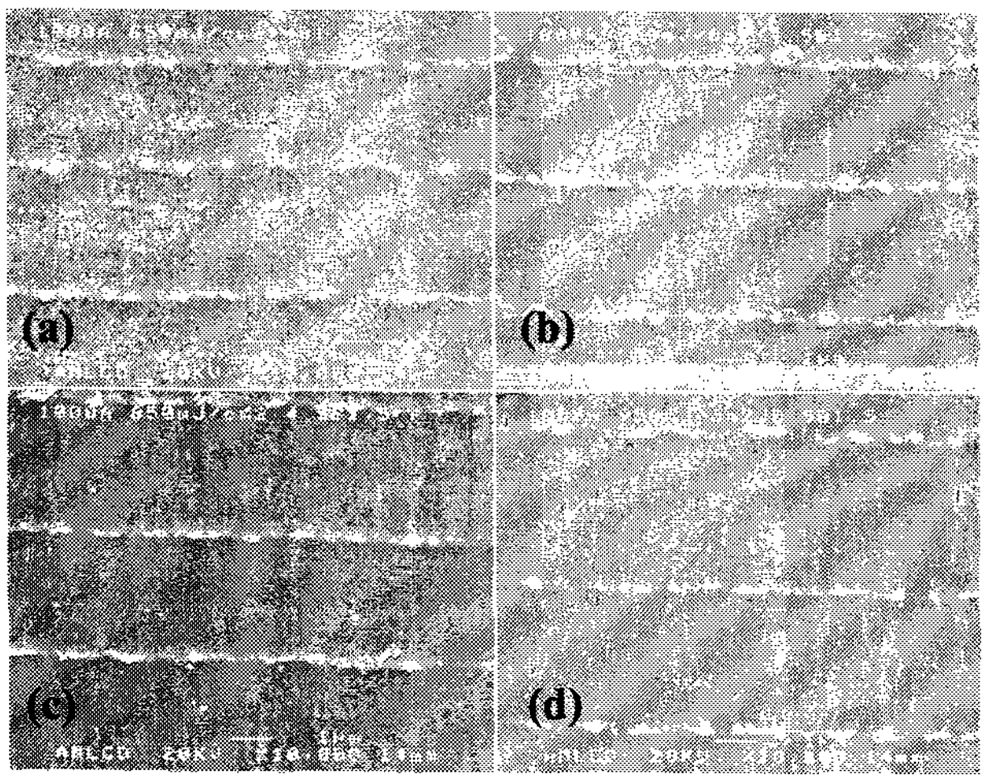

Figure 4 Surface images as a function of SLS length and laser intensities with precursor thickness of 100nm. (a) 4/1.5μm, 650mJ/cm^2, (b) 4.5/1.5μm, 750mJ/cm^2, (c) 4.5/1.5μm, 850mJ/cm^2, (d) 5.5/1.5 μm, 950mJ/cm^2

In order to examine the relationship between laser energy density and protrusion, we fixed the sample thickness of 100nm. This sample was observed the protrusion height about 950mJ/cm^2 and 1000mJ/cm^2 respectively, by an atomic force microscopy (AFM) as shown the figure 5. As the laser energy intensity increases, the protrusion height becomes higher. This result means that the higher laser energy density dominates the increase of the grain growth speed. When the impact took place to match point of the two side grown grains, protrusion height is higher than low laser energy because of the fast grain growth speed. Although the protrusion height is observed at the high laser energy, the crystallinity of crystallized film does not change as shown the figure 6. Generally, Raman spectra of a-Si phase show a broad TO-mode peak around 480cm^{-1}, while those of c-Si phase show only the sharp Raman TO-mode peak at 520cm^{-1}[5]. In our experiment, the Raman spectra of crystallized Si films showed a sharp TO-mode peak without a broad 480 cm^{-1} of amorphous phase.

