평판 디스플레이용 Laser Direct Imging에 관한 연구(I)

A Study on the Laser Direct Imaging for FPD (I)

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Abstract

When screen size of the Flat Panel Display (FPD) becomes larger, the traditional photo-lithography using photomasks and UV lamps might not be possible to make patterns on Photo Resist (PR) material due to limitation of the mask size Though the maskless photo-lithography using UV lasers and scanners had been developed to implement large screen display, it was very slow to apply the process for mass-production systems The laser exposure system using 405 nm semi-conductor lasers and Digital Micromirror Devices (DMD) has been developed to overcome above-mentioned problems and make more than 100 inches FPD devices It makes very fine patterns for full HD display and exposes them very fast The optical engines which contain DMD, Micro Lens Array (MLA) and projection lenses are designed for 10 to 50 μm bitmap pattern resolutions The test patterns for LCD and PDP displays are exposed on PR and Dry Film Resists (DFR) which are coated or laminated on some specific substrates and developed The fabricated edges of the sample patterns are well-defined and the results are satisfied with tight manufacturing requirements

I . Introduction

Since the cost of masks for FPD and semiconductor is very high and their fabrication takes a lot of time, some electronics companies have been developed maskless lithography technologies [1,2] The maskless lithography can be implemented using electron beam, AFM-based technology, laser direct writing, or Laser Direct Imaging (LDI) technology However, it is not easy to develop a system which is satisfying the sufficient productivity, feature size, and cost efficiency [3] The Laser Direct Imaging system which is developed by LG electronics is based on the 405 nm wavelength, violet semi-conductor lasers and Digital Micromirror Device (DMD) which was invented in 1987 by Dr Larry J Hornbeck of Texas Instruments (TI) The LDI system can be applied to maskless photography for all kinds of FPD applications including LCD TFT In addition, we achieve very high speed exposing for mass-production system [4,5] The DMD chip is controlled by computer signals and the design of chip makes it possible to move mirrors with great precision The TI, originally, developed the DMD for a high-resolution projection display Since a High-Definition TV (HDTV) version of DMD was demonstrated to United Sates Defense Advanced Research Agency in 1994, the DMD has been used for a lot of projectors and projection TVs [6,7] In this paper, we will present the DMD technology which is a very basic component of LDI system as well as LG Electronics (LGE) LDI system In addition, we will present two SEM photos of test patterns which are exposed and developed by the system

II. Digital Micromirror Technology

The DMD chip is a pixelated Spatial Light Modulator (SLM) using a 5V, 0 8 micron CMOS process For a DMD chip, the surface is divided into a mosaic of discrete elements referred to pixel The discrete pixel elements are micrometer sized reflecting mirrors which are movable and fabricated by very thin aluminum alloy The figure 1 shows the simple structure of DMD chip The DMD SLM structure is located on the CMOS static random accessmemory (SRAM) substrate and consists of three parts Top portion is a mirror part which is reflecting incident lights The size of mirror is 16 x 16 μm and the center area of mirror is connected to the mirror supporting post which is suspended over an air gap by yoke and two torsion hinges These are supported by hinge support posts which are connected to an underlying bus These torsion hinges, hinge supporting post and yoke are three major parts of operating portion In addition, a pair of address electrodes that are connected to the SRAM cellis also a member of operating portion The figure 2 is showing the mirror portion and operating portion The bus interconnects all the mirrors to a bond pad which is connected to SRAM cell These bonding pads and the bus are the bottom part of the DMD SLM structure The DMD mirror can rotate ± 12 degrees Depending on the voltage (on/off) which is "1" or "0"signal from the SRAM, the mirror is electrostatically attracted by the bias and address voltage to one of the others of the address electrodes and rotate until its tip touches on a landing electrode A "1" in the memory causes the mirror to rotate + 12 degrees and it makes reflections from incoming light to any projection lens or target In contrast, a "0"causes it rotate 12 degrees This means that the reflecting light disappears in the light absorber Using this DMD chip, the TI developed Digital Light ProcessingTM which is providing bright and high quality pictures for Projectors and TVs The DLP technology consists of DMD chip and other electronic logic, memory and control circuitry which make full digital control possible The popular DLP projectors and DLP projection TVs in the world markets are main achievement of the DLP technology

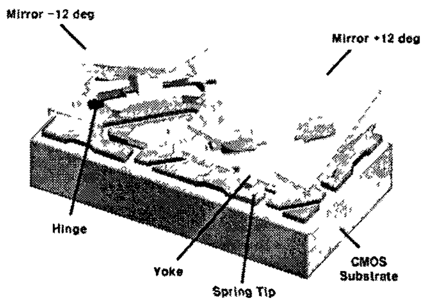

Figure 1. The structure of Digital Micromirror Device (DMD) TM of Texas Instrument

