Laser Direct Imaging – Towards a Universal Tool for Display Manufacturing

Eran Elizur and Dan Gelbart, Creo Inc., Burnaby, B.C., Canada

Abstract
The constant push to reduce prices is forcing display manufacturers to continuously look for cheaper manufacturing methods. One of the main cost drivers in display manufacturing is patterning. The process of manufacturing a modern display includes several steps of patterning which are conventionally done by photolithography. Photolithography certainly delivers the level of quality that is required in modern displays but it requires costly equipment and, being a subtractive process, also considerable chemical infrastructure for handling the developing, stripping and etching steps which follow the patterning. Laser direct imaging, now the predominant patterning method in computer-to-plate (CTP) applications in graphic arts, has already been proposed as a replacement for photolithography in manufacturing LCD color filters and inkjet barrier ribs.[1]

The purpose of this paper is to present recent work done by Creo Inc. and our partners that demonstrates additional applications where laser direct imaging could replace photolithography in display manufacturing. Such applications include surface energy patterning, conductor sintering and process-less masks.

Technical Summary
Objective and Background
Laser imaging is today the predominant patterning method used in computer-to-plate (CTP) applications in the graphic arts industry with thousands of systems installed worldwide. More specifically, thermal laser imaging and thermal processes have become so widely spread that the quantity of thermal resists sold annually world-wide is approaching the quantity of annual photo-resist sales.

The use of laser direct imaging for manufacturing LCD color filters and inkjet barrier ribs has already been presented.[1] In addition to eliminating costly masks, laser direct imaging offers material savings, considerable savings in clean room space and elimination of wet chemistry and related infrastructure.

In recent work done by Creo Inc. and our partners we found further uses for laser direct imaging in various parts of the display manufacturing process. In some applications, such as LCD color filters the laser imaging device is the sole patterning tool. In other applications, such as inkjet barrier ribs and surface energy patterning, laser imaging is used in conjunction with inkjet and other liquid deposition methods to improve the accuracy of the patterning process. In yet further applications, such as conductor-sintering, laser imaging could be used as a post processing tool to improve material properties after deposition. Finally, in cases where photolithography is an essential part of the process which could not be replaced, laser direct imaging could now be used to manufacture process-less photolithographic masks cheaply and rapidly.

Results
Surface Energy Patterning
Inkjet has become widely spread as a material deposition method in display manufacturing. It offers excellent parallelism, volumetric accuracy, efficient material use and material versatility. However, inkjet systems lack in spatial accuracy and critical dimension (CD) control. These shortcomings could be overcome by combining laser direct imaging in the patterning process. One method for doing that is the use of barrier ribs.[1] Yet another way to achieve this improvement is by using surface energy patterning. First, the substrate is coated with a material which changes surface energy under laser imaging. Following that a surface energy pattern is created on the substrate. Liquid is then deposited, using inkjet or other liquid deposition methods, aligning itself appropriately according to the surface energy pattern. For example, if the ink is water-based, the surface energy could change from hydrophobic to hydrophilic (or vice-versa) under laser imaging and the ink will then cover only the hydrophilic areas. Thanks to the high resolution of laser imaging systems, the resolution achievable with such technique is much higher compared to the natural resolution of liquid deposition methods.

It is worthwhile to note that a similar process is successfully used commercially for many years in offset printing where the printing plate is the substrate onto which a surface energy pattern is imaged using lased direct imaging.

This technique has been successfully applied by Plastic Logic in their process for making organic transistors achieving critical dimensions as low as 3 um.

Conductor Line Sintering
Over the past few years inkjet has also become widespread in conductor patterning using specially formulated nano-particle inks.[2] In order to achieve high conductivity the ink has to be heated, following deposition, to evaporate the liquid in which the nano-particles are immersed and allow agglomeration. Such heating may not be compatible with flexible substrates as it might cause deformation. Laser direct imaging could be used to selectively heat the conductor lines for this purpose without any change in underlying substrate temperature.

This technique has been successfully applied by Plastic Logic in their process for producing display back-planes.

