High Performance of Crystallization for LPTS TFTs Using Solid Green Laser

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Abstract

We developed the laser annealing system using green laser of 261W(5kHz) and 75.5mJ/pulse(2kHz). We confirmed that this system makes it possible to form two kinds(large or uniformed grain) of poly-Si by changing its polarized directions. By using μ-crystal-Si as irradiated films, grain size uniformity is better than that using a-Si.

1. Introduction

Excimer laser annealing (ELA) is used for the manufacturing of low temperature poly-Si TFTs (LTPS) for liquid crystal displays and organic light emitting diode displays (OLED). However, it has issue of low process stability caused by narrow process window and instability of excimer laser. Its low process stability makes it to produce high quality poly-Si film making, especially for active matrix OLED. Therefore, in recent years the laser annealing process using the solid-state laser that is by nature stable in comparison with excimer laser is studied. [1,2,3]

Because of this situation, we have developed laser annealing system used the high power pulsed green laser that is completely developed as in-house laser. In this paper, we describe about the laser annealing system and polycrystallization using this system with changing the polarization direction and the irradiated films.

2.Outline of YAG laser annealing system

We developed high power solid green laser of maximum output 261W as light source of laser annealing system. The repetition rate is 5kHz, and energy per pulse is 52mJ/pulse. Figure 1 shows the dependence of output power and energy per pulse of this laser on repetition rate. As well known, energy per pulse is increased by repetition rate decreasing. When repetition rate is 2kHz, energy per pulse is maximum 75.5mJ/pulse.

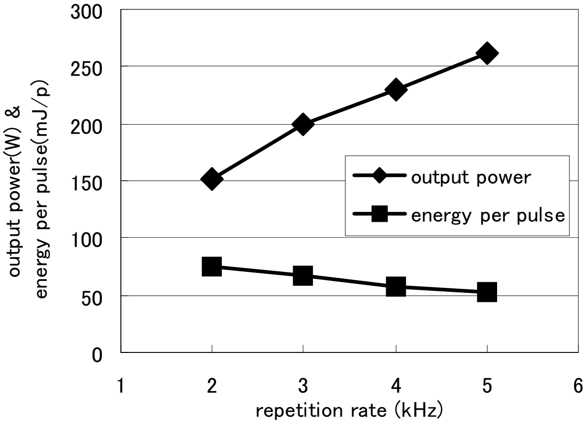


Fig.1. Dependence of output power and energy per pulse on repetition rate

Figure 2 shows the output power for 8 hours running. The output power stability is calculated at ±1.3%.

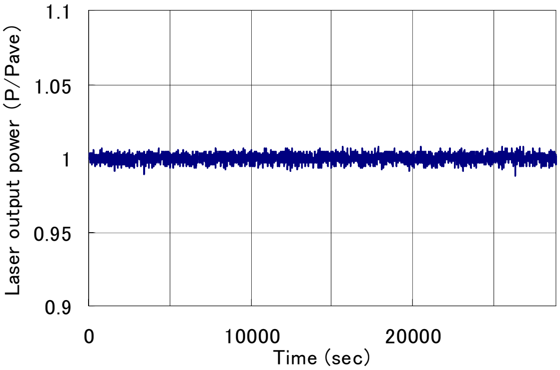
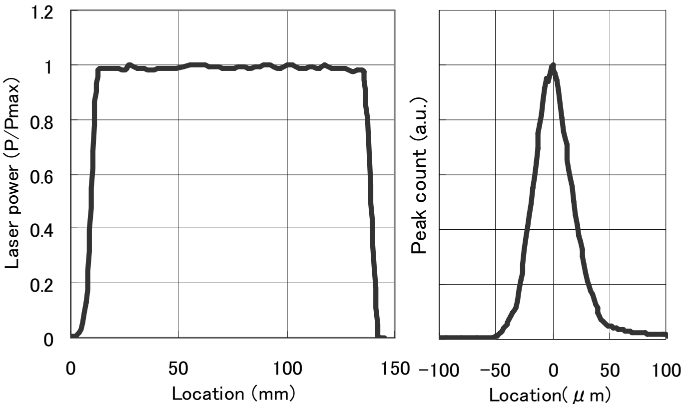


Fig.2. Laser output power for 8 hours running

Figure 3 shows the long axis and short axis beam profiles of YLS. The uniformity of long axis profile is ± 1.22% (multiple shots integration). And, the FWHM (full width half maximum) of short axis is 39.5μm. The energy density can be changed from 350 to 650mJ/cm^2 by laser power control attenuator.



