Chapter 3

Fabrication Technologies and Measurement Instruments

The fabrication techniques utilized to fabricate the designed LCD backlights will be first described in this chapter. These techniques include diamond knife micro-machining, embossing/extrusion technology and injection molding. The factors that affect the replication of lightguides will be also discussed. The instruments, such as a Conoscopic system, for evaluating the angular profiles and the brightness intensities of the designed LCD backlights will be depicted then.

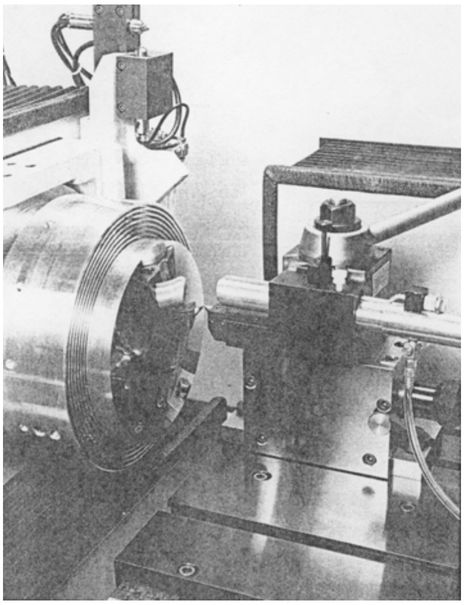
3.1 Introduction

As the applications of LCD are getting broader, one of most aggressive effort for market application is developing new fabrication technologies to satisfy the requirements of mass quantity and low cost of LCD backlights. Since once dots printed on the backside of lightguide in print-type lightguide plate (LGP), the fabrication must be accompanied intrinsically in print process. An easily varied concentration of white ink results in low productivity yield, thus, increasing the cost of backlight unit. Additionally, a drawback of the printed LGPs is the difficulty in applying printed LGPs on mobile sized backlight units. Hence many efforts are focused on developing print-less type of LGPs. To eliminate the print process in LGPs, fabrication of the micro-structures by directly carving in the surface of lightguide, such as diamond knife micro-machining technology[1], was introduced in this chapter. Followed by the description of embossing/extrusion technology[2] and injection molding[3][4][5], which is utilized for good replication and high productivity of lightguides.

3.2 Diamond Knife Micro-machining Technology

For the fabrication of lightguides, the diamond knife micro-machining technology is the most popular approach due to the excellent surface quality of fabricated devices. The diamond knife micro-machining is a precisely mechanical cutting by diamond tools, which is shown in Fig. 3-1(a). The shape accuracy of micro structures under 1 μm and surface roughness under 0.1 μm can be easily achieved. Nevertheless, the materials used in the diamond knife micro-machining process constrain the surface quality of samples. Either direct carving on the plastic substrates or micro-machining on the metal molds can be adopted in the fabrication of lightguides. However, the latter approach shall be accompanied with the replication process, such as embossing/extrusion and injection molding.

(a)



(b)

Fig. 3-1. (a) Schematics of diamond knife micro-machine and (b) Sharp edge of diamond knife.

Carving directly on the plastic substrates, polymethyl methacrylate (PMMA) and polycarbonate (PC) are the most commonly used materials. PMMA is an important plastic material for optical devices for its high transparency and good stability. However, it is easily intruded by the moisture. In contrast, PC is advantageous in wide working temperature range and good stability. However, PC is too soft to be a substantial substrate. On the other hand, for micro-machining on the metallic molds, soft metals, such as copper, aluminum and nickel, are generally used. Nevertheless, for those materials which are unsuitable in the diamond knife micromachining process, rough mechanical machining is used first. After the deposition of a thin nickel layer (around 0.1~0.2 mm), diamond cutting is then applied for precise micro-machining.

The surface quality in micromachining is usually determined by the machined materials and diamond tools. Some materials, such as aluminum, easily accumulate metal pieces on the edge of diamond knife, thus, degrading the machined quality and life time of diamond tools. Oxidation of diamond tools due to the rubbing effects at high speed, high pressure and high temperature micromachining also deteriorates the machined quality. The issues that degrade the diamond knife can be improved by spraying adequate mechanical oil to remove the metal pieces in machining process and cool down the working temperature.[1] The oil is essentially sprayed at an adequate quantity, otherwise scratch on the surface of devices easily occurs. Additionally, metal pieces need to be immediately removed to avoid an accumulation on the knife edge by the vacuum cleaner or the air blower system, which is shown in Fig. 3-1(b).

3.3 Embossing/Extrusion Technology

For achieving mass productivity and low cost, yet, maintain acceptable qualities of lightguides, the replication process was therefore developed and applied in this thesis. After the fabrication of metallic molds with micro structures, embossing/extrusion technology and injection molding can be then applied. In this section, embossing/extrusion technology will be discussed.

