New High Stability Excimer Laser for LTPS Manufacturing

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Abstract

LTPS TFT backplanes for AM OLED displays have advantages in regard to reliability and performance compared to TFT backplanes based on amorphous silicon. However, the requirements for homogeneous laser crystallization during LTPS process are much higher than for LCD backplanes. Most important is the energy stability of the laser source. In this paper we describe a new excimer laser which meets the requirements of LTPS manufacturing process with high homogeneity.

1. Objectives and Background

Active matrix Organic Light Emitting Displays (AM OLED) are self emissive devices, no backlight and no color filters are necessary. The light is emitted by applying a current to a colored organic or polymer material. Hence, OLED are current driven devices whereas the LCD technology is voltage driven. A uniform and stable threshold voltage (Vth) distribution of the thin film transistors (TFT) on the active matrix (AM) panel is essential for a good visual impression to the human eye.

Therefore, the lifetime of an AM OLED is not only determined by the light emitting material but also by the reliability of the active matrix. Low temperature polycrystalline silicon (LTPS) backplanes have shown better long term stability compared to amorphous silicon (a-Si) backplanes [1].

The required high TFT Vth uniformity leads to the demand for LTPS panels with a higher degree of crystal homogeneity compared to a common LCD LTPS backplane [1]. Shifts in Vth can cause mura defects or differential aging in OLED devices. Due to the narrow process window of laser annealing a laser source with high energy stability is very beneficial for the crystallization process in order to reduce the mura effect [2]. Therefore, the development of high power UV laser sources for excimer laser crystallization (ELC) has to focus on best possible peak-to-peak energy stability.

2. Results

We have developed a XeCl (308 nm) excimer laser with high degree of pulse energy stability at 1050 mJ which meets the requirements for manufacturing of LTPS suitable for AM OLED devices.

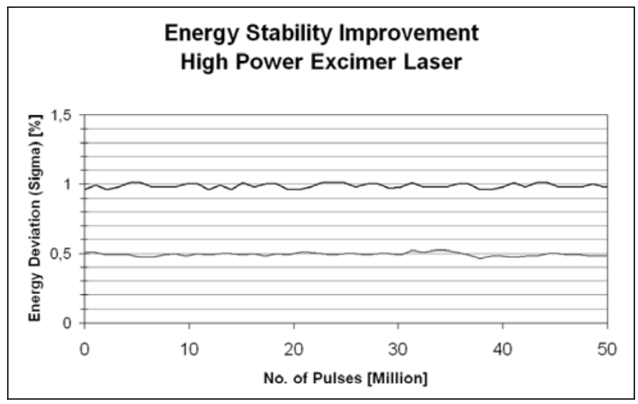

Figure 1: Lower line: energy stability of the new LAMBDA SX 315C excimer laser at 300 Hz repetition rate and 315 watts of output power. The good energy stability is maintained at 0.5% (sigma) over 50 million pulses. Upper line: typical energy stability of former 315 Watts lasers is about 0.9% (sigma).

The laser achieves an almost twofold better energy stability compared to former laser sources used for line beam excimer laser annealing (ELA).

Achieving exceptional pulse stability and pulse energy control have been a key focus of our development efforts. Although the ELA process utilizes overlapping pulses, it is still the energy of the final pulse that primarily determines the crystal structure at that location. Thus, every single laser pulse must meet the exact energy target value.

Several design improvements have been implemented in order to bring peak-to-peak energy fluctuations to below 5% (+/- 3 Sigma). Figure 1: shows the measured energy deviation (Sigma) of the LAMBDA SX 315C excimer laser operating with XeCl in burst trigger mode, at 300 Hz repetition rate and a stabilized energy of 1050 mJ. In this non-stop run of over 50 million laser pulses (corresponds to more than 2 days non-stop operation), the energy fluctuation is typical 0.5% (Sigma) which translates into a peak-to-peak energy fluctuation of typical 3.27% for +/- 3 Sigma (99.7%) of all pulses.

This highly stable laser performance was achieved by improvement of the laser discharge unit and the metal-ceramic NovaTube laser chamber. Furthermore, an integrated energy feedback system has been developed to maximize the benefit of this very high laser stability over continuous (24-hour, 7-day) operation. By increasing the data rate and the measurement resolution in the energy feedback-loop it has been possible to improve detection of individual pulse energies. This, in turn, allows the control electronics to apply miniature corrections to the high voltage for the next laser pulse in order to minimize deviations from the nominal set point energy.

