Excimer-Laser Crystallization for Low-Temperature Polycrystalline Si TFTs

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ABSTRACT

For excimer laser crystallization (ELC), energy density, number of pulses, beam uniformity, and condition of initial amorphous Si (a-Si) films are significant factors contributing the final microstructure and the performance of low-temperature polycrystalline Si TFTs. The process and equipment have been achieved a significant improvement, but still, environmental factors associated with initial amorphous Si (a-Si) films and process conditions need to be optimized.

Introduction

Despite considerable effort toward the excimer laser crystallization (ELC) process, ELC is still considered as a "bottleneck" of low temperature polycrystalline (LTPS) TFT fabrication processes. This is due to the fact that it requires frequent maintenance such as gas change, window cleaning, tube change, lack of uniformity, and etc. Since pulsed laser beam is extremely sensitive to the initial condition of the as deposited a-Si films, both the quality of the precursor a-Si and the beam uniformity is equally important.

Recently, using the multiple-pulse-grain growth (MPGG) method, which is basically long-line-beam-scanning method, most of the developments and even early stage of productions are conducted. In order to compete with well-developed a-Si TFT manufacturing technology, one must come up with more process-friendly ELC technique.

In this paper, briefly review the current status of ELC and some of the new ideas, which produce laterally grown large poly-Si microstructure.

Amorphous Si Precursor

For the a-Si film, as a pre-cursor, either LPCVD or PECVD is currently employed. LPCVD has been traditionally used in LTPS TFT because it produced a-Si films with nearly no hydrogen content. Amorphous Si thin films prepared by PECVD, on the other hand, has suffered from having high hydrogen content (typically 10-20%). It requires additional cumbersome dehydrogenation process.

Previously physical understanding of ELC process has been identified [1,2, and Figure 1] and various techniques have been employed to produce high quality and large-grain sized poly-Si films. [for example, 3-6].

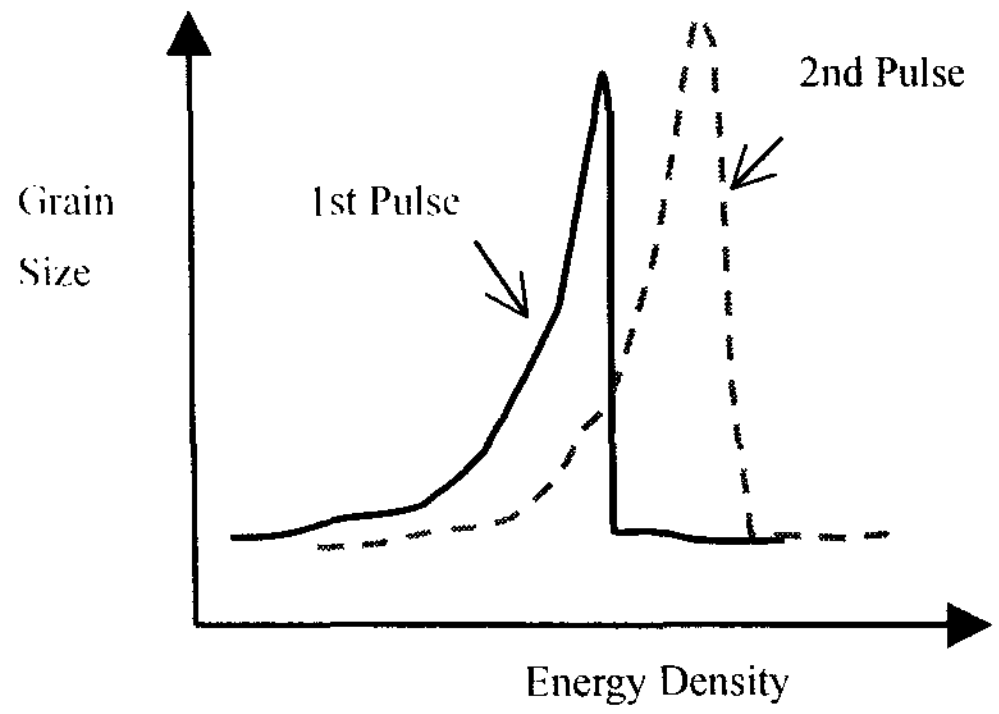
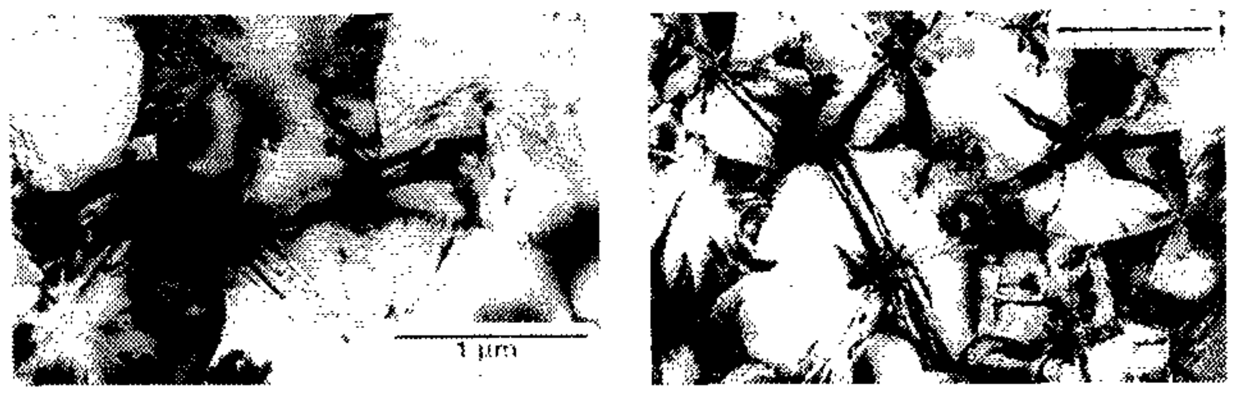