Embossing technology is typically used to produce relatively medium quality surface relief micro structures in high volume at low-cost. Diffraction grating and micro-grooves are examples which can be manufactured using embossing. This technology applies heat and pressure to transfer surface relief micro structures from stamping rollers into a plastic substrate. The thermoplastic substrate is heated above its glass transition temperature (Tg), then pressed between embosser plates or rollers, and allowed to cool before release. Embossing is capable of producing sub-micron structures when properly designed equipment is used. Due to the inherent limitations of thermoplastics, microstructure features produced by embossing lack the fidelity and aspect ratios required for demanding applications.

Extrusion technology, which is closely related to embossing technology, starts with the thermal plastic material in a molten state vs. the preformed plastic sheet material used in embossing technology. The molten plastic material is then extruded between rollers containing the microstructure pattern, and because of it's lower viscosity molten plastic material, it is better to replicate both finer features and higher aspect ratio structures than can be achieved by the above noted embossing technology.[2] Optical foils, such as anisotropic PEN and PET foils with micro-grooves and focusing foils, were applied the embossing/extrusion technology in fabrication, which is shown in Fig. 3-2.

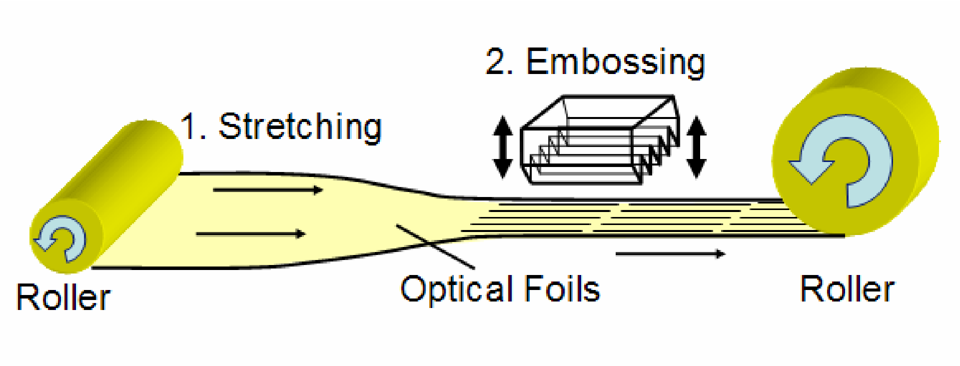


Fig. 3-2. Schematics of the fabrication process of embossing optical foils.

3.4 Injection Molding Technology

Injection molding technology is another economical approach that can produce good quality surface relief micro structures in high-volume. Injection molding provides added flexibility as to mounting tabs and other features that can be designed directly into the resulting component for easier assembly and alignment. The micro structures are directly carved in the surface of injection mold by diamond knife micro-machining. Then, direct mold injection has characteristic optical pattern to get the brightness and uniformity wanted. The process of injection molding is shown in Fig. 3-3. Injection machine stamp plate is attached on the surface of the moving part or the fixed part of mold. Mold core was mechanically carved by diamond turning machine. Molten plastic materials were then injected into the metallic mold at the high speed, high pressure and high temperature. It is very important to constantly control the speed of molten plastic materials and uniformly fill the mold core with molten plastic materials to avoid the occurrence of fringes on the surface of lightguide.

Generally, molten plastic materials pass through a very narrow tunnel shown in Fig. 3-3. to increase the speed and the temperature of plastic materials before injecting into the metal mold. Hence, the mold core can be fully filled with molten plastic materials. The constraints on injection molding are similar to that of embossing, where one is limited to thermal plastic materials, which in many cases do not possess the quality characteristics necessary to produce high fidelity microstructured components. In addition, the microstructured mold tends to degrade relatively rapidly under repeated cycles of having the hot shot of plastic materials into the mold over its very fine microstructured pattern.

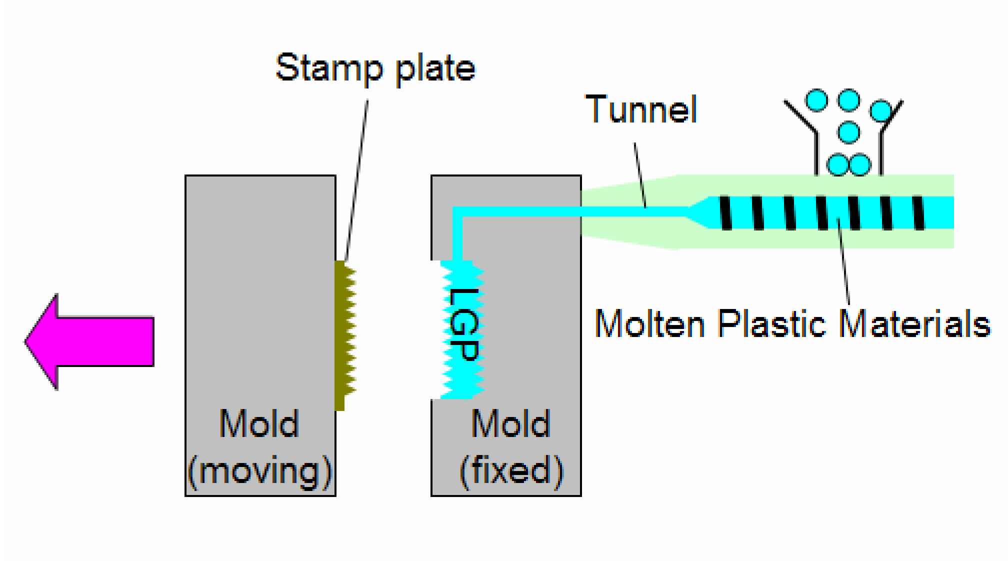


Fig. 3-3. Schematics of injection molding machine. The left and right parts of mold are shown. The stamp plate is attached on the left side of mold.