Figure 2: LAMBDA SX 315C high power excimer laser.

This high speed energy feedback system, which eliminates drift in the laser output, also enables feed-forward correction of the laser's high voltage. This provides for stable output in the discontinuous burst mode operation typically utilized for this application. However, in burst operation, the leading pulse of each burst train in most pulsed lasers has a systematic deviation from the set point. To correct for this, Coherent developed its proprietary PowerLok™ technology, which brings every pulse of a burst train to the desired energy level. PowerLok employs a self-learning algorithm and a look-up table to smooth cycling bursts by feed-forward control of the operating voltage. This delivers a substantial improvement in energy stability, and is critical to successful ELA processing for the demanding OLED application. Higher pulse to pulse stability also makes it possible to reduce pulse overlap (because dosage is stable, even with just a few pulses), thus resulting in higher system throughput.

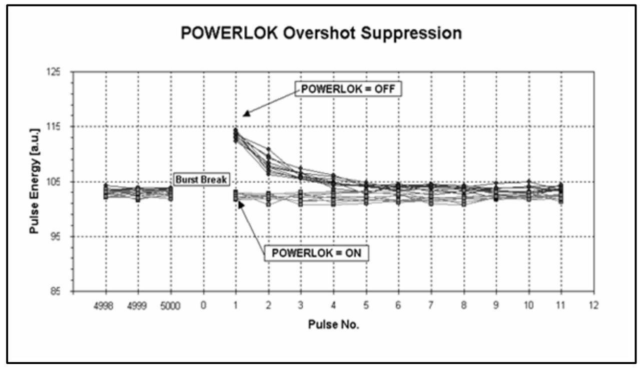

Figure 3: Burst mode operation with PowerLok switch on and off: the algorithm brings the leading pulses of a burst train to the desired energy level

Other practical improvements in the laser's design have also been implemented in order to reduce total cost-of-ownership. In particular, component lifetimes have been extended through enhanced predictive maintenance capabilities. For example, laser performance can be controlled online with the advanced e-Diagnostics software tools.

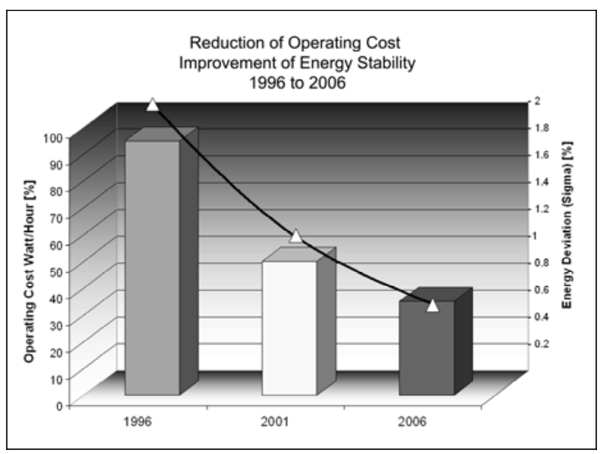

Figure 4: Progress in high power excimer laser performance and reduction of operation costs over the last decade. The LSX 315C (black bar) reduces significantly running costs and offers much better energy stability.

2.2 Sequential Lateral Solidification (SLS)

Over the past few years, another approach called Sequential Lateral Solidification (SLS) has emerged as an alternative to ELA [3],[4]. SLS is designed to grow the grains (crystals) in a lateral direction rather than the vertical direction that is characteristic of ELA.

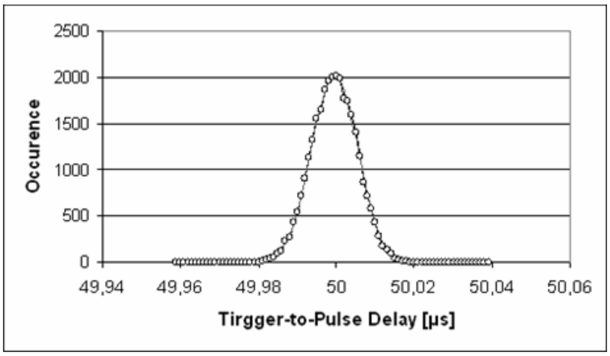

Figure 5: Delay-stability of LAMBDA SX excimer laser using active delay stabilization called TimeLok.

