Chapter 7

Dot Matrix Amorphous Thin Film Light Emitting Diode Flat Panel Displays

7.1 Introduction

In this work amorphous p-i-n junction thin film LEDs (TFLEDs) have been fabricated from several wide gap amorphous silicon alloys so-called, a-SiN:H, a-SiC:H and a-SiO:H [1-3]. The amorphous TFLED gathers attentions as a possibility of a new type of flat panel display. The amorphous TFLED display has several advantages such as low cost, ease of fabrication with large area and light weight. The details of the designs, fabrications, basic characteristics including some improvements of the device performances of the TFLEDs have been described in chapters 2-6. However, the reports of the TFLEDs in chapters 2-6 were restricted to the TFLED that has a small area and can emit only a fixed pattern of light. In a practical display, the display that has a larger area and can emit movable pattern of light is generally required.

In this work, another effort has been done on the design and fabrication of the TFLED that has a large area and can emit a movable pattern of light by proposing a novel "dot matrix array structure" [4-6]. By using a scanning electronic circuit, one will get movable emitting patterns from the dot matrix array TFLEDs.

In this chapter, a large area dot matrix amorphous TFLED display is proposed. Any moving emitting pattern can be obtained in this type of display. The dot matrix TFLED display consists of a number of grid ITO electrodes deposited perpendicularly to a number of grid Al electrodes. Several versions of the dot matrix yellowish-orange displays with the screen size ranging from $4 \times 4\ cm^2$ to $8 \times 8\ cm^2$ were fabricated and demonstrated. It is clarified that there is no cross talk in the display, and the analysis indicates that the minimum spacing distance between the adjacent two ITO or Al electrodes that can be as small as the order of micron [7-9].

7.2 Design and Fabrication of Dot Matrix Amorphous TFLED Displays

Figure 7.1 shows the structure of the dot matrix TFLED display. The basic configuration of the TFLED is the p-i-n junctions of hydrogenated amorphous silicon alloys. The result in this chapter is based on a-SiC:H material system. Figure 7.2 shows the fabrication process of the dot matrix TFLED display.

Firstly, a number of grids of the ITO front electrodes were deposited on a glass substrate by electron beam technique. Second, the a-SiC:H p-i-n layers were deposited on the whole area of the glass substrate by a glow discharge plasma CVD method. The thicknesses of the p-i-n layers were 150 Å, 500Å and 500Å, respectively. The optical energy gaps of the a-SiC:H p-i-n layers are 2.0 eV, 3.0 eV and 2.0 eV, respectively. The details of the deposition conditions of a-SiC:H p-i-n layers were the same as reported in the previous chapters. Finally a number of grids of Al rear electrodes were deposited perpendicular to the ITO electrodes.

The photolithography and lift-off techniques were used for the realization of the Al electrodes as shown in Fig. 7.3. Figure 7.3 shows photolithography and lift-off techniques for Al grid electrodes. The emission was observed at the crossing area of the front and rear electrodes.

In this work two versions of dot matrix a-SiC:H TFLEDs were demonstrated. Table 7.1 summarizes the basic specifications of the two versions of the dot matrix TFLED displays fabricated in the work.

In version No.1, the pixel size is 2 x 2 mm^2, with 2 mm spacing and screen size of 40 x 40 mm^2.

In version No. 2, the pixel size is 1 x 1 mm^2, with 1 mm spacing and screen size of 80 x 80 mm^2.

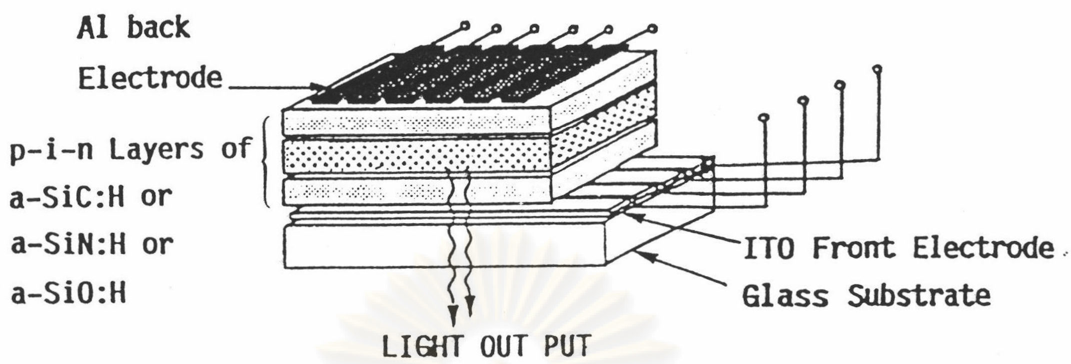

Figure 7.1 Structure of the dot matrix TFLED display.

