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Excimer-Laser Annealing for Low-Temperature Poly-Si TFTs

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Abstract

For excimer laser annealing (ELA), energy density, number of pulses, beam uniformity, and condition of initial amorphous Si (a-Si) films are significant factors contributing to the final microstructure and the performance of low-temperature polycrystalline Si (LTPS) TFTs. Although the process and equipment have been significantly improved, the environmental factors associated with initial amorphous Si (a-Si) films and process conditions are yet to be optimized.

Keywords : LTPS, Crystallization, ELA

1. Introduction

Despite considerable efforts toward improving the excimer laser annealing (ELA) process, ELA 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, 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, most of the developments and even early stage of productions are conducted using the multiple-pulse-grain growth (MPGG) method, which is basically long-line-beam-scanning method. In order to compete with well-developed a-Si TFT manufacturing technology, it is essential to develop a process-friendly ELA technique.

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

2. Amorphous Si Precursor

For the a-Si film, as a pre-cursor, either LPCVD or PECVD is employed. LPCVD has been traditionally used in LTPS TFT because it produces a-Si films with nearly no hydrogen content. Amorphous Si thin films prepared by PECVD, on the other hand, has shown to contain high hydrogen content of typically 10-20 %, and thus, requires additional cumbersome dehydrogenation process to be carried out.

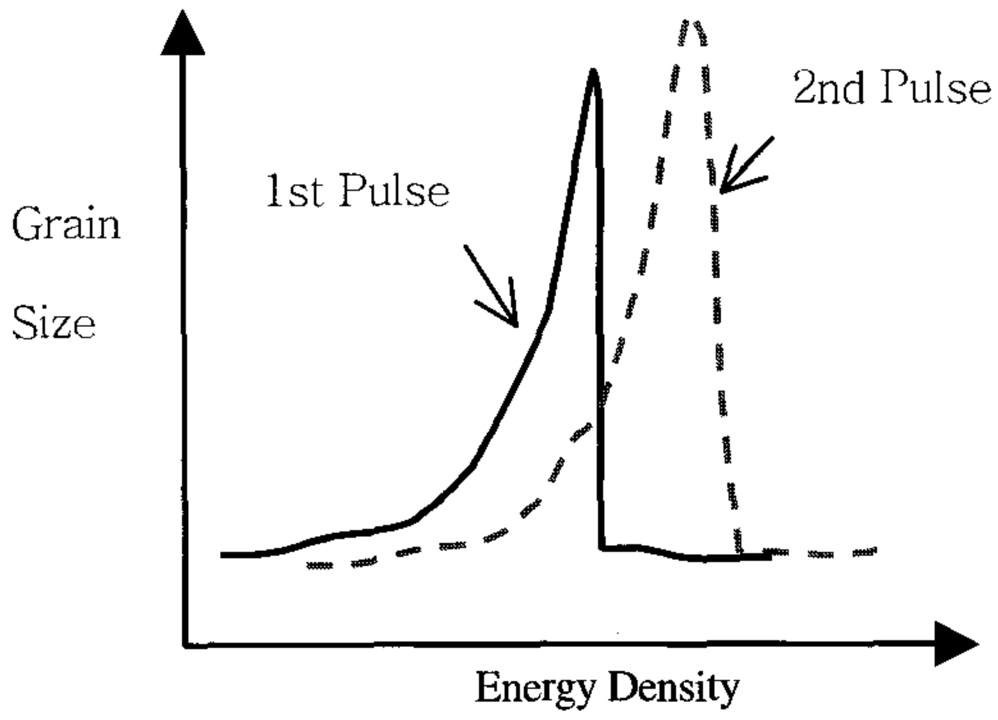

Fig. 1. Schematic variation of grain size of single-pulse and dual-pulse crystallized a-Si films.

Previously, physical understanding of ELA process has been identified [1,2] and [Fig. 1] and various

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techniques have been employed to produce high quality and large-grain sized poly-Si films. [for example, 3-6].

(a) (b)