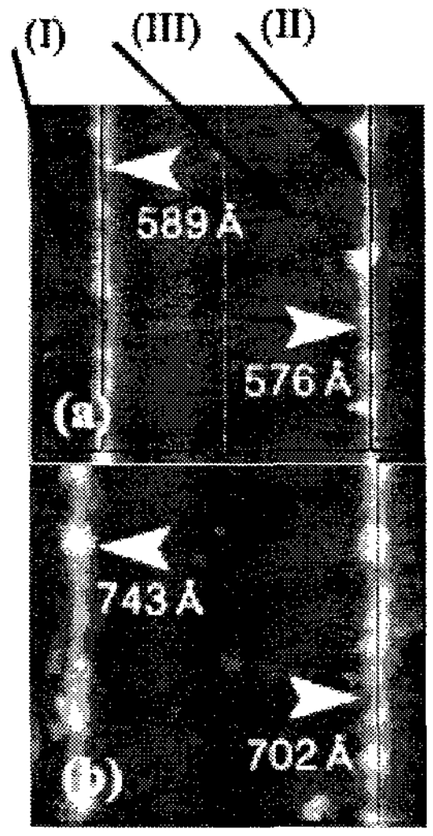

Figure 5 Protrusion formation of surface as a function of laser energy density (a) 950mJ/cm^2, (b) 1000mJ/cm^2.

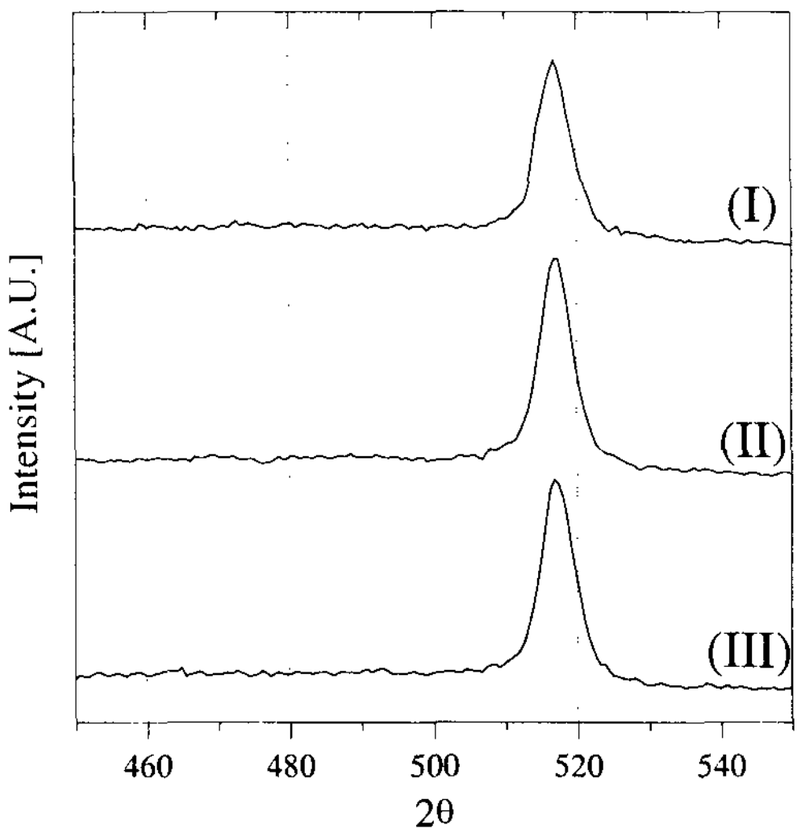

Figure 6 Raman spectroscopy as the variation of crystallized surface site with the precursor

thickness of 100nm, laser annealed to the 900mJ/cm^2. Legends (I, II, III) indicate the surface sites in the figure 5.

4. Conclusion

In this study, we learnt the suitable SLS length is determined by mask size and laser intensity. It means that the larger grain size requires higher laser intensity and mask length. In other words, we can acquire the actual grain growth effects for the larger complete melting area of mask with the increase in energy density and melting time duration to the exposed regions. In the case of greater precursor thickness, nucleation or agglomeration is formed at higher energy density and the broader formation energy gap between nucleation and agglomeration. It indicates the large energy window for the SLS process. As the precursor thickness is large, it plays a role of reservoir related in constant irradiated energy density. If the energy density irradiated is enough for Si crystalline growth to the edge of films and has much incubation time, the poly-Si films can be grown without nucleation. But, agglomeration happens at very high energy. Therefore, energy density has a limitation for high quality poly-Si films. Interface growth speed is proportional to the temperature gradient from the unmelted region to melted region by Interface Response Function (IRF). In the condition of high energy density and thick precursor film, the energy of crystalline growth through the centered region having a high temperature is higher. This results in the higher protrusion height induced the impact of interfaces.

5. Acknowledgement

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