Figure 1. Schematic variation of grain size of single-pulse and dual-pulse crystallized a-Si films

Many LTPS TFT-LCD developers are using PECVD a-Si as a precursor even if it requires a cumbersome dehydrogenation process after deposition of a-Si. The issue of the crystallization is not applied only ELC process itself. The microstructure of the ELC, which directly affect the performance and uniformity of TFTs, is greatly dependent on the conditions of an excimer laser. Most of all, the initial condition of the precursor is critical. For the case of LPCVD, the explosive crystallization always occurs with the 1st pulse of the laser [2].



(a) (b)

Figure 2. Planar-view TEM images of Super-Lateral Growth (SLG) poly-Si for (a) LPCVD, and (b) Ion implanted LPCVD. Laser energy density is same for both cases. [Ref: 1,2]

Figure 3 shows representative transient reflectance (TR)

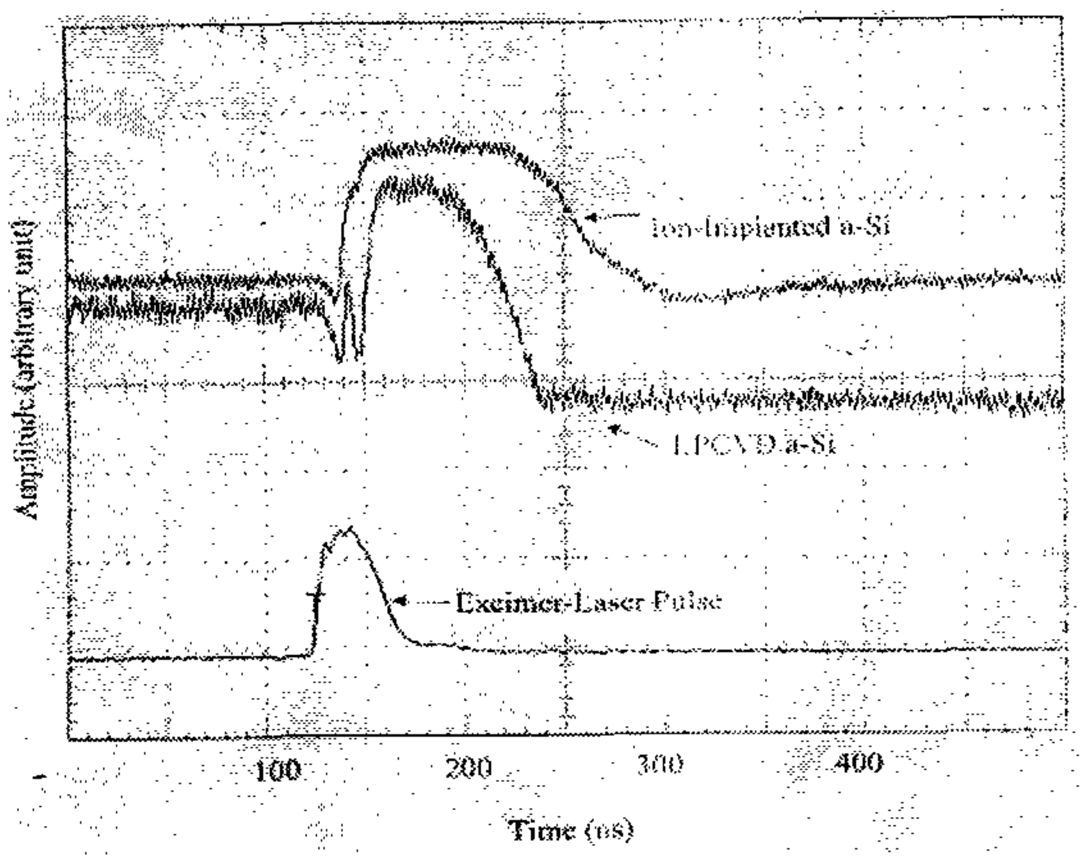
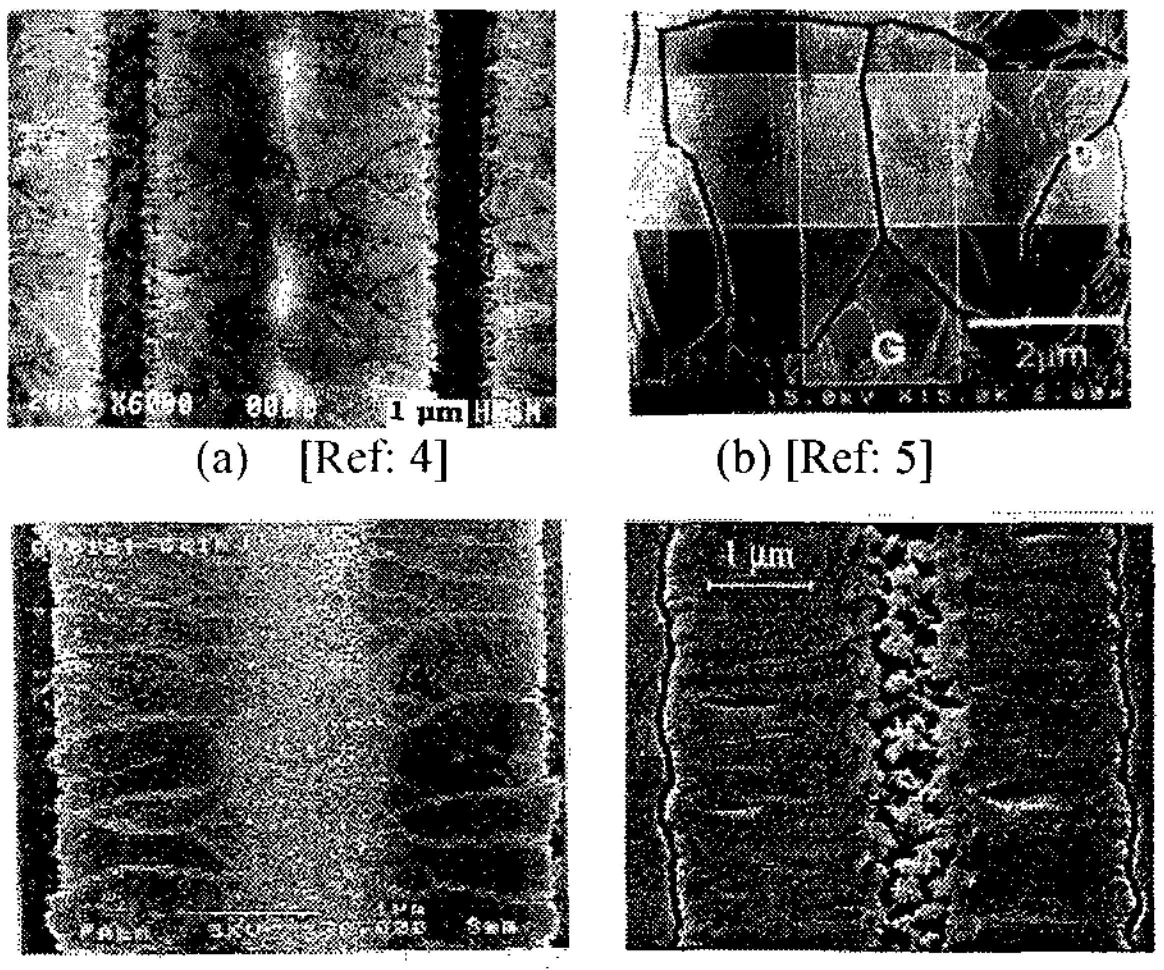


Figure 3. Comparison of transient reflectance (TR) data from a-Si prepared by LPCVD and by ion-implanted LPCVD. (Energy density: 416 mJ/cm^2) [Ref: 2]

signals for both LPCVD a-Si and ion-implanted LPCVD a-Si films. It is important to note that the incident energy densities are the same for both cases. The sample configurations exactly same for both cases except one has a high-doped ion-implantation after LPCVD. The significant differences between them are: (1) the melt-duration of ion-implanted Si was much longer than that of LPCVD-Si—i.e., the energy density required to completely melt the ion-implanted Si was significantly lower than that for LPCVD-Si, and (2) there are no initial oscillations for ion-implanted Si film, which means explosive crystallization was not triggered at the beginning of irradiation [2]. What this figure implies is that the initial condition of the precursor is crucial for final microstructure of the ELC poly-Si thin films, which also significantly affects the performance and uniformity of TFTs. Recently, using Super Lateral Growth (SLG) phenomena, single-crystal Si technology on glass is drawing an attention [3, Figure 5]. This technology is rather focusing on wider ELC process window, higher throughput, lower maintenance cost, and etc

Lateral Growth by ELC

Based on SLG phenomenon, numerous new techniques, which produce distinctively large poly-Si films, have been presented.