(a)Long axis (b)Short

Fig.3. Long axis and short axis beam profiles of YLS

3. Polycrystallization

Influence of polarizing direction of irradiation beam on polycrystallization condition

In system on glass (SOG), the high-quality poly-Si films are necessary for circuit area TFTs. Several methods utilizing the lateral growth for enlarging grains of poly-Si film are proposed, for example, sequential lateral solidification(SLS) [4] and CW laser lateral crystallization(CLC) [5]. On the other hand, the high grain size uniformity in scanning direction and perpendicular direction is necessary for pixel area TFTs. However, the lateral growth grains are not equal in a scanning direction and a perpendicular direction. Therefore, grain size uniformity shows tendency to turn worse. This grain size nonuniformity is not suitable for manufacturing pixel area TFTs, because of limitation in designing the circuit arrangement.

It has been reported that the linearly polarized laser irradiation induces the periodic energy distribution on the surfaces of a-Si films. [6,7] Figure 4 shows a schematic diagram of linearly polarized irradiation beam. The direction of periodic energy distribution is parallel to the electric field vector. When p-polarized and s- polarized beam is irradiated, the periodic energy distribution is occurred along a scanning direction and perpendicular direction respectively.

By using this phenomenon, it can be expected that the occurrence of lateral growth is prevented and grain size uniformity is better. Then, we investigated the influence of polarizing directions of irradiation beams on polycrystallization condition.

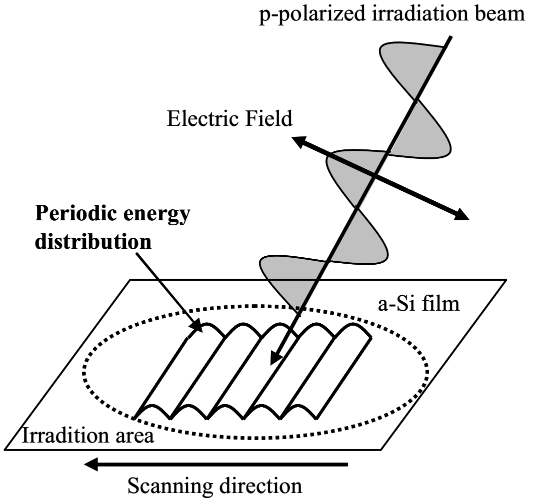
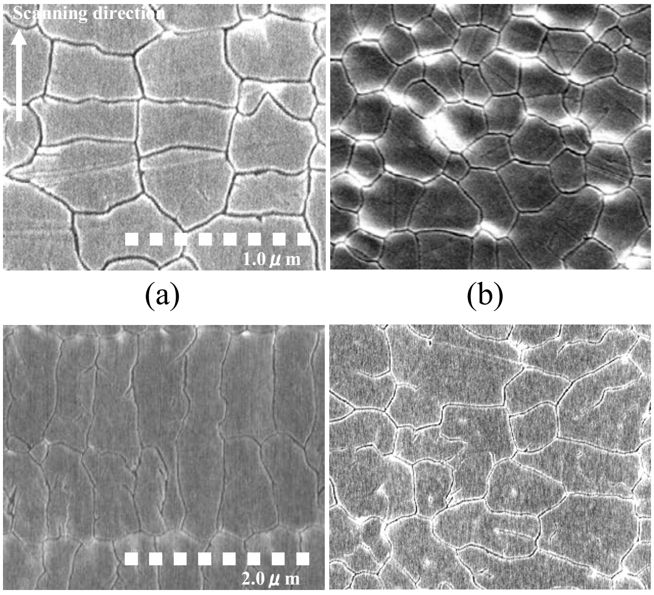


Fig.4. Schematic diagram of linearly polarized irradiation beam

Figure 5 (a)(b)(c)(d) shows SEM images of typical samples crystallized with s-polarized and p-polarized beams respectively. Magnification of the SEM images is 20K for (a) and (b), 10K for (c) and (d). At the sample crystallized with s-polarized beam, it can be



