Chapter 3

Fabrication and Measurement Instruments

3.1 Overview

OLED device is adopted as the EL device in our emi-flective display because of the advantages of thickness, power conversion efficiency, and color saturation. Moreover, the low temperature of the process is available to flexible displays. In this chapter, the fabrication flows of R-LCD and OLED will be depicted, and the measurement instruments will also be introduced. The performance of the emi-flective display, such as luminance, contrast ratio, electrical characteristics, is measured by Conoscope and PR-650. The surface profile and thickness of each layer is examined by atomic force microscope (AFM).

3.2 Fabrication Process

The fabrication of the emi-flective display is basically the integration of the R-LCD and EL device processes. As shown in Fig. 2.8, the R-LCD is fabricated on the top emission OLED (TOLED) with TFE. Thin film encapsulation provides a robust barrier to prevent the intrusion from the water vapor and oxygen and remains the thin structure. The steps to develop the emiflective display are divided into two parts: RLCD and TOLED. TOLED is fabricated first and the whole device is completed in sequence. The detailed steps of the fabrication process are illustrated in Fig. 3.1.

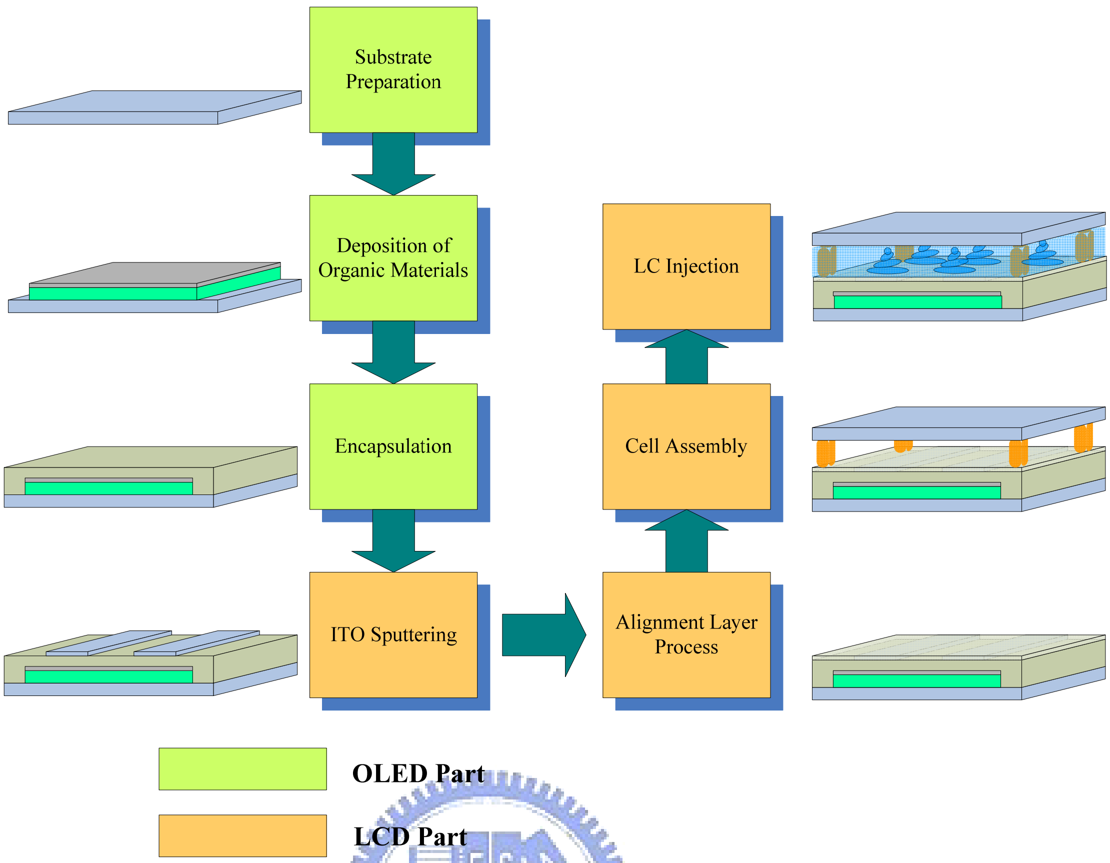

Fig. 3.1 The flow chart of the fabrication process of the emiflective display

(A) Top emission OLED part

(1) **Substrate preparation:** the glass substrates are widely used as substrates in applications of displays. The indium tin oxide (ITO) glass as the anode of TOLED requires roughness which is lower than 2nm to assure the operation of TOLED. The roughness can be reduced by the process of O_2/CF_X plasma on the substrate.

