17-4: New Technology for Creation of LTPS with Excimer Laser Annealing

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Abstract

We report on progress in developing high-power excimer lasers as well as UV-optics for creating low-temperature poly silicon (LTPS). A new high-power excimer laser offers 315 Watts with high pulse to pulse energy stability. Larger substrates can now be processed in better quality with either the SLS process or the new optics for line beam excimer laser annealing.

1. Introduction

Middle and small size flat panel displays (FPD) are under a constant challenge to provide higher resolution for the increasing performance demands of mobile devices such as QVGA TFT-LCD for mobile phones and digital cameras. A technology which is capable to support the market requirements is low-temperature polycrystalline silicon (LTPS). LTPS is the base for high performance thin film transistors (TFT) for active matrix liquid crystal displays (AM-LCD) as well as organic light emitting diode (OLED) displays.

The established process for manufacturing of LTPS is excimer laser annealing (ELA) with line beam (LB) technology [4]. A new ELA technology which is now available for production is sequential lateral solidification (SLS) [5]. Both technologies require high performance industrial excimer lasers and UV-optics. This paper introduces the LAMBDA STEEL 2000 excimer laser, the CrystaLas UV-optics, and the entire production system FLX™ (Flexible Lateral X(c)rystallization) made by The Japan Steel Works (JSW) incorporating the laser as well as the UV-optics.

2. Improved High Power Excimer Laser

The development in excimer laser technology for creation of poly silicon (p-Si) has lead to the availability of extremely stable, high power XeCl lasers. The focus of development was on

- increasing the pulse energy
- improving the energy stability
- and extent the laser gas as well as component lifetime.

Whereas the early lasers for ELA delivered 670 mJ at 300 Hz with an energy stability of 3% (sigma), the current model, the LAMBDA STEEL 2000, delivers 1050 mJ at 300 Hz with an energy stability of typical 1.1% (sigma) over more than 55 million pulses (52 hours) with one single gas fill as shown in Figure 1. Figure 2 shows the result of the component and laser gas lifetime extension over the last years: the cost of operation (CoO) could be reduced from 1997 to 2003 by 66% nevertheless the laser power was increased during this time.

	LAMBDA STEEL 2000
Wavelength	308 nm
Max. stabilized energy	1050 mJ
Max. stabilized power	315 W
Max. repetition rate	300 Hz
Pulse energy deviation	Sigma ≤ 1.8%
Beam size (FWHM, v x h)	(37 x 13) mm^2
Dynamic gas lifetime (at max. stabilized energy)	> 40 mio pulses
Polarization	random

Table 1: Specification of the high power industrial excimer laser LAMBDA STEEL 2000.

Furthermore, the LAMBDA STEEL 2000 features

- maintenance free all solid state high voltage switch (Pulser or ASSP) instead of thyratron
- enhanced gas purification for doubled gas lifetime of more than 40 million laser pulses
- improved pre-ionization for better energy stability.