(a) [Ref: 4] (b) [Ref: 5]

(c) [Ref: 6] (d) [Ref: 7]

Figure 4. Laterally grown poly-Si using various techniques; (a) GLC (Grain-boundary Location Control), (b) Phase Shift Mask, (c) backside ELC, and (d) Two-pass ELC.

Figure 4 shows controlled-large-grained poly-Si using various methods. Columbia University group has developed "grain-boundary-location-controlled (GLC)" poly-Si using patterned SiO_2 as an anti-reflective coating layer on top of a-Si film, which is shown Fig.4(a) [4]. Tokyo Institute of Tech. group presented a lateral grain-growth of poly-Si using "phase-shift mask", as shown in Fig. 4(b) [5]. Fujitus group demonstrated a new lateral growth method of poly-Si by using an a-Si island and backside ELC, as shown Fig. 4(c) [6]. Italian group also achieved a control of the location of the nucleation site, which results in controlled and laterally grown poly-Si as shown in Fig. 4(d) [7].

Most of the methods are utilizing the SLG phenomenon. Although above methods are producing large- and controlled-grain poly-Si microstructures, in order to implement these techniques into production level, uniformity of poly-Si on glass substrate, equipment compatibility, and simpler process should be addressed.

As shown in Fig. 5, James Im et al at Columbia University developed "sequential lateral solidification (SLS)" method, which produce large-grained, directionally solidified, and location –controlled single-crystal regions.

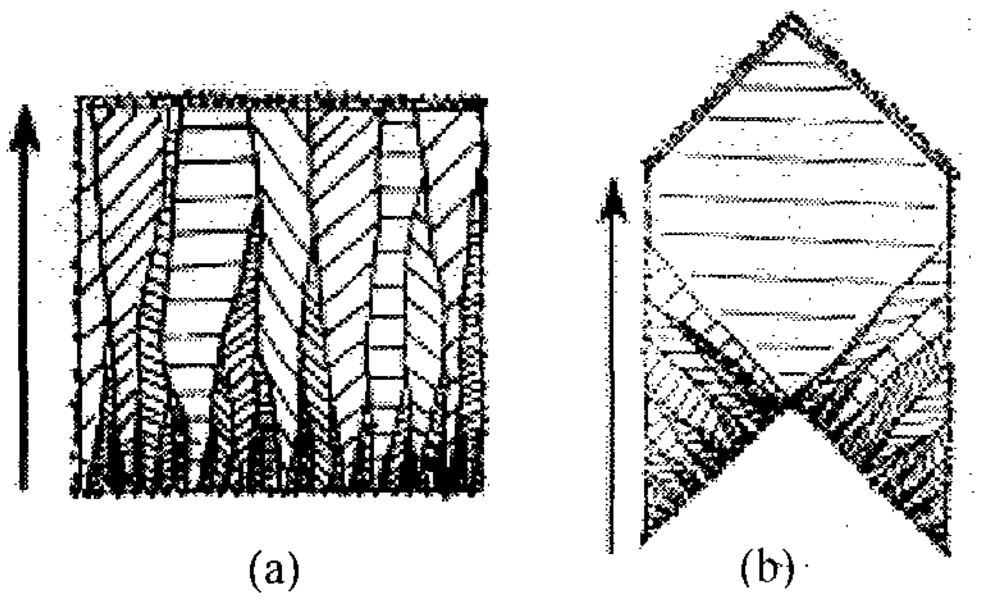


Figure 5. Schematic showing the SLS microstructure for a) a straight-slit and b) a chevron-shaped beamlet. The arrow shows the solidification direction [ref:3]

Table 1. Lateral Growth ELC related factors contributing the high-quality and large-grain size of poly-Si films.

Melting Condition of a-Si	Selective Complete Melting
Substrate temperature	Room Temperature
Precursor Preparation	Low-H content CVD
Number of shots	Less than 10
Pulse Duration	Up to a few hundreds nano sec.
Process Window	Wider than MPGG
Irradiation environs	Air
Film thickness	300 - 800 Å

Conclusion

The factors contribute the final microstructure and quality of the TFTs are as follows; energy density of excimer laser, pulse duration and shape, number of pulses, precursor a-Si film, and etc. Especially lateral growth ELC related factors contributing the high-quality and large-grain size of poly-Si were summarized in Table 1.

References

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