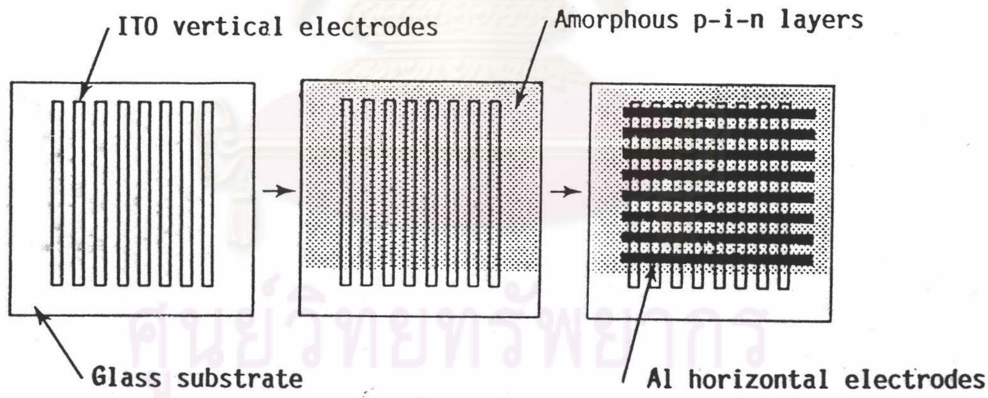

Figure 7.2 Fabrication process of the dot matrix TFLED display.

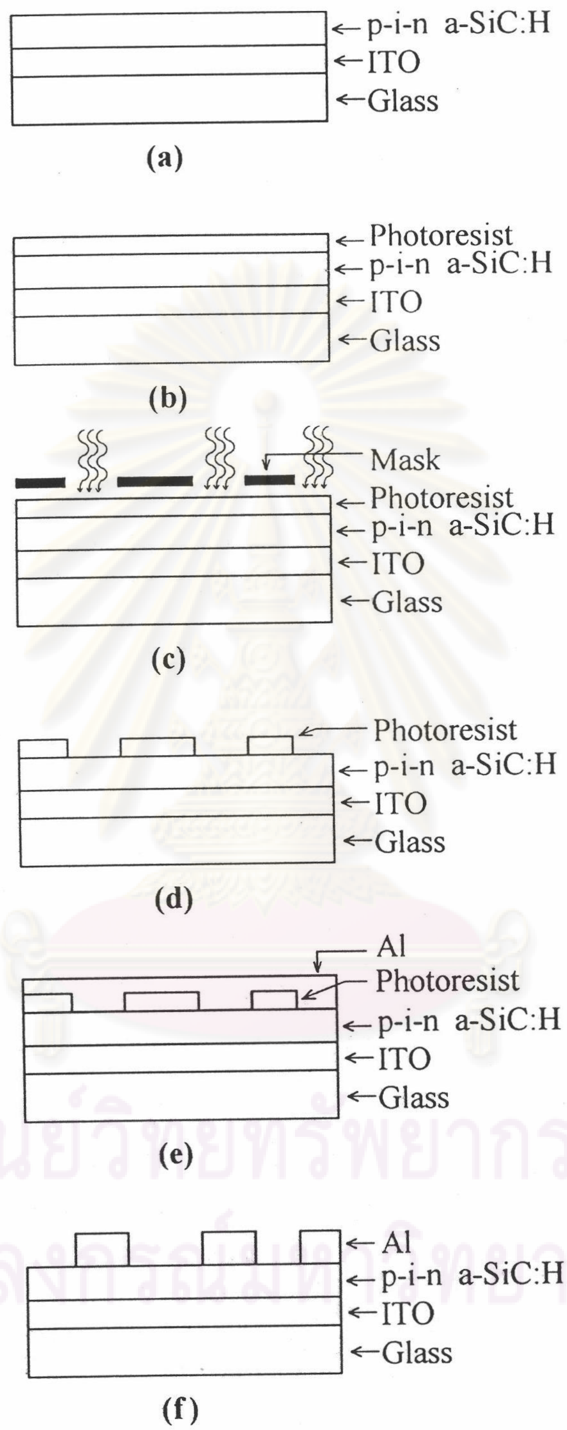

Figure 7.3 Photolithography and lift-off techniques for Al grid electrodes.