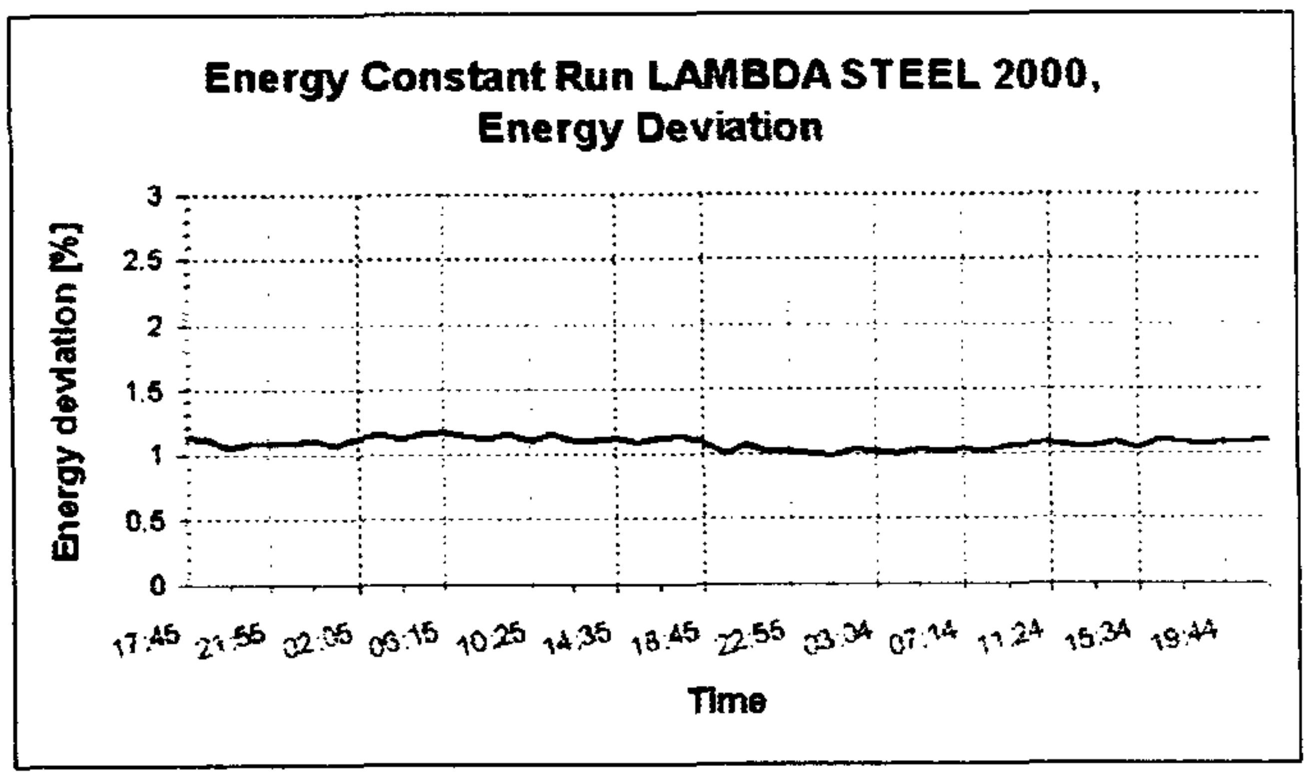

Figure 1: Energy stability of LAMBDA STEEL 2000 over a 52 hours non-stop run at 1050 mJ / 300 Hz. Sigma average 1.1%.