Four steps of injection was developed and applied to improve the quality of replication by injection molding. Molten plastic materials were shot at a medium speed. Then, a low speed was applied to partially fill the mold for avoiding a swirl of molten plastic materials. Next, the mold was filled at a medium speed. Finally, a low speed was applied again in filling the mold to avoid a residual stress and remove the bubbles as well.[3][4][5]

3.5 Measurement Instruments

For the LCD backlights, image brightness distribution in polar coordinate and uniformity of image are important parameters to evaluate the performance of LCD backlightss. The specific instruments which measure the image brightness at different angles are essential in the LCDs research and development. ELDIM EZContrast 160 is a conoscopic measurement system which utilizes Fourier transform lens to transfer the light beams emitted from the test area of different angles to the CCD array. Therefore, the angular properties can be easily measured on the CCD sensor plane.

The ELDIM EZContrast 160R utilizes a plane detector consisting of various directional CCD sensors to detect the transmissive light measure the luminance, color, and angular distributions of the LCD backlights at one time. The schematic diagram of the display measurements setup of ELDIM EZContrast 160R is as shown in Fig. 3-4.

The options for testing under illumination are based on the combination of Fourier Optics and cooled CCD sensor head. As shown in Fig. 3-4, the measurement is used for transmissive LCD backlights, where the first lens provides a Fourier transform image of the testing device surface. Every light beam emitted from the test area with a q incident angle will be focused on the focal plane at the same azimuth and at a position x=F(q). The angular characteristics of the sample are thus measured simply and quickly, without any mechanical movement.

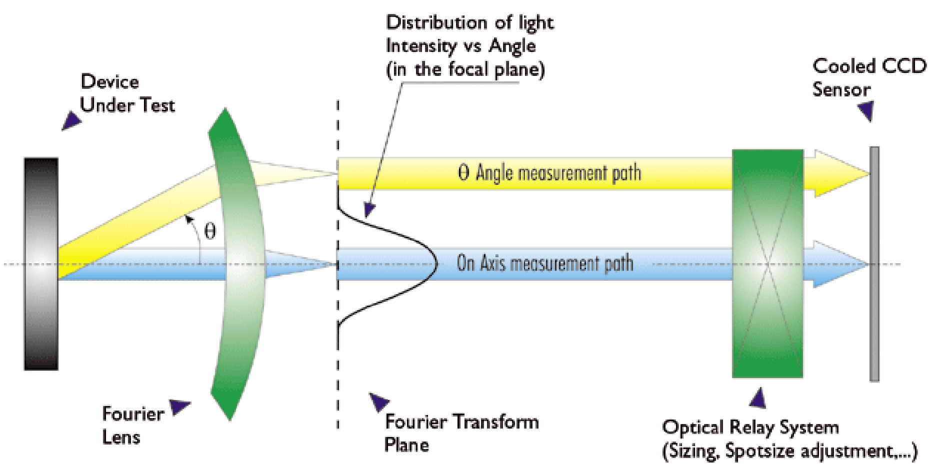


Fig. 3-4. Schematics of measurement setup of ELDIM EZContrast 160R.

3.6 Summary

For achieving mass replication of lightguides, yet, remain moderate surface quality, several economical approaches were introduced. Using the mechanical machined oil and 4-steps injection were developed and applied for further improving the replication quality of lightguides. After the fabrication of the lightguides by the diamond knife micro-machining accompanying with the embossing/extrusion technology and the injection molding, the microscopic instruments were first utilized to examine the profile of the micro structures on the surface of lightguide. Nevertheless, the light distribution and uniformity are two important parameters to be evaluated for LCD backlights. Then, this ELDIM EZContrast 160 conoscopic system was utilized to measure these parameters to determine the performance of the LCD backlights.

3.7 References

[1] 楊義成, 機械工業雜誌第 90 卷 9 月號, p.173 (1990)

[2] D. G. Pelka, C. C. Rich, J. M. Petersen, K. H. Patel, Society Information Display (SID) Digest, p.72 (2003).

[3] Y. Oki, Society Information Display (SID) Digest, p.157 (1998).

[4] 葉金娟, 電子月刊第三卷第一期, p. 115 (1997)

[5] 魏明正, 高分子工業第 102 卷 10 月號, p.48 (2002)