Table 7.1 Specifications of 2 versions of the dot matrix a-SiC:H TFLEDs fabricated in the work.

Version	Glass Area	Pixel Area	Spacing Distance	Number of Pixels
1	4 x 4 cm^2	2 x 2 mm^2	2 mm	8 x 8
2	8 x 8 cm^2	1 x 1 mm^2	1 mm	28 x 28

7.3 Basic Characteristics of Dot Matrix Amorphous TFLED Displays

The operation voltage and the injection current density for each pixel were typically 10-15 V and 100-1000 mA/cm^2, respectively. This operation condition gives the brightness of about 1-5 cd/m^2. The emission can be observed in a bright room.

Figures 7.4 and 7.5 demonstrate photographs of the actual emissions from the dot matrix TFLED displays versions No.1 and No.2, respectively. It is noted that the total thickness of the display is only 1 mm.

Figure 7.6 shows the photographs of the dot matrix TFLED display where some pixels were selected to emit. It is seen in Fig. 7.4 - 7.6 that there was not any cross talk in these display. The emission color was yellowish-orange. The uniformity of the brightness was sensitive to the uniformity of the thicknesses of the a-SiC:H p-i-n layers. Although the uniformity of the brightens was not yet perfect, it was expected that it can be improved from technological viewpoint (for example increasing the size of the RF electrodes).

Figure 7.7 shows a schematic illustration of the top view of the dot matrix TFLED display. Figure 7.8 shows equivalent circuit of dot matrix TFLED display. By using a scanning electronic circuit, one can obtain movable emitting pattern of light.

Since the adjacent ITO electrodes and the adjacent Al electrodes were connected by the conductive lateral p- and n-a-SiC:H layers, respectively as schematically shown in Fig. 7.9, it might be doubtful whether there was any leakage