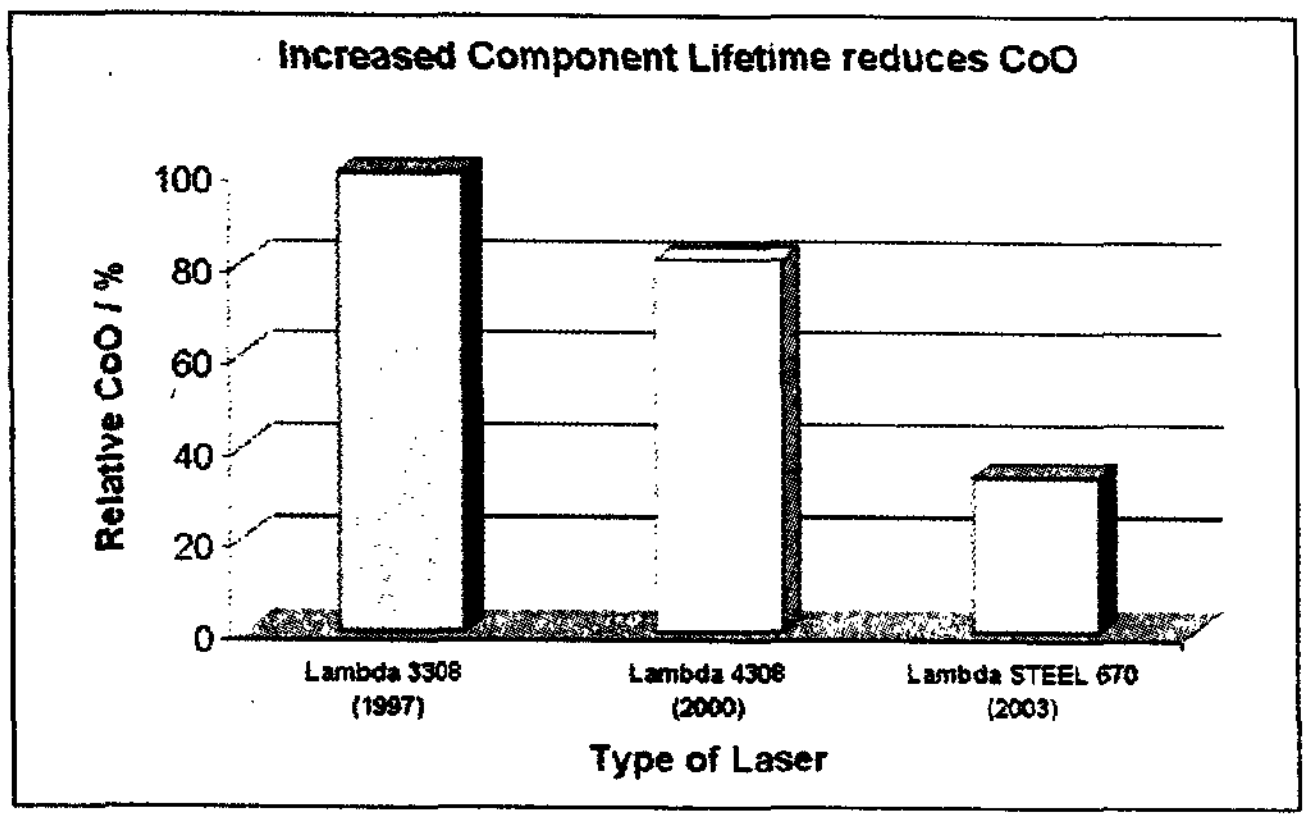

Figure 2: Increased power (L3308: 150W to L4308/LS670: 200W, all at 308 nm) and nevertheless reduction of cost of operation: it has been reduced for the LAMBDA STEEL 670 by 66% compared to its early predecessor, LAMBDA 3308 (source: Lambda Physik).

3. SLS

Sequential lateral solidification (SLS) enables generation of near-single-crystal silicon films for the fabrication of LTPS for FPD TFT. systems-on-a-substrate such as system-on-insulator or system-on-glass [5][6].

The key of this technology is to control the size of melted film zones to a micrometer level using a high resolution mask imaging technique. Such patterning yields melted zones some microns wide with well defined edges and the crystals grow laterally from the solid edges. The principle set up of the CrystaLas SLS optics. developed by MicroLas Laser Systems (Germany) is shown in Figure 3.