(2) **Deposition of hole transport layer:** the material of HTL, N,N -Bis(naphthalen-1-yl)- N,N-bis(phenyl)benzidine (NPB), is evaporated on the ITO substrate.

(3) **Deposition of emission layer:** the material of emission layer, tris-(8-hydroxyquinoline) aluminum (Alq3), is deposited on the HTL by thermal coater.

(4) **Deposition of electron injection layer:** the electron injection layer enhances the efficiency of electron injection to improve power conversion efficiency. In this device, the 10nm LiF is selected and evaporated on the EL.

(5) **Deposition of cathode:** the thickness of metal cathode directly determines which type of OLED is developed. The 25nm aluminum (Al) is applied as the cathode of TOLED.

(6) **Encapsulation of TOLED:** TFE is adopted as the encapsulation of TOLED and fabricated by evaporating SiO_2, SiO_xN_y, organic material repeatedly.

(B) Planation process: before the fabrication of R-LCD, the planation material for the device, UV glue, provides smooth surface and mechanical stress resistance.

(C) R-LCD part

(1) **ITO sputtering:** R-LCD bottom electrode is sputtered on the planation layer by the sputter.

(2) **Alignment layer process:** the alignment material is polyimide (PI). PI is coated on R-LCD bottom electrode by spin-coater and solidified by hard baking. Then, the PI film is rubbed with a roller to form microgrooves which LC molecules align with. The speeds of a roller and a rubbing table are set as 500 and 1000 rpm respectively. It should be noted that conventional hard baking, about 200℃, may cause the degradation of TOLED. Thus, the low temperature PI is applied to the emi-flective display, and curing temperature is lowered to 100℃.

(3) **R-LCD top substrate preparation:** R-LCD top substrate with photo spacer is fabricated through alignment layer process as bottom electrode is developed. Thus, photo spacer is formed to maintain homogeneous cell gap and prevent short circuit connection of R-LCD top and bottom electrodes.

(4) **Cell assembly and LC injection:** the LC cell is assembled by sealing the top substrate to the TOLED device with R-LCD bottom electrode. Then, LC is injected through capillarity injection.

(D) Characterization: After fabrication, the performance of the device will be measured by Conoscope.

3.3 Measurement Instruments

3.3.1 Optical Performance Measurement System

After preliminary fabrication of the emi-flective display, the optical performance such as luminance, contrast ratio, viewing angle is verified by ConoScope.

3.3.1.1 ConoScope

Fig. 3.2 Schematic diagram of a conoscope

The ConoScope shown in Fig. 3.2 can be used for visual performance evaluation, luminance, contrast ratio, color shift, gray scale and many characteristics. The basic working principle of the ConoScope is described as follows. A typical scanning device (so called "gonioscopic system") scans the half cone above the display to detect the deviations of luminance and color for each specific direction, as it can be seen in the upper right part of Fig. 3.3. Plotting each azimuth angle on a circle is the radius from the center additionally indicates the polar angle results in the so called polar coordinate system as shown in the left upper part of Fig. 3.3. Using such a polar plot to mark for each direction luminance and / or color will result (in the case of color) a colored figure as it is shown in the lower part of Fig. 3.3.