(a) (b)

(c) (d)

Fig.5. SEM images of samples crystallized with (a) s-polarized at 412mJ/cm2 (b) p-polarized at 412mJ/m2 (c) s-polarized at 485mJ/cm2 (d) p-polarized at 485mJ/cm2

seen that the lateral growth grains. The lateral grain growth is along a perpendicular direction at low energy density, and it is along a scanning direction at high energy density. This grain growth at low energy density is caused by periodic energy distribution, and that at high energy density is caused by the inherent energy slope of short axis profile. On the other hand, at the sample crystallized with p-polarized beam, the grains which grow lateral are not found and grain sizes are approximately equal in a scanning direction and a perpendicular direction at low and high energy density.

Influence of irradiated films on grain size uniformity

Next, we investigated the influence of irradiated films on grain size uniformity. Figure 6 shows the dependence of grain size uniformity (σ %) on polarized directions and irradiated films. Grain size uniformity (σ %) is standard deviation of grain sizes measured along scanning direction and perpendicular direction. We used image processing software to analyze grain size and grain uniformity from those SEM images (about 500 grains for one condition). Irradiated films were normal a-Si film(deposited by low pressure chemical vapor deposition) and μ-crystal Si film. The μ-crystal Si film was prepared using YLS irradiation at energy density 350mJ/cm2 and overlap ratio 33%. The grain size uniformity of sample crystallized with μ-crystal Si film improves more than 3% than that with a-Si film. It is considered that the nuclei condition of irradiated films influences the grain size uniformity.

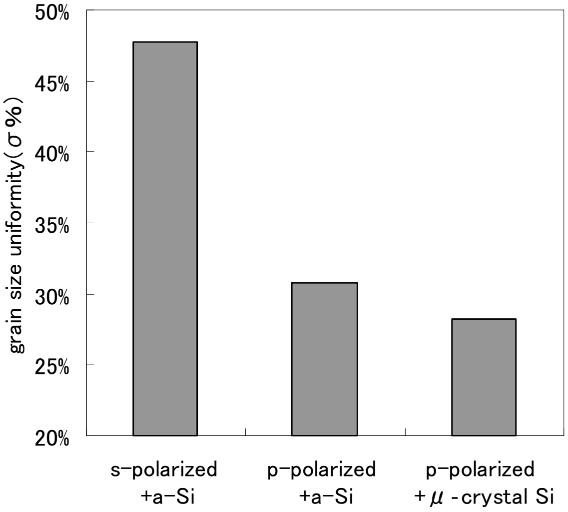


Fig.6. Dependence of grain size uniformity (σ %) on polarized directions and irradiated films

Dependence of grain size and its unifomity on laser energy density

From the above-mentioned result, we evaluated the average grain size and grain size uniformity of samples crystallized with μ-crystal Si film as irradiated film. Figure 7 shows the dependence of average grain size of samples crystallized with YLS(s, p-polarized) and ELA [8] on laser energy density. The average grain size of YLS samples is increased gradually by increasing energy density, whereas that of ELA samples is very sensitive to energy density change. It can be said that energy margin of the polycrystallization with YLS is very wide. It is considered that the difference of absorbance of a-Si for excimer laser and that for green laser influences this energy margin.

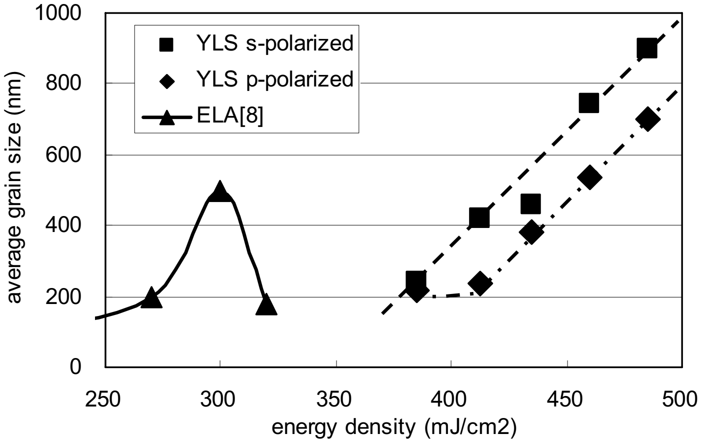


Fig.7. Dependence of the average grain size of YLS and ELA samples on energy density