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

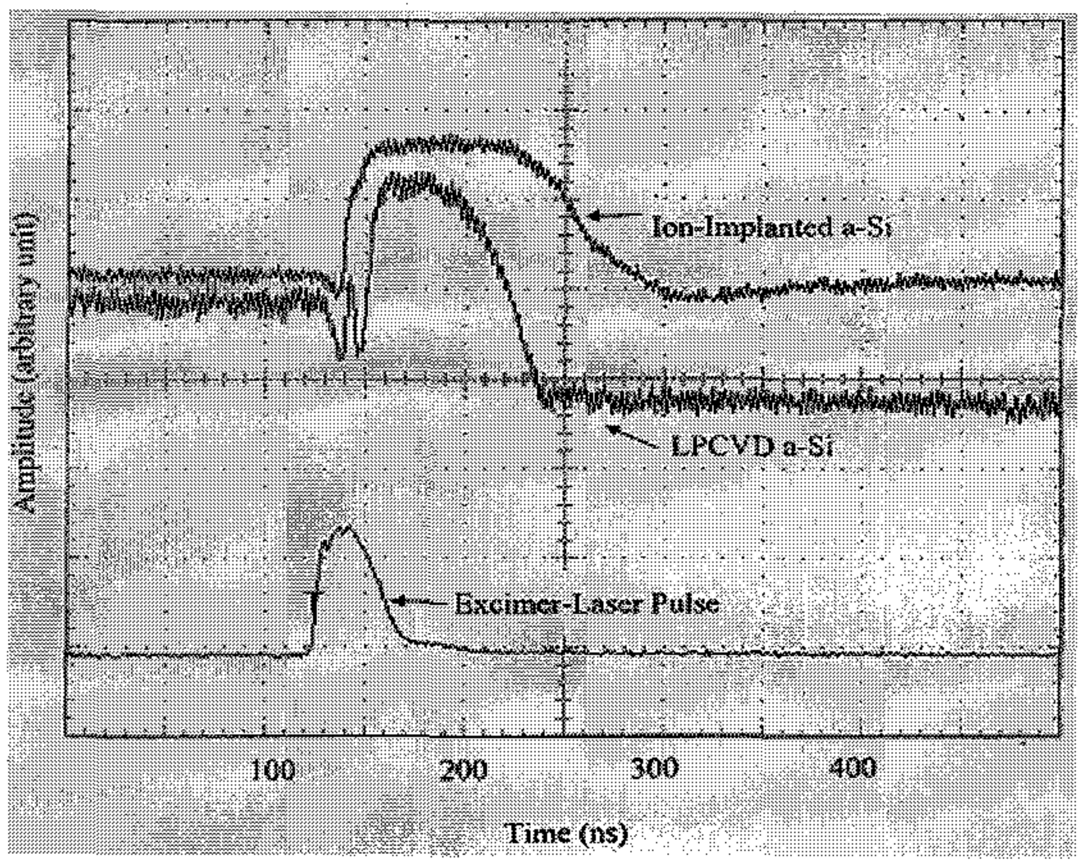


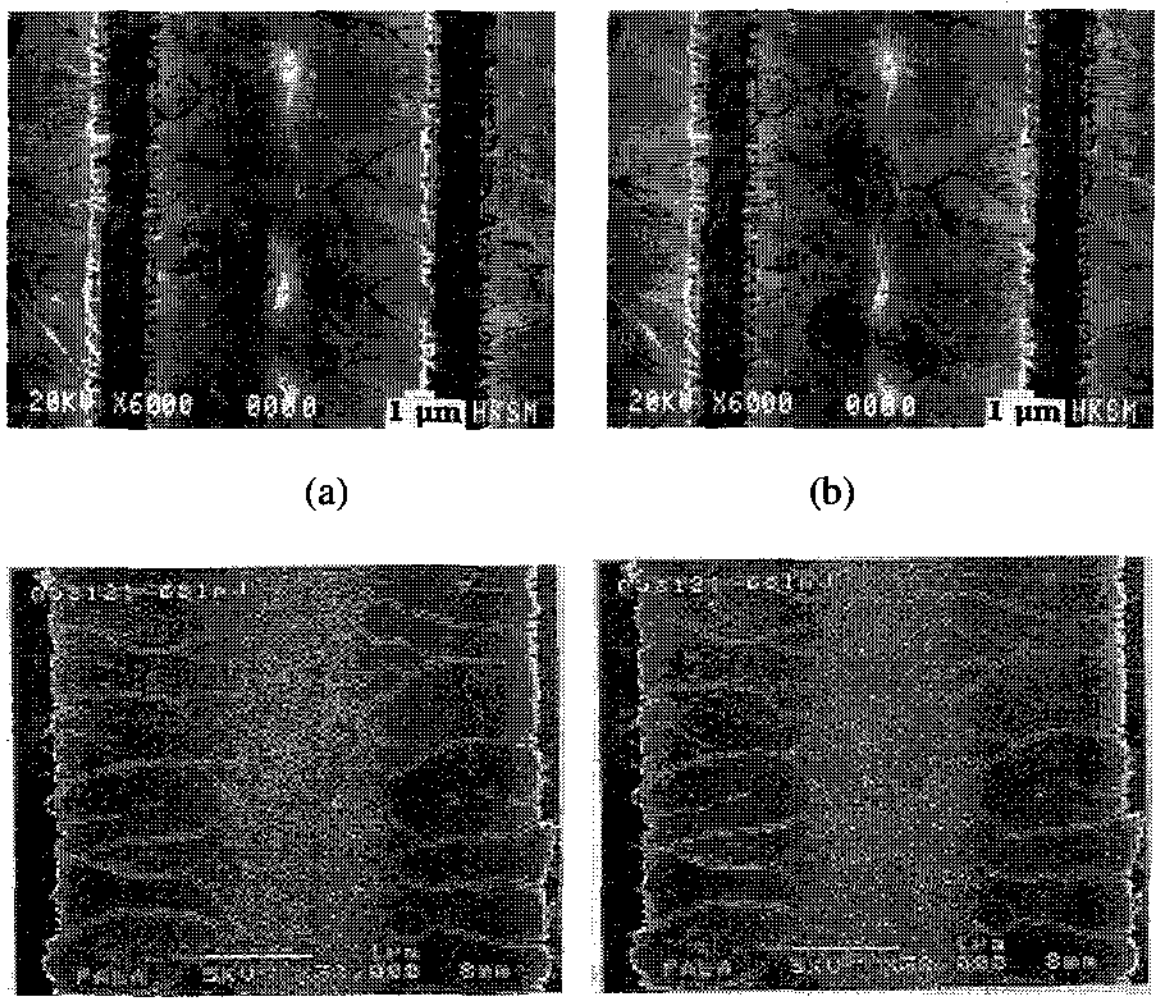
Fig. 3. Comparison of transient reflectance (TR) data from a-Si prepared by LPCVD and by ion-implanted LPCVD. (Energy density: 416 mJ/cm^2). [Ref: 2]