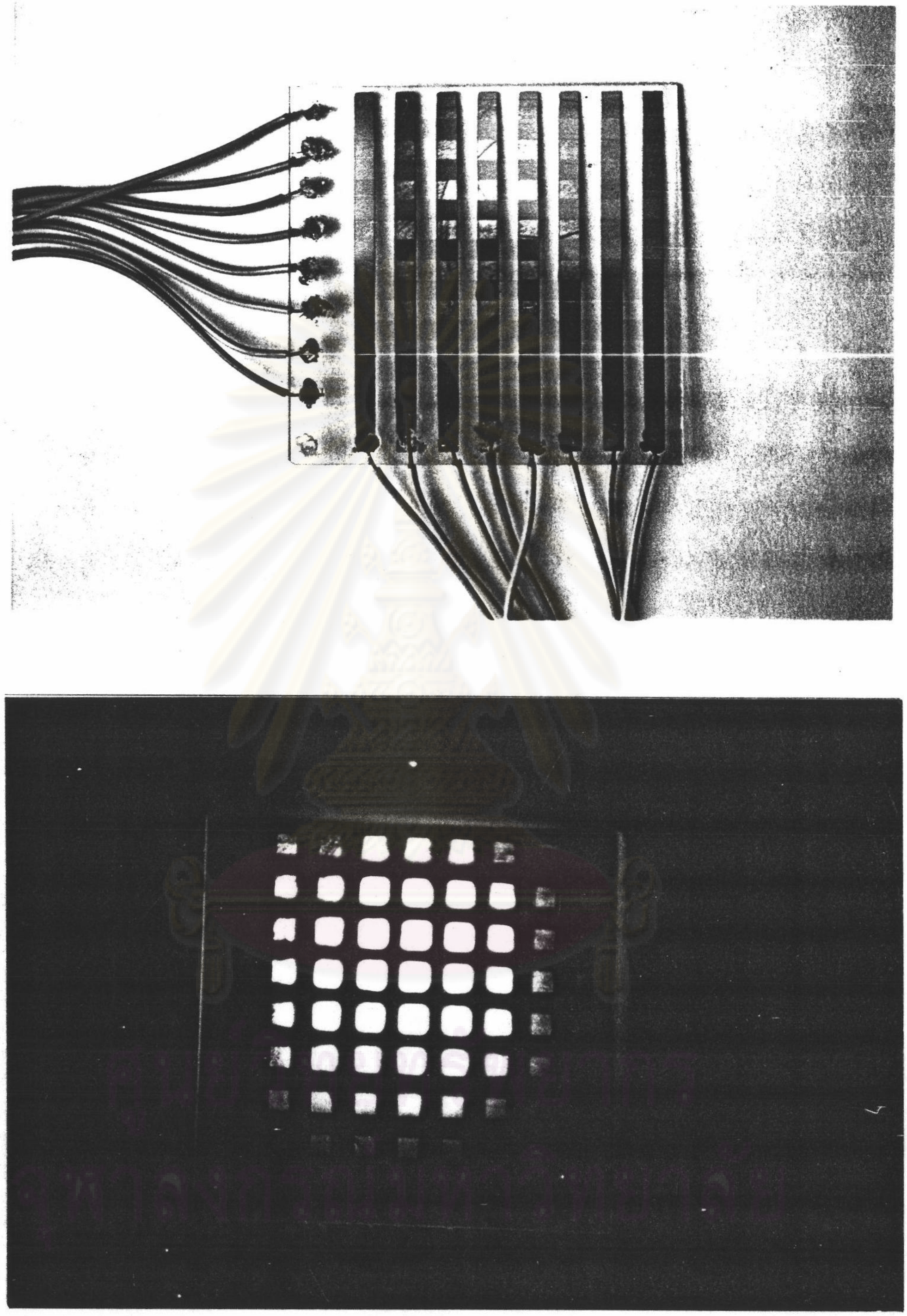

Figure 7.4 Photographs of the actual emissions from the dot matrix TFLED displays version No.1.