Figure 8 shows the dependence of grain size uniformity (σ %) on laser energy density for each polarization direction. As mentioned above, grains crystallized with p-polarized beam grow isotropically in any direction. So, grain size uniformity estimated from SEM images can be less than 30% at the best energy condition. On the other hand, at the sample crystallized with s-polarized beam, if energy density changes, grain size uniformity should not be less than 35%. At higher energy density, crystallized with p-polarized beam, some grains can not grow sufficiently like s-polarized beam, grain size uniformity gets worse than that irradiated with s-polarized beam.

From the mentioned results, using p-polarized beam and μ-crystal Si film as irradiated film, poly-Si films with high grain size uniformity can be formed. And, using s- polarized beam, high-quality poly-Si films with large grains can be formed. We confirmed that YLS made it possible to form two kinds of poly-Si films suitable for SOG panel.

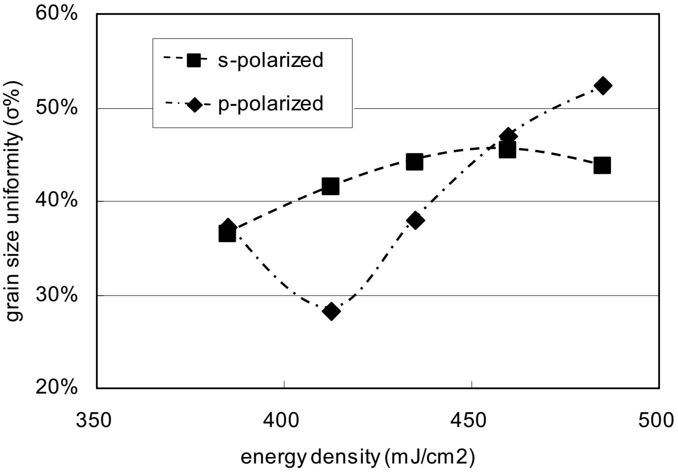


Fig.8. Dependence of grain size uniformity of samples crystallized with different polarized beam on energy density

4. Demo Macine

We have released the new YLS demo machine that is available for user's sample test since April 2007. YLS demo machine includes high power green laser described above, beam delivery optical system equipped with auto focus system for uniform processing on whole area of the plate, nitrogen purge unit that can sufficiently reduce oxygen density at the irradiation area without chamber system, and X-Y stage that can make high accuracy positioning and achieve high speed stability. It can make irradiation up to 7392 plate and offer two kinds of beam polarization direction and beam short axis profile described above.

We are now advancing the next development of demo machine for 300W laser, and that will be released around the end of this year.

5. Summary

We developed the laser annealing system used the pulsed green laser. The maximum output power of solid green laser is 261W at repetition rate 5kHz, and the maximum energy per pulse is 75.5mJ/pulse at repetition rate 2kHz.

The energy margin of polycrystallization with YAG laser is much wider than that with excimer laser. Then, it is found that the process stability of YLS is much higher than that of ELA.

We confirmed that large grains were formed by using s-polarized beams, and that small grains with good uniformity were formed by using p-polarized beams and μ-crystal Si film as irradiated film. This technique is suitable for manufacturing SOG.

5. References

1.A.Hara, et.al., :Dig.Tech.Papers AM-LCD'02,p227 (2002)
2.M.Tai, et.al., :Dig.Tech.Papers AM-LCD'02,p231 (2002)
3.S.Sakuragi, et.al., : Dig.Tech.Papers IDW'05,p965 (2005)
4. J.S.Im, et.al., MRS Bulletin March/April , 39(1996)
5. F.Takeuchi, et.al., :Proc.of IDMC'02,73(2002)
6. S.Horita, et.al., Appl.Phys.Lett. **78**,2250(2001)
7. Y.Nakata, et.al. :Dig.Tech.Papers AM-LCD'02, p141,2002
8.T.Voutsas,M.Marmorstein and R.Solanki, J.Electrochemical Soc. 146(9) p3500(1999)