Many LTPS TFT-LCD developers use 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 ELA process itself. The microstructure of the ELA, which directly affect the performance and uniformity of TFTs, is greatly dependent on the conditions of the excimer laser. But most of all, the initial condition of the precursor is critical. For the case of LPCVD, the explosive crystallization always occurs at the onset of the 1st pulse of the laser [2].

Fig. 3 shows the representative transient reflectance (TR) 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 are exactly the same for both cases except that one has a high-doped ion-implantation after LPCVD. The significant differences between these two types of films are as follows: (1) The melt-duration of ion-implanted Si is much longer than that of LPCVD-Si—i.e., the energy density required to completely melt the ion-implanted Si is 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 ELA poly-Si thin films, which in turn 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], [Fig. 5]. This technology is rather focusing on wider ELA process window, higher throughput, lower maintenance cost, and etc

3. Lateral Growth by ELA

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



(a) (b)

(c) (d)

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

Fig. 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 ELA, 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 utilize the SLG phenomenon. Although the above methods produce large- and controlled- grain poly-Si microstructures, in order to implement these techniques into production level, it is important to address the uniformity of poly-Si on glass substrate, equipment compatibility, and simpler process.

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.

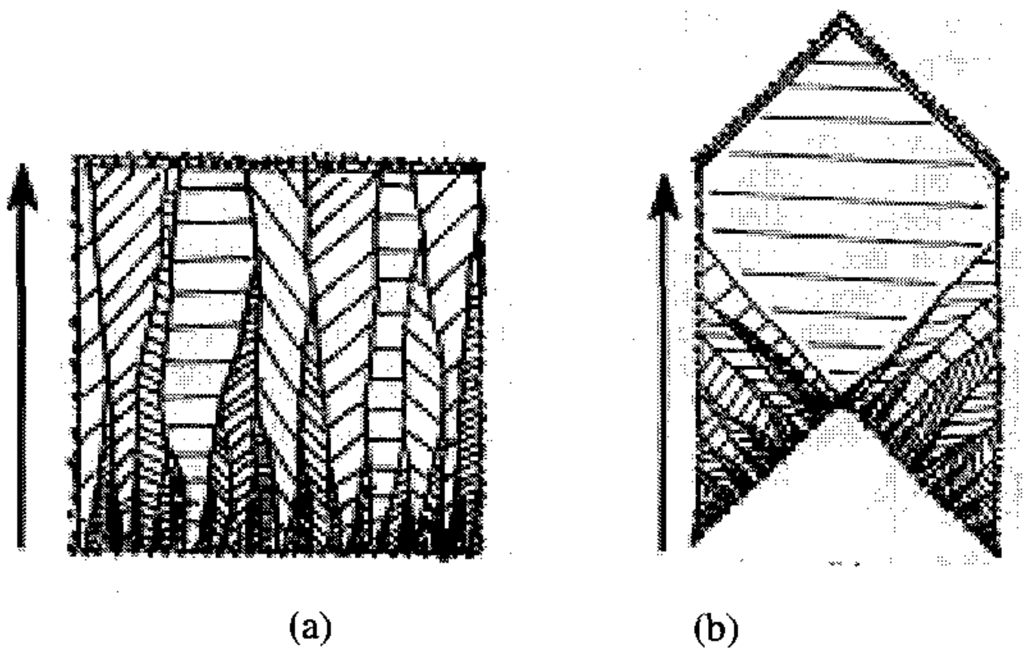

(a) (b)

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

Table 1. Lateral Growth ELA related factors contributing to 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

The factors contributing to 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 the lateral growth ELA related factors, contributing to the high quality and large-grain size of poly-Si are summarized in Table 1.

References

[1] J. S. Im, H. J. Kim and M. O. Thompson, Appl. Phys. Lett. **63**, 1969 (1993).
[2] H. J. Kim, Ph.D. Thesis, Columbia Univ. (1996).
[3] R.S. Sposili and J.S. Im, Appl.Phys. A **67**, 273 (1998)
[4] H.J.Kim and J.S. Im, MRS Symp. Proc. **397**, 401 (1996).
[5] C.H. Oh and M. Matsumura, AMLCD'99, 255 (1999).
[6] A. Hara and N. Sasaki, AMLCD'99, 275 (1999).
[7] L. Mariucci, R. Carluccio, A. Pecora, V. Foglietti, G. Fortunato, and D. D. Sella, AMLCD'99, 283 (1999).