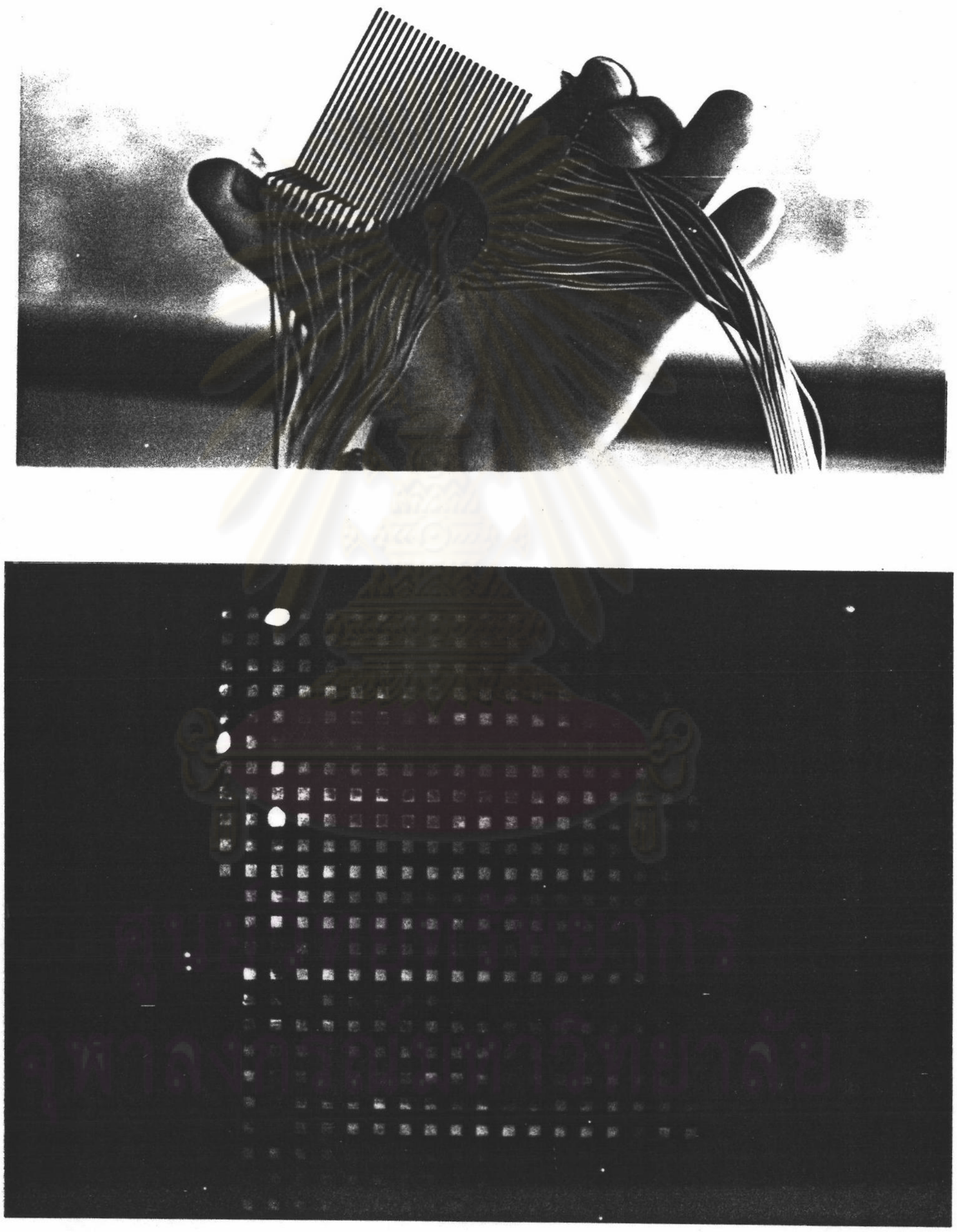

Figure 7.5 Photographs of the actual emissions from the dot matrix TFLED displays version No.2.

Figure 7.6 Photographs of the dot matrix TFLED displays of some selected emitting pixels.

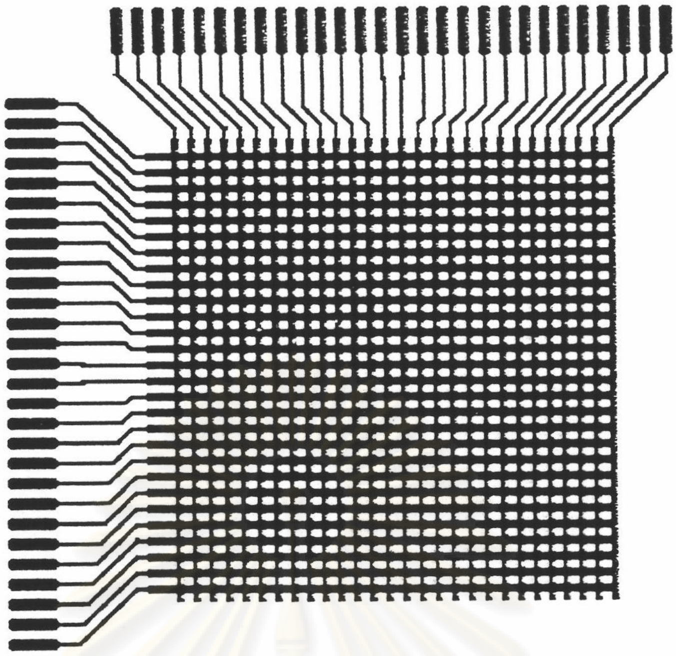

Figure 7.7 Schematic illustration of top view of a dot matrix TFLED display.