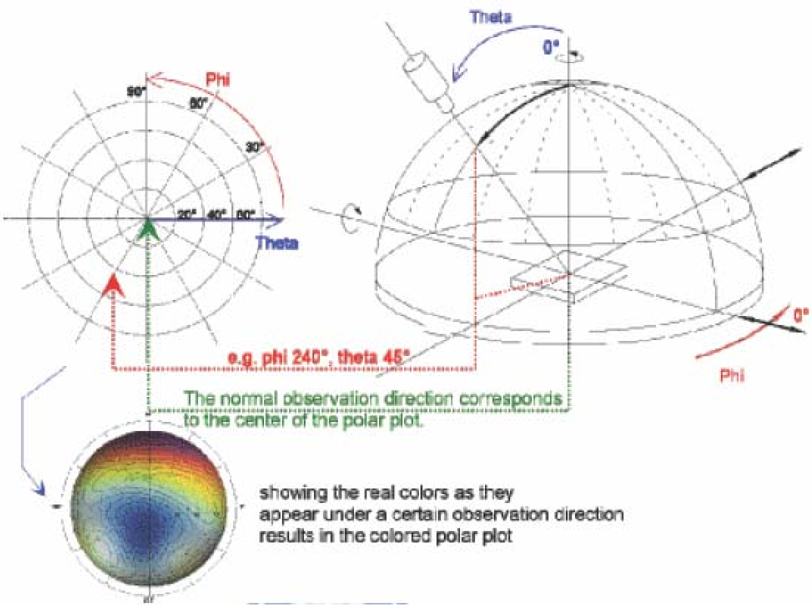

Fig. 3.3 The concept of a conoscope reciever

The conoscopic lens changes the direction of propagation of the elementary parallel beams coming from the measuring spot in such a way that they converge in the rear focal plane of the lens to form the 2-dimensional pattern (also called "conoscopic figure"). In this pattern each area element (spot) corresponds to one specific direction of light propagation. The pattern is projected onto a special CCD-array detector and analyzed with respect to intensity (e.g. luminance) and chromaticity.

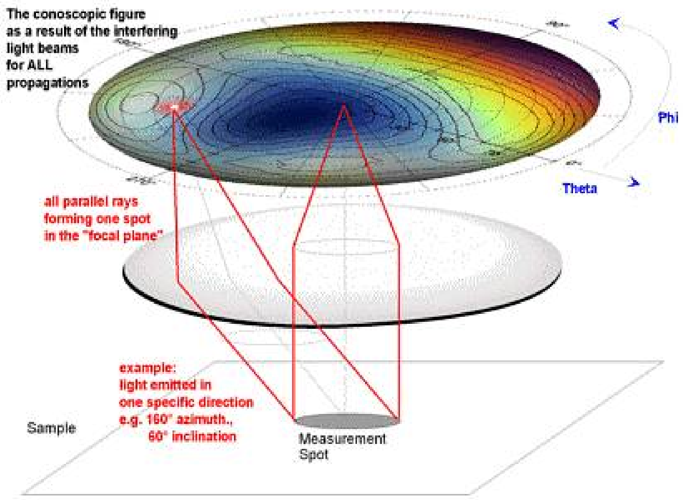

Fig. 3.4 The function of a conoscope lens system

3.3.2 Surface Measurement System

Roughness and thickness are concerns of thin film deposition, especially in the OLED fabrication. Even though a deviation of several μm, OLED device may fail due to a total thickness about 2 μm.

3.3.2.1 Atomic Force Microscope

Atomic force microscope (AFM), shown in Fig. 3.5, can be used for properties of surfaces. Besides surface morphology and roughness, the techniques concluding phase detection, force imaging can be performed by AFM. The signals are detected by the probe with a nano-sized tip. The operation principle is shown in Fig. 3.6. The computer responds received signals and generates feedback signals to modulate the movement of the probe. Thus, the image is plotted by the received signals. The operations of AFM can be divided into four parts: Contact Mode, Tapping Mode, Non-contact Mode and Lift Mode. The adopted Tapping mode overcomes the limitations that can arise due to the thin layer of liquid that forms on most sample surfaces in an ambient imaging environment.

Fig. 3.5 Schematic diagram of AFM

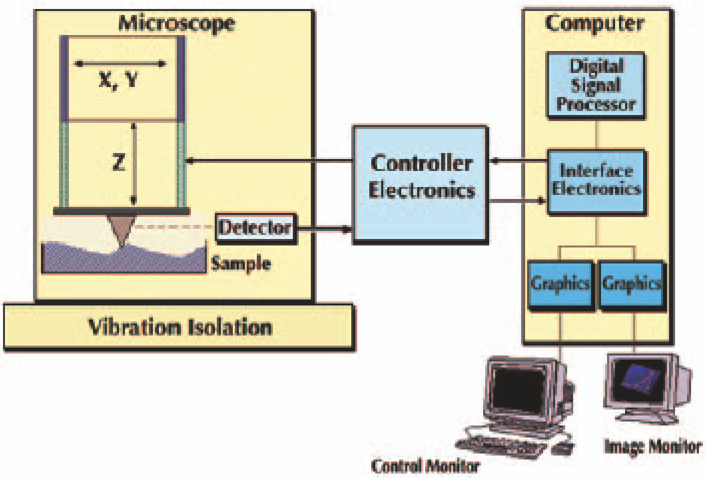

Fig. 3.6 The operation principle of AFM