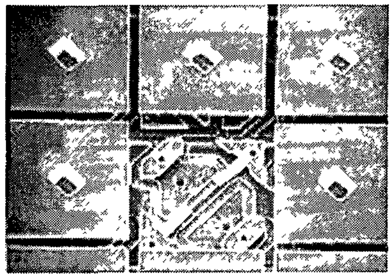

Figure 2. A SEM photo of DMD mirrors and operating portion

Ⅲ. Laser Direct Imaging System

The biggest advantage of Laser Direct Imaging technology is that it is essential for patterning of very large sized FPD panels like more than 100 inches PDP and LCD In addition, adapting of LDI technology has a lot of benefits like no costly mask for FPD pattern exposure, applicable for OLED, LCD, PDP patterning, fast exposure speed using multi-array optical engines, and using 405 nm wavelength semi-conductor laser which has eight times longer life time than the conventional UV lamps The Laser Direct Imaging System, LG LAMISTM mainly consists of four parts, which are optical engines, very precise stage, super-computing image processing technology, and 405 nm violet LD modules and controllers The key module for the LDI technology is optical engines and image processing technology which are projecting the 405 nm laser radiation into the substrate PR or DFR for maskless pattern exposing Generally, the line and space requirement of pattern for Ag conductor on PDP front panel or barrier rib on PDP rear panel is 30 to 50 μm Furthermore, the color filter pattern for LCD requires 5 to 12 μm line and space The exposing source, laser beam is delivered through fiber optic cable from LD module to the fiber inlet on optical engine The beam is homogenized and delivered to DMD mirror which is generating and scrolling FPD patterns The reflected beam is going through some lenses and MLA for image projection on FPD substrate panel The FPD patterns that should be exposed are originally generated from the CAD PC and the pattern images are send to high performance computer for data processing The data transfers to image controlling board which is processing series of pattern data and finally the optical engine is projecting the scrolling patterns for high speed exposing The pattern exposing can be possible by image scrolling while the stage is synchronized and moving forward A simple structure diagram of optical engine is shown in following figure 3

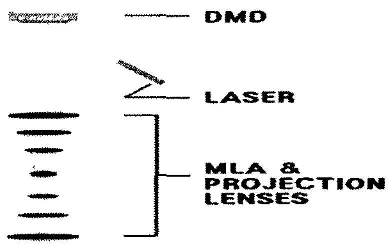

Figure 3. The structure of an optical engine The arrangements of MLA and projection lenses are different from real system

Ⅳ. Results and Discussion

The exposing results for test pattern are shown in figure 4 and 5 A SEM photo of the test stripe pattern from the top view is figure 4 The sample is exposed using the LG LAMIS on the copper plate using 405 nm sensitive DFR and developed by 1 0 % Na2CO3 developing liquid Usually, it is easy to make good quality patterns on PR or DFR on the copper plate because of less scattered reflection It seems that the sidewall of stripe pattern is perpendicular from the bottom substrate Since the DFR for the 405 nm wavelengths is not in the market yet, we used R&D purpose test samples from the material companies in South Korea and Japan The test result on the copper plate is used to developmass-production quality DFR for 405 nm sensitivity The companies modified and optimized their formulae and the test result on real target is shown below In figure 5, the stripe patterns on barrier rib of PDP rear panel are shown The sidewall of the DFR is perpendicular from the substrate and the edges of the patterns are well-defined The bonding force between the bottom of DFR and barrier rib satisfies post-processing, etching process requirements The overall test results show that the performance of LG LAMIS using specially formulated 405 nm DFR satisfies tight manufacturing requirements

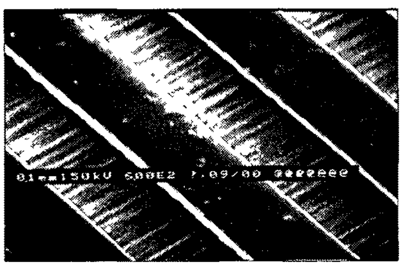

Figure 4 A SEM photo of test pattern copper plate The DFR is 405 nm sensitive

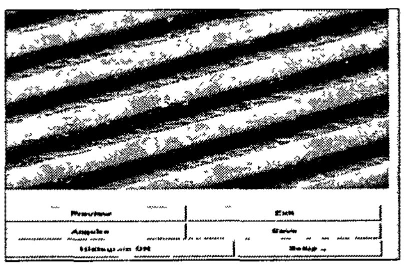

Figure 5 A SEM photo of Test pattern on on barrier rib of PDP Rear Panel

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