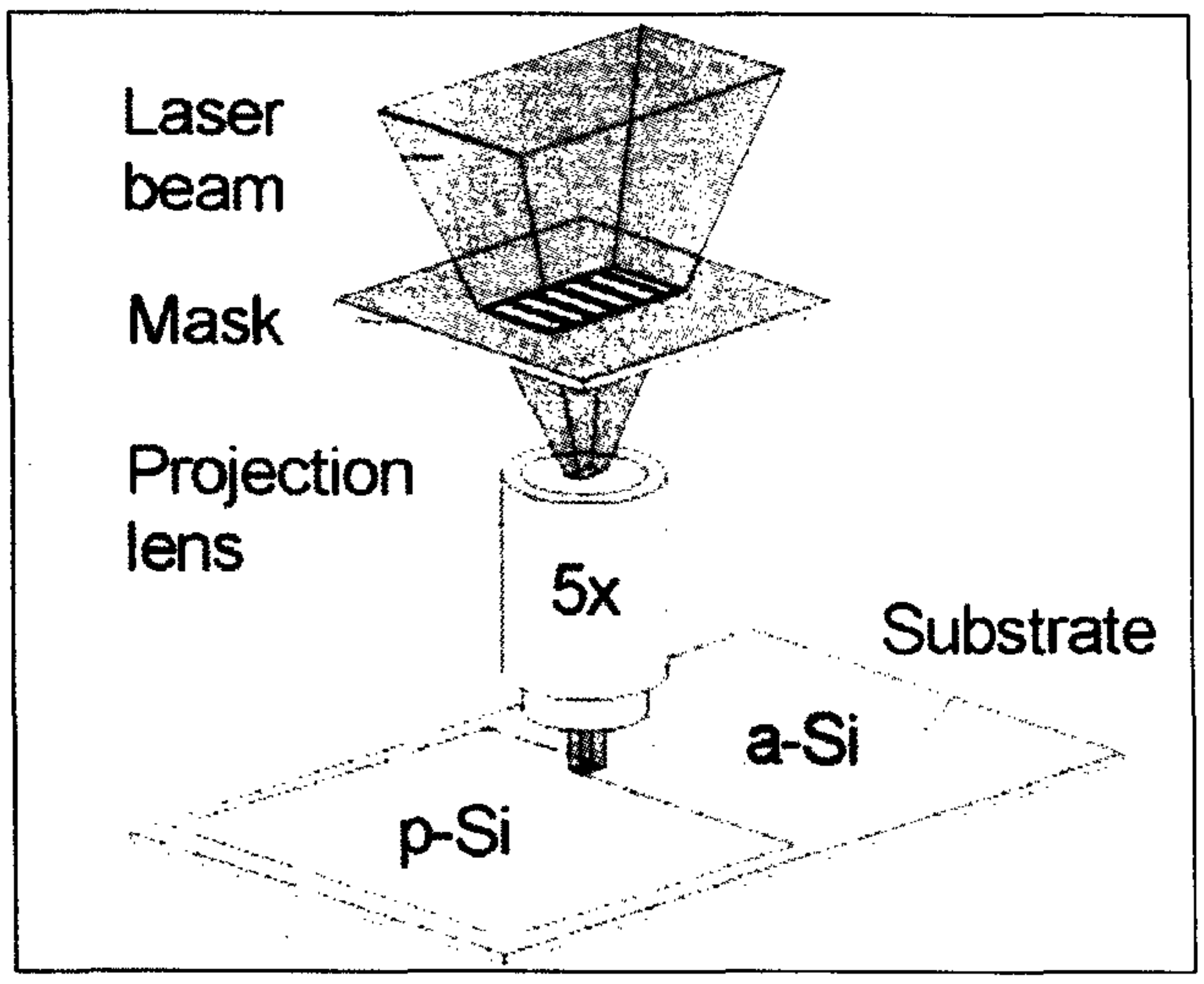

Figure 3: The principle of CrystaLas SLS optics: the homogenized laser beam images the pattern of a mask through a projection lens to the substrate. The pattern is stepped over the panel.

Different from the line beam ELA process, the panel is scanned for SLS several times irradiating each location only twice. Figure 4 shows the principle of the common two shot process: a mask pattern of some micron wide lines and spaces is stepped over the panel and creates p-Si lines (Figure 5, left picture). The 2nd irradiation crystallizes the a-Si lines between the p-Si lines whereas the pattern overlaps with latter part (Figure 5, right picture).

The advantages of SLS over line beam ELA are

- larger crystal size combined with higher electron mobility,
- higher throughput (1.5 to 1.8 faster than line beam, see Table 2)
- potentially no limitation of panel size
- wider process window in regard to energy because Si must be melted completely

The entire SLS manufacturing system JSW FLX™ is shown in Figure 6.

	Throughput / sheet hr⁻¹ Glass size / mm			
	370 x 470	600 x 720	730 x 920	1150 x 1250
	2003		2004	2005
FLX™ System (SLS 2 shots) Beam size 15 x 2.0mm	29.2	18.8	13.9	
25 x 1.5mm			17.7	9.9
Line Beam method Beam size 370 x 0.4mm	22.0	10.1	9.7	
465 x 0.4mm			11.8	5.6

Table 2: Throughput of SLS and Line Beam method with glass substrate handling time included (source: The Japan Steel Works [1])

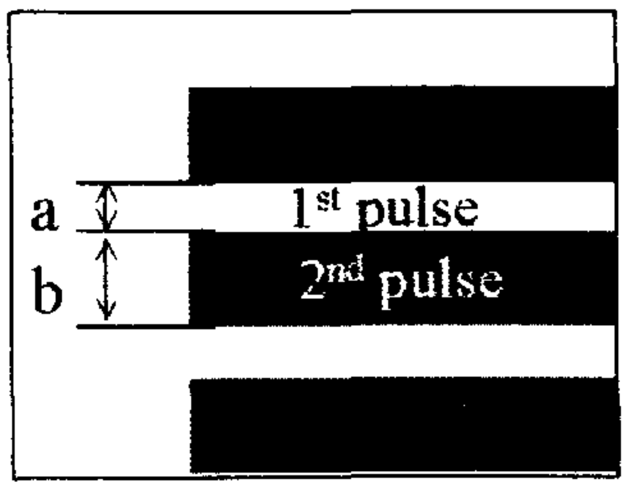

Figure 4: Principle of SLS 2 shot process: 2nd pulse pattern (black) overlaps with 1st pulse crystallized part (gray) after relocation whereas maskpattern space width a < line width b [1].

