Laserod News

LASER PATTERNING INDIUM TIN OXIDE FOR FLAT PANEL DISPLAYS

by

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MASKLESS PATTERN GENERATION
FOR CUSTOMER SAMPLES AND PROTOTYPING

This paper describes our experience in laser patterning indium tin oxide (ITO) coated glass and plastic plates as typically used in flat panel displays (FPD).

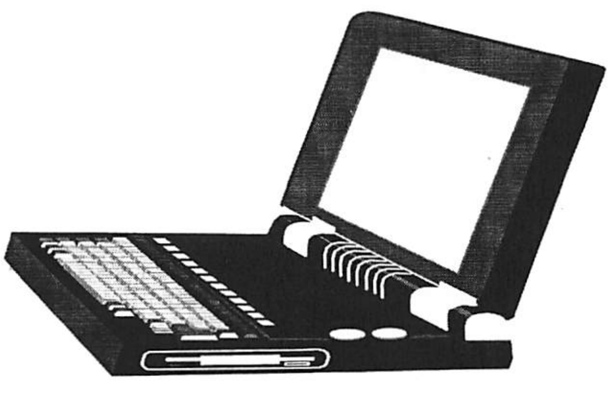

FIGURE 1: ITO coatings on a display can be laser patterned.

ITO is a thin optical coating and functions as a transparent conductor. It is transparent to allow viewing through the FPD. It is electrically conductive so as to serve as "wires" for the grid pattern and as electrodes. Patterning ITO is a process step in the fabrication of most FPDs (1)

The conventional method of patterning is chemical etching, a wet chemistry process. Conventional patterning consists of etching to remove ITO not protected by the mask. By contrast the laser method is a dry process performed in ambient atmosphere. Additionally, laser pattern generation is maskless. Bypassing the photomask step saves both time and money. Laser pattern generation is therefore useful for prototyping, quick turnaround jobs and customer samples. It can be price competitive with chemical etching in low line density plate generation. The ability to laser generate large area patterns greater than 14" x 14" exists.

Yet another laser attribute is patterning down to half mil lines and spaces. Laser linewidths to 5 microns have been achieved but this presents a problem for large travel applications due to decreased depth of focus. The typical range of our laser cuts is 0.5-3 mils. Patterning involves generating grid lines, fanouts, fiducial marks, borders and alignment aids. DXF file downloads from diskette or e-mail are readily accomplished. By way of comparison—the term "laser scribing" usually refers to rectilinear X-Y patterns only.

Basically, laser scribing of ITO is drilling a series of overlapping holes in the thin film. Drilling proceeds at a rate of one hole per laser pulse. The holes are then overlapped at linear speeds up to 10 inches per second. ITO is an interesting material to laser scribe. In all other materials the thicker the material, the more difficult it is to cut by laser. With ITO the thinner, the more difficult to cut. This follows from the inverse relationship between thickness and transmission, viz. the thinner the coating the higher the transmission. This means the laser beam is transmitted and does not cut easily.

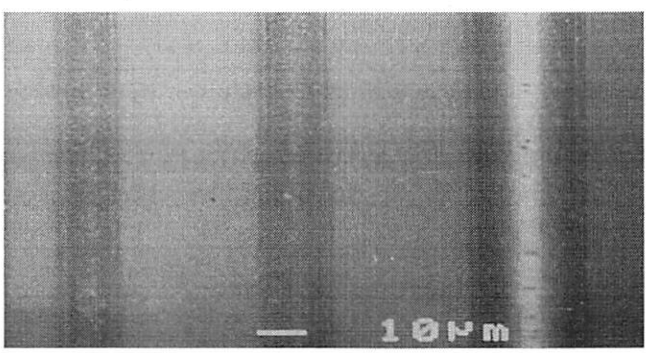

Figure 2. SEM of ITO scribed by Q-switched Green YAG in half mil lines. Magnification 50X.