In actual use, a large glass panel is continuously scanned and the timing of the laser pulses is synchronized with this movement. Since proper crystallization depends upon the spatial accuracy of the exposures, the trigger-to-light delay of the laser must be stable. This is achieved in the Coherent laser by utilizing our proprietary TimeLok™ technology. This involves active stabilization of the time delay between an electronic trigger pulse and the laser pulse. This provides “pulse on demand” which is useful for high speed sequential lateral solidification (SLS) processing where the stepping of the panel and the pulsing of the laser need to be closely synchronized. It is an advantage in excimer laser annealing systems such as those produced by Japan Steel Works (JSW), which utilize external triggering of the laser.

This feature, which provides active control of the delay, is now standard for the LAMBDA SX 315C excimer laser. A typical result of 5 ns (Sigma) delay stability is shown in Figure 5. The LAMBDA SX 315C laser is packaged with the same form, fit and function as the well-established Lambda STEEL. It fits to the Coherent MicroLas LineBeam and SLS optical systems.

3. Pulse Energy versus Pulse Repetition Rate

A key process parameter in regard to production throughput is the average laser power (Watts). With pulsed lasers such as excimers, there are two ways to increase laser power: increase the energy per pulse or increase the pulse repetition rate. There has recently been some debate in this area regarding possible use of high pulse rate lasers for LTPS. Namely, can a laser optimized for a high repetition rate application such as microlithography be used for LTPS, an entirely different application. These microlithography lasers deliver pulse rates as high as thousands of Hz, but with very small pulse energies: less than 200mJ. In principal, these lasers can be used for LTPS annealing, but we believe the best approach is to use a high pulse energy laser specifically developed to meet the needs of LTPS. Moreover, this high-energy approach has been widely accepted in conjunction with ELA and 2-shot SLS, the only mass production methods currently in use for real-world consumer products.

The use of microlithography-type lasers may lead to several practical limitations compared to the other well established methods. First a conventional one-tube high repetition rate excimer laser is limited to relatively low power levels. Instead, the laser must be built as a two-stage MOPA device with an oscillator and amplifier tube. Since the laser tube is the main consumable with excimer lasers, this two-tube approach automatically raises the direct cost and indirect (downtime) service costs associated with practical LTPS.

Proponents of low pulse energy lasers have argued that the tubes have a longer lifetime because the low pulse energy is less stressful on the components. This has been shown to be a very misleading argument because the lifetime of an excimer laser is defined by the total number of pulses. When this is translated into total number of hours (and total number of panels), the lifetime between the two laser types is comparable. But due to the higher repetition rates, MOPA lasers accumulate up to 20 times more pulses per hour than high pulse energy lasers (Figure 6). So the two MOPA tubes must be replaced roughly six times more often than the single tube in a LTPS laser.

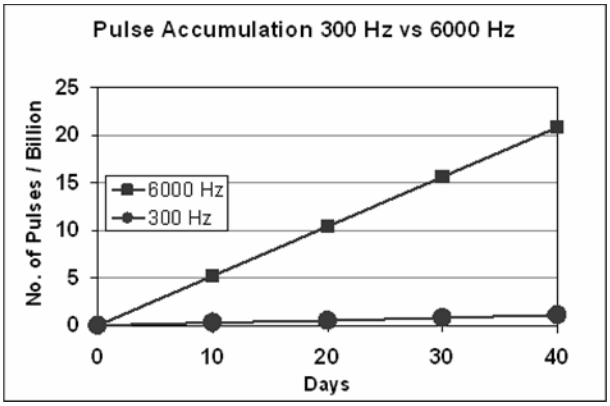

Figure 6: Pulse lifetime translated in to days: high repetition rate lasers accumulate much more pulses compared to high power single tube lasers.

4. Conclusion

The excimer laser is currently the best choice for high throughput LTPS annealing applications. It is well established as an industrial workhorse, demonstrating the output, reliability and cost of ownership characteristics required for practical use in this application. Specifically, the use of optimized design beam delivery systems, combined with the high absorption of a-Si at the 308 nm UV wavelength, results in high overall efficiency and a low operating costs. The ELA process has been proven to yield high uniformity poly-Si films, providing a straightforward migration path for TFT-based products. The 2-shot SLS process provides higher electron mobility than ELA, and also has the capability for local control of crystallization. Overall, the quality, throughput and cost demands of the flat panel display industry are satisfied by this inherently high efficiency.

Tests with the new excimer laser combined with 465 mm LineBeam optics on different substrates have shown the benefit of the high energy stability in regard to better LTPS homogeneity. The laser is designed for LTPS mass production and fits to line beam ELA and SLS systems such as made by JSW.

5. References

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