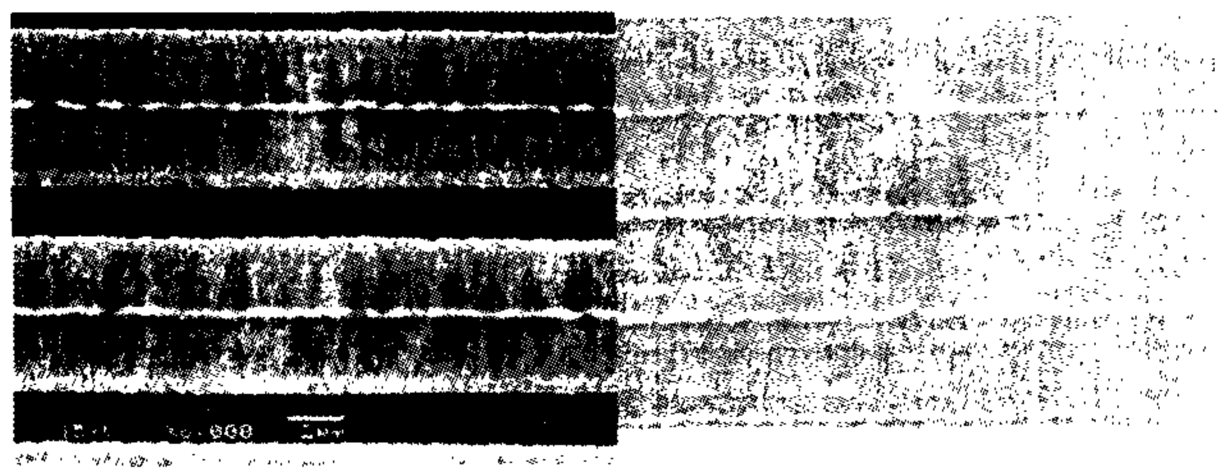

Figure 5: SLS 2 shot process on 50 nm thick a-Si layer. The left picture shows the crystallization after the 1st shot, the right picture the final crystallization after the

2nd shot. Beam edge of 2nd shot should overlap with 1st shot [1].