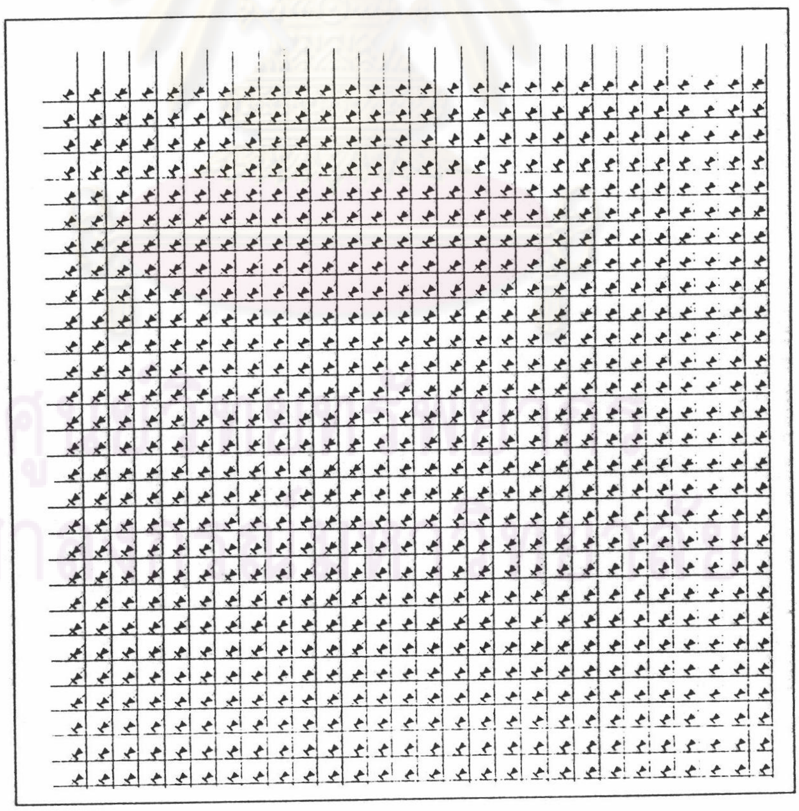

Figure 7.8 Equivalent circuit of a dot matrix TFLED display.

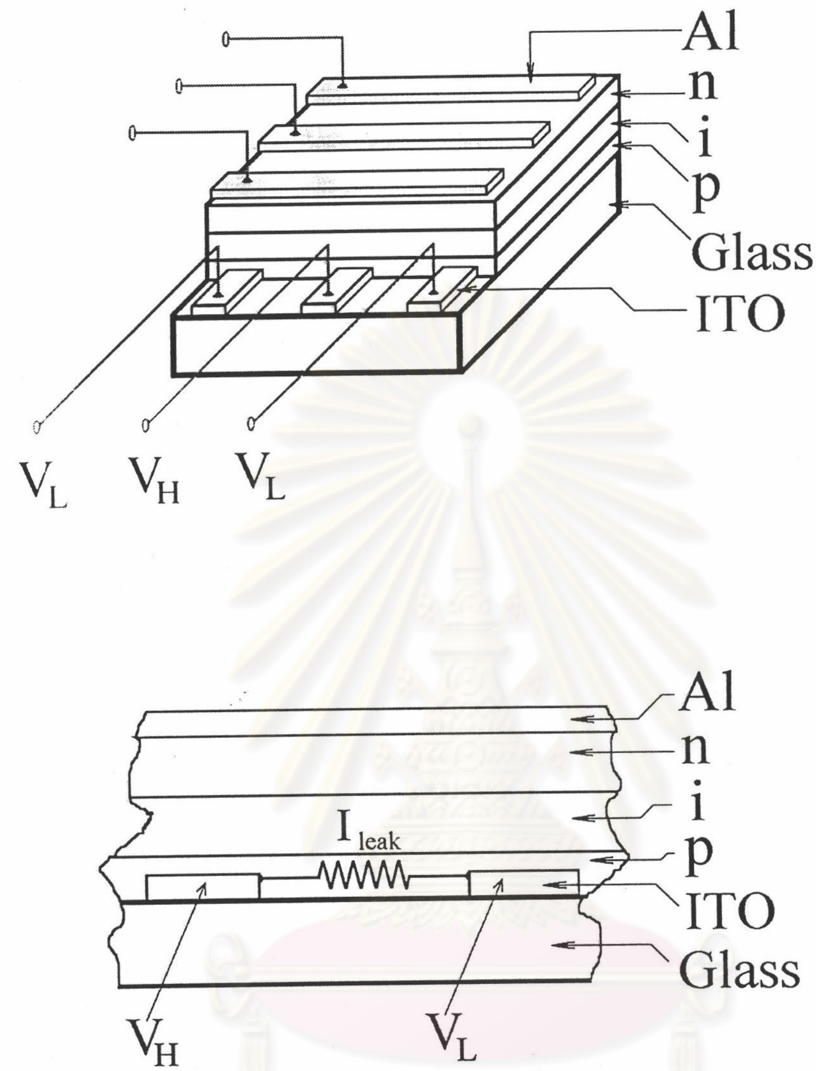

Figure 7.9 Schematic diagrams of ITO grid electrodes connected by the conductive lateral p-a-SiC:H layer.

current among the adjacent ITO electrodes and the adjacent Al electrodes. Here we will discuss on this item.