Figure 1. Flatbed Imaging Tool Developed by Creo

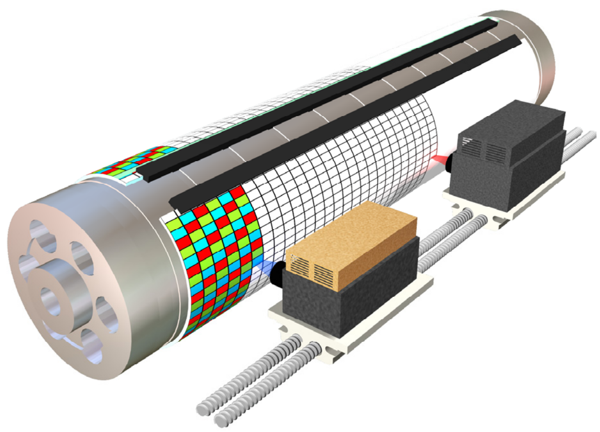

Figure 2. Extremely compact machine design combining thermal laser direct imaging with inkjet

Process-less Masks

While laser direct imaging is becoming available for ever more processes in display manufacturing photolithography will certainly maintain its position as an excellent patterning tool for years to come. In work performed recently by Chapman et-al[3-6] it was demonstrated that laser direct imaging could be used to make photolithographic masks in a rapid and cheap process which does not require development. OD range now reaches 0.12-3.0 (for wavelengths as low as 365 nm) and is improving to the point that it could soon become usable for making photolithographic masks for display manufacturing.

Equipment Development

The tool used to prove the concepts described in this paper is shown in figure 1. It is a flatbed imager capable of imaging substrates up to 400 × 400 mm and utilizes a variety of standard Creo thermal heads with 830 nm IR diodes. Depending on head model, pixel sizes range from 20 um to as low as 5 um.

As described in the previous sections the combination of inkjet and laser imaging is a very powerful one. A futuristic all-in-one manufacturing tool that combines the two and is suitable for flexible substrates is depicted below.

Impact and Conclusion

The work presented in this paper demonstrates the ever increasing number of applications for laser direct imaging in display manufacturing. The potential for cost reduction and process simplification is huge. As demonstrated, a laser imaging device is extremely versatile and may soon become a universal tool for display manufacturing.

References

1. Eran Elizur, Dan Gelbart, Thermal Lithography for Flat Panel Display Manufacturing, SID02 Digest (2002).
2. Szczech, J.B. et al, Fine-line conductor manufacturing using drop-on demand PZT printing technology, IEEE Transactions on Electronics Packaging Manufacturing, Jan 2002, Vol. 25, Issue: 1, p. 26-33 (2002).
3. G.H. Chapman et al, Single Step Direct-Write Photomask Made From Bimetallic Bi/In Thermal Resist, Proc. SPIE LASE 2003 Photonics West, Photon Processing in Microelectronics and Photonics II, San-Jose, Jan. 2003, vol. 4977, p 257-268 (2003).
4. G.H. Chapman et al, Creating Gray-scale Photomasks with Bimetallic Thin Film Thermal Resists, Proc. SPIE Bacus 2003, Monterey, CA, Sept. 2003, vol. 5256, p 400-411(2003).
5. G.H. Chapman et al, Creating 3D Structures with A Direct-Write Gray Scale Photomask Made From Sn/In Bimetallic Films, Proc. SPIE Photonics West: Laser Applications in Microelectronics and Optoelectronics Manufacturing IX, San Jose, CA Jan. 2004, vol. 5339, p 321-332 (2004).
6. Y. Tu et al, Calibrating Gray-scale Direct Write Bimetallic Photomasks to Create 3D Photoresist Structures, accepted by SPIE Bacus Photomask Conference, Sept. 2004, Monterey, CA (2004).

Author Biographies

Eran Elizur is a graduate of Tel-Aviv University in Israel, where he earned a MBA in 1996 and a BSc (Physics & Computer Science) in 1987. He also holds a MSc in Physics, which he was granted in 1990 from the Weizmann Institute of Science in Rehovot, Israel. Eran joined Creo Inc. in 2000, taking on responsibility for a major display and electronics initiative. His work led to a multi-million dollar agreement – signed in June 2002 – with DuPont for the development of thermal imaging equipment for the manufacture of LCD color filters. Prior to joining Creo, Eran spent three years as VP Marketing for El-Mul Technologies, and three years in various positions with Nova Measuring Instruments.

Dan Gelbart holds a B.Sc. and M.Sc. in Electrical engineering from the Technion, Israel. After arriving in Canada, Dan worked first for MacDonald, Dettwiler and Associates Ltd. (MDA) where he was involved in starting two local high-tech companies: MDI-Motorola and Cymbolic Sciences (CSI). Both companies were founded to exploit technology patented by Dan. In 1984, he co-founded Creo Products Inc. From 1984-1992 Creo was involved in optical data storage, shifting to printing in 1992. Today Creo employs over 4,300 people, has annual revenues of a billion dollar (C$) and is the world's largest supplier of computer-to-plate systems. Dan's work has been recognized within the scientific and research community, as well as in the marketplace. In 1986 he was awarded the B.C. Science Council Gold Medal, in 1994 an Honorary Doctorate from Simon Fraser University, and in 1999 he was awarded the Gold Medal by the Institute of Printing.