The first production ITO patterning by laser, of which we are aware, began in 1985(3). The engineer-in-charge, Peter Barbee, says of that experience, "We questioned whether it would work or not and if it did, would it work in production?" The answer to both questions was yes. For many years the green YAG laser produced transparent membrane switches by patterning ITO on plastic substrates. This production laser was also capable of patterning chrome and gold films, also on plastic substrates. Currently, as a laser job shop, we pattern ITO coated glass and plastic.

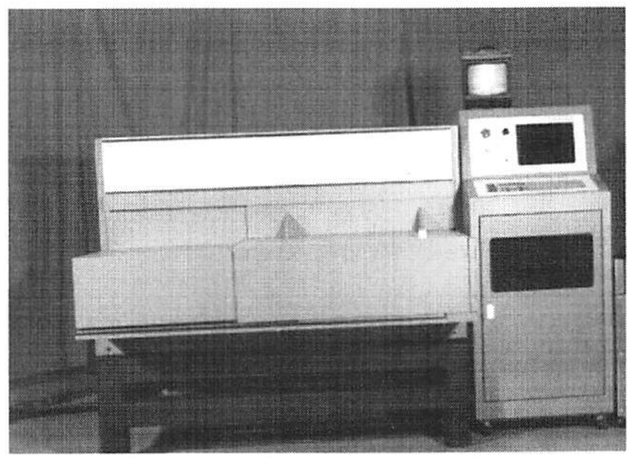

Figure 3. Q-switched YAG laser system for patterning ITO.

Q-Switched YAG

The equipment used for this work is a high power arc lamp pumped Q-switched YAG laser equipped with a computer controlled X-Y linear translation stage and beam delivery optics. "Arc lamp pumped" refers to the input energy source for the laser. It is an arc, not a flash, lamp. Arc lamps are familiar as football stadium illuminators. Since these arc lamps are continuously on, not flashing, the scientific description is cw pumped. (The abbreviation "cw" stands for continuous wave). A synonym for pump is input. Another scientific descriptor therefore is optically pumped solid state laser. The (solid) laser crystal is made of ionized neodymium doped yttrium aluminum garnet (Nd:YAG). Only about two percent of the laser crystal is Nd, the rest is YAG. The acousto-optic Q-switch (AOQ) is capable of rep rates to 20,000 and very good pulse-to-pulse stability has a direct relationship to throughput due to the amount of overlap required to cover any instability.

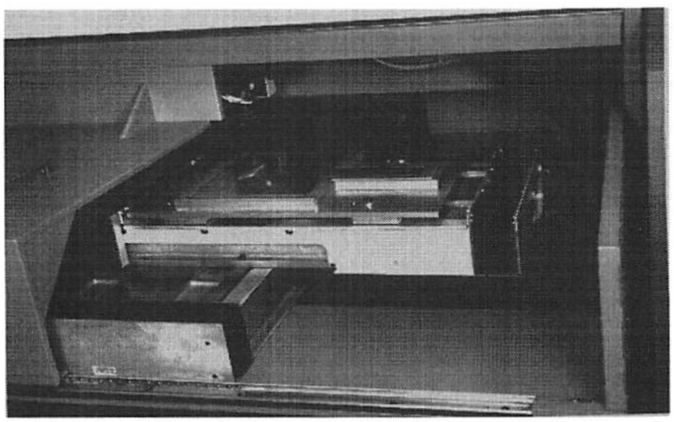

Figure 4. Laser focusing lens and X-Y stage for positioning under a stationary laser beam.

Diode Pumped YAG

Pulsed, diode laser pumped and diode pumped are some other laser types. Although this work was performed using arc lamp pumped Nd:YAG, another candidate is diode pumped Nd:YAG. In the future when prices of diode pumped YAG become competitive, it will undoubtedly enjoy usage.