Figure 7.10 shows the equivalent circuit of an amorphous TFLED dot matrix TFLED display indicating series lateral resistances between the two adjacent electrodes. If there was leakage current, the lateral leakage current would induce the generation of heat that degrades the performances of the display. The voltage drop arises from the difference of the "high level" and "low level" of pulse voltage simultaneously applied to the two adjacent Al electrodes. In this work an estimation of the relation between the magnitude of the leakage current and the spacing distance and the conductivity of the a-SiC:H p-layer was done on the basis of a simple resistance model as shown in Fig. 7.9. The spacing distance (s) of the pixels can be calculated by using a simple equation as follows:

$$s = \frac{\sigma \times l \times d \times V}{I_{leak}} \qquad (7.1)$$

where σ and d are the conductivity and the thickness of the amorphous layers, l is the length of the ITO electrode. V is the dropped voltage across the two ITO adjacent electrodes, and I_{leak} is the allowable leakage current. The thickness d here is the thickness of the p-layer.

Figure 7.11 shows example of calculated results of the relationship between the magnitude of the leakage current and the spacing distance in dot matrix amorphous TFLED display. The parameter is conductivity of the p-a-SiC:H layer. The result in Fig. 7.11 means that for example if one allows the leakage current of 1 μA, and the conductivity of the p-layer is 10^{-7} S/cm, the spacing distance of the ITO electrodes must exceed approximately 0.3 μm.

Fortunately, from the above estimation it is found that the minimum value of the spacing distance of the pixels can be as small as the order of μm. This value is small enough for the condition of a practical high resolution display.

Another important characteristic of the a-SiC:H TFLED display is the frequency modulation characteristic. It has been described in chapter 4 that the

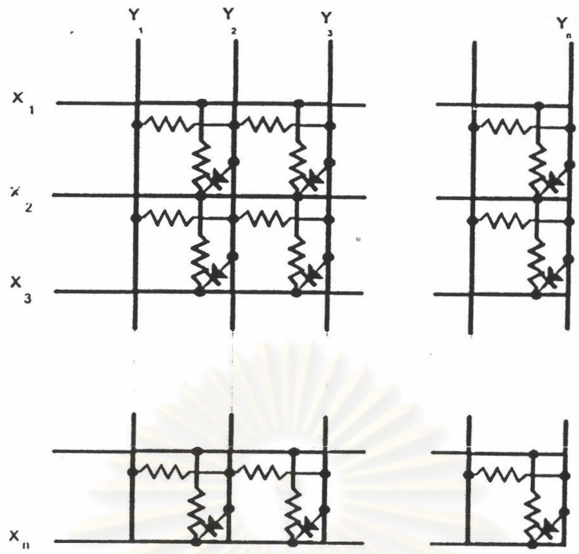

Figure 7.10 Equivalent circuit of dot matrix amorphous TFLED display indicating series lateral resistances between the two adjacent electrodes.

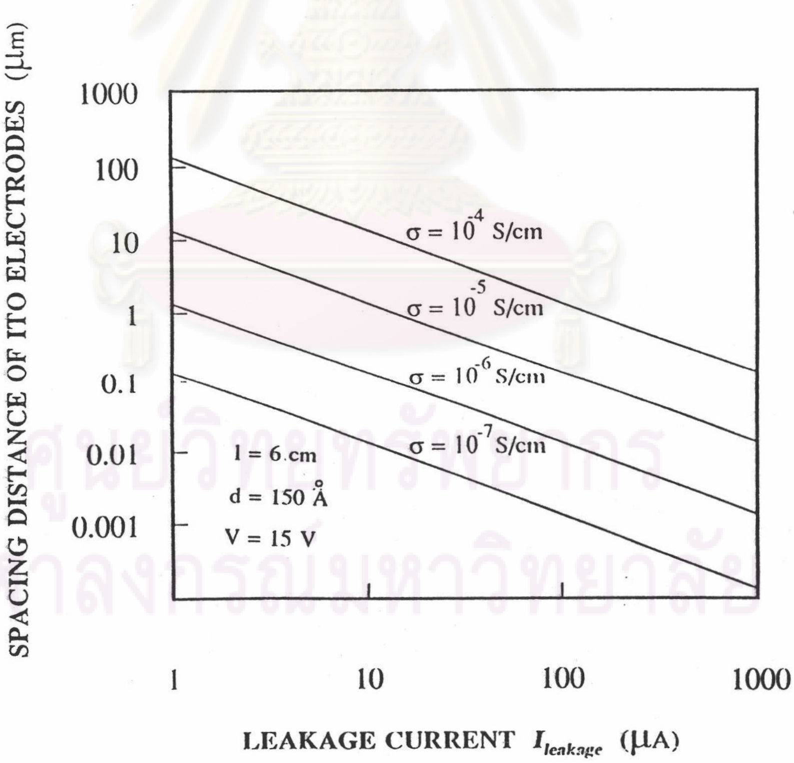

Figure 7.11 Calculated result of the relationship between the magnitude of the leakage current and the spacing distance of ITO electrodes in dot matrix amorphous TFLED display. The parameter is the conductivity of the p-a-SiC:H layer.