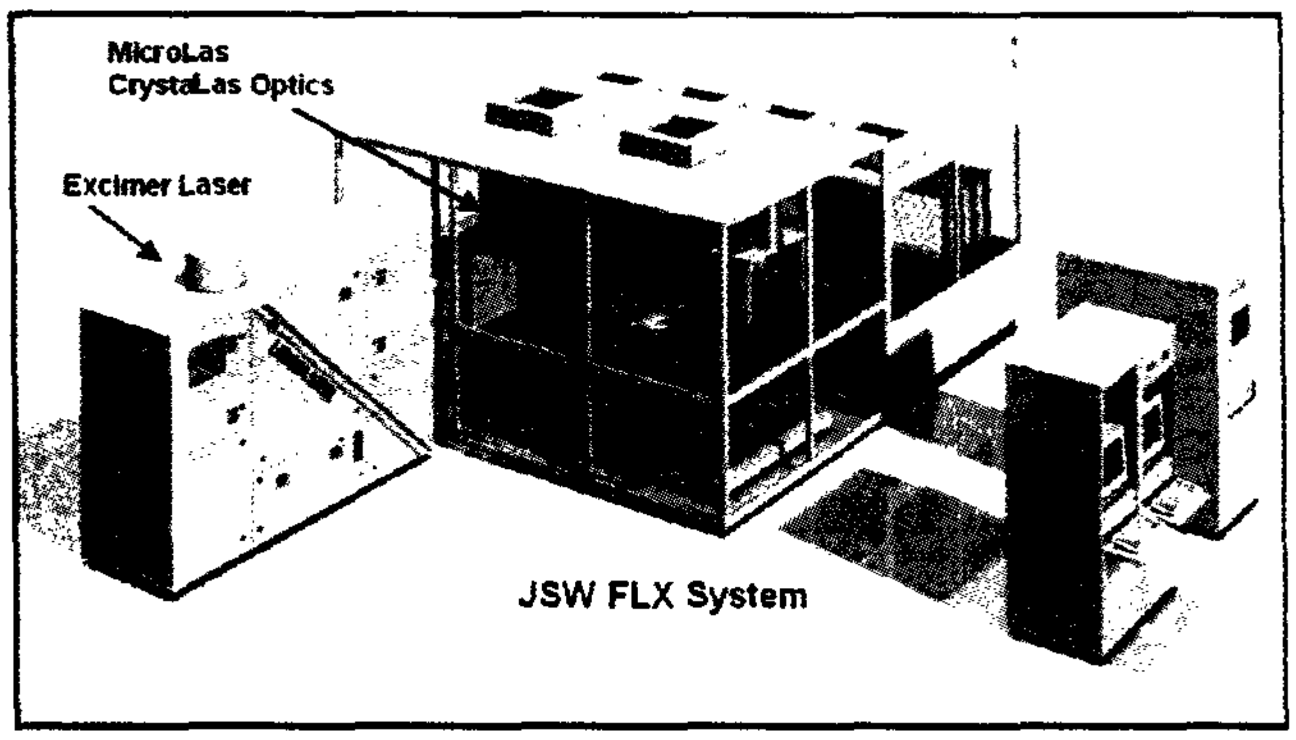

Figure 6: The JSW FLX™ system incorporating the LAMBDA STEEL 2000 and the CrystaLas optics (source: The Japan Steel Works).

Recent progress of SLS system development made it possible to use 30 mm FOV lenses for projection of a big image field that guarantees high throughput. Together with the use of a pulse duration extender with flexible extension rates and high transmission, a focus monitoring system and a technique to cope with the challenge of high laser power imaging the SLS system is ready for use in mass production.

4. Line Beam ELA

Line Beam ELA is nowadays widely used for creation of LTPS for LCD TFT, hence it is the established production process [2][3]. Typical length used for production are 200 to 365 mm, whereas the beam width is 400 microns. The most current optics system developed by MicroLas Laser Systems (Germany) enables a length of 465 mm which has only become feasible with the LAMBDA STEEL 2000 high power laser.
The resulting very homogenous p-Si makes line beam ELA very suitable for the demanding OLED TFT.

5. Conclusion

The excimer laser annealing systems developed by Lambda Physik, MicroLas, and the Japan Steel Works are established for creation of LTPS at major display manufacturers. The systems have been proved to fulfill the most stringent design and manufacturing quality standards, to be reliable, user-friendly and economic for LTPS LCD manufacturing. Due to the remarkable progress in display technology over the last few years a continuous improvement and highly sophisticated development of the total annealing setup is required. With the aim of fulfilling today's and future demands, Lambda Physik and MicroLas are continuously improving the laser and optics for that process. The recent result of investigations is a high power excimer laser and a line beam optics system for wide beam width. This annealing system opens the door to achieve high quality and throughput for the next generation of large AM-LCDs and OLED displays.
In addition, a new recrystallization technology, the sequential lateral solidification, has now become available for use on an industrial scale.

6. References

[1] J. Shida, "JSW FLX Series SLS Method ELA System", presentation at The Display Search 2004 Taiwan FPD International Conference, (2004)

[2] D. Basting et al., "Excimer Laser Technology: laser sources, optics, systems and applications", Lambda Physik AG, pp 125 – 134, (2001)

[3] I.-J. Chung et al: "Manufacturing Issues for Low Cost TFT-LCD", IDMC 2002 Proceedings, pp 415 – 419, (2002)

[4] J. Shida et al., "Crystallization of a-Si Films by Excimer Laser Annealing Method", Japan Steel Works Technical Review, (1997)

[5] James S. Im: „Sequential Lateral Solidification", Phys. Stat. Sol. A 166, 1998, pp. 603

[6] H.-J. Kahlert: "Creating Crystals", oe magazine, (11-2001)