PULSED YAG, CO_2 and EXCIMER LASERS

When pumped by a flash lamp, the laser is called "pulsed". Pulsed YAG lasers are used for welding and thick metal cutting. They typically are limited to pulse rates of hundreds per second. By contrast the cw pumped YAG, when Q-switched, produces upwards of 25,000 pulses per second. Processing speed is critical to laser patterning. Thus, pulsed YAG as a candidate is ruled out. Other types of industrial lasers such as the two gas lasers, CO_2 and excimer, are also ruled out. The former is a powerful source of far infrared laser energy at 10.6 microns wavelength while the latter is an ultraviolet source under 0.308 micron wavelength. The far infrared source's wavelength is too large to focus to the small spots required for ITO. The other gas laser, the excimer, has a limited rep rate and suffers optical difficulties with focusing ultraviolet.

Laser Scribing

When the almost parallel laser beam is run through a lens to focus to a spot of about one thousandths of an inch on the ITO film, the Q-switched giant pule vaporizes the thin coating of ITO in a round circle or hole of diameter one mil. Overlapping these spots by, say fifty percent, produces a laser scribed line of width one mil. With a laser repetition rate (rep rate) of 20,000 per second, a laser spot size of 0.001 inch and a spot overlap of 50 percent: the linear patterning rate is 10 inches per second. This is the speed at which the motion system must move in a production environment. Typical laser patterning rates are in the range of 8 inches per second.

Our cw pumped YAG laser without a Q-switch produces tens of watts of output cw power. Placing a Q-switch in our laser cavity generates pulse powers on the order of 50,000 watts. Although other YAG lasers can create thousands of cw watts, they cannot be Q-switched because of self-destruction by the high powered beam. Be that as it may, putting that 50,000 watts down on the, in our case, ITO, creates a power density on the order of a billion watts per square centimeter. This vaporizes the ITO.

Laser Wavelength	**0.532 nm**
Laser Pulse Rep. Rate	**8 KHz**
Laser Average Power	**0.5 w**
Laser Pulse Duration	**100-200 ns**
ITO Thickness	**150-1000 nm**
Linewidth/Hole Diameter	**0.0005 inch**
Hole Overlap	**50 percent**
Hole Depth in ITO	**complete**
Linear Speed	**2 ips**

Table 1. Conservative Q-switched YAG Laser Parameters for Patterning ITO.

Green YAG

Our laser is capable of operation at both it's fundamental wavelength and frequency doubled. Doubled YAG is also called "green YAG". The fundamental wavelength is infrared at 1.06 microns and the frequency doubled wavelength is exactly one half or 0.53 microns which is a bright green colored laser beam. This somewhat magical process is done quite simply using a frequency doubling crystal such as KTP and LBO. Converting the normally infrared invisible "color" of the laser to green carries a cost of over fifty percent (50%) reduction in maximum laser average power. As in automobiles, power is speed. Halving laser power halves the linear processing speed. So why reduce your throughput so significantly? The answer is linewidth. Using the same laser beam delivery optics, laser processing linewidth is reduced by one half. For example if the minimum linewidth of the infrared beam is one mil, green will provide one half mil. As a plus, green cuts cleaner on certain materials due to its higher absorption. On the negative side green YAG is more difficult to maintain. The doubling crystals are both temperature and alignment sensitive. They are also sensitive to laser mode structure, requiring the laser to operate in it's lowest order transverse electromagnetic mode, TEMoo.

Conclusion

One of the nice features of laser patterning is repairability. Defective plates failing testing for shorts may be repaired with nearly 100 percent yield. Laser patterning ITO is a maskless process ideal for quick turnaround prototyping and production of large plates having low line density.

References:

(1) Personal communication with Saleem Shaikh at Thin Film Device, Anaheim, CA.

(2) C. Barratt, C. Constantine, D. Johnson and W. Barrow, 1995 SID Digest, p. 681 (http:// www.display.org/sid)

(3) Personal communication with Peter Barbee at Fluke Corp. in Everett, WA.