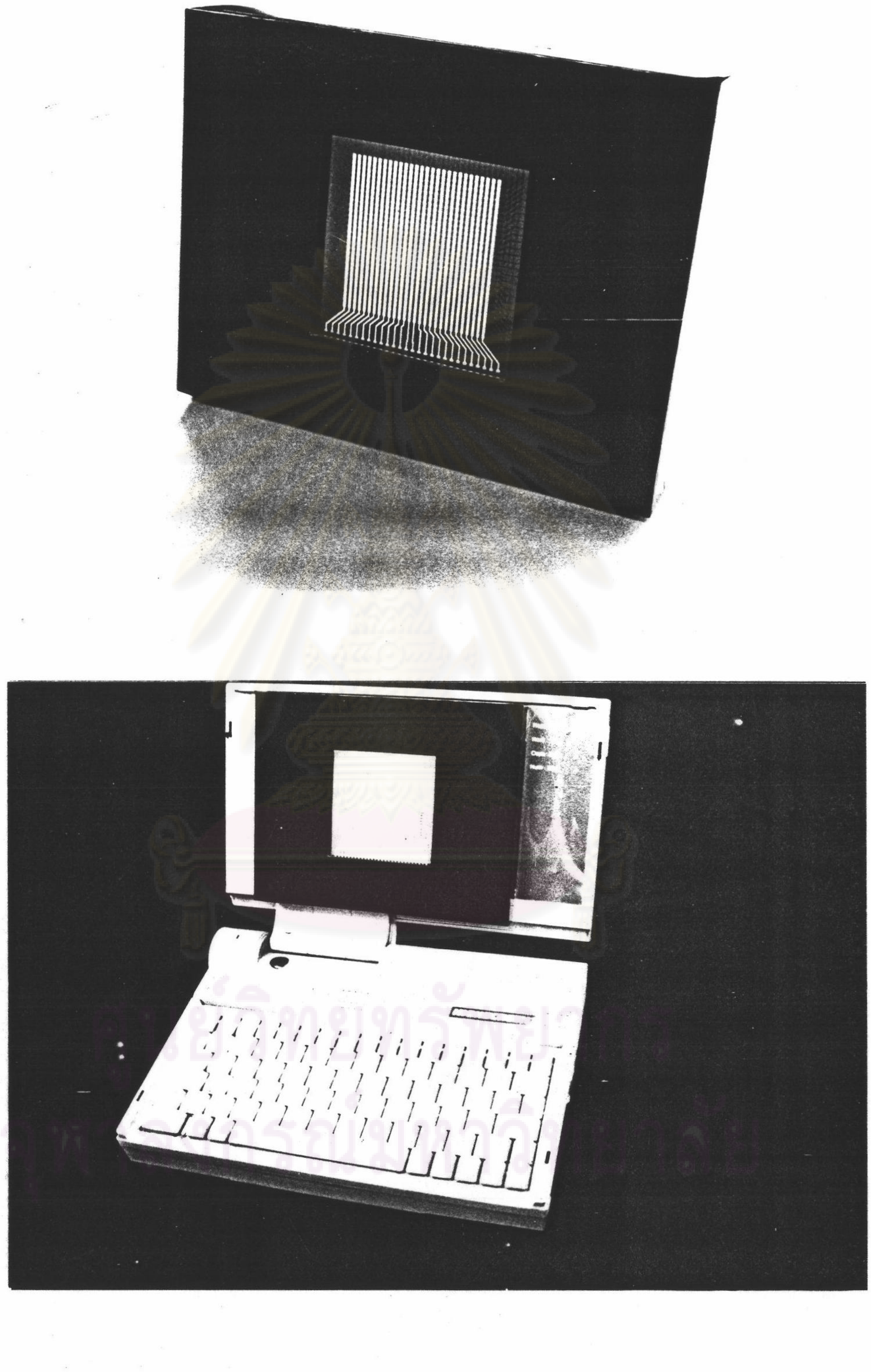

Figure 7.12 Examples of the packages of the dot matrix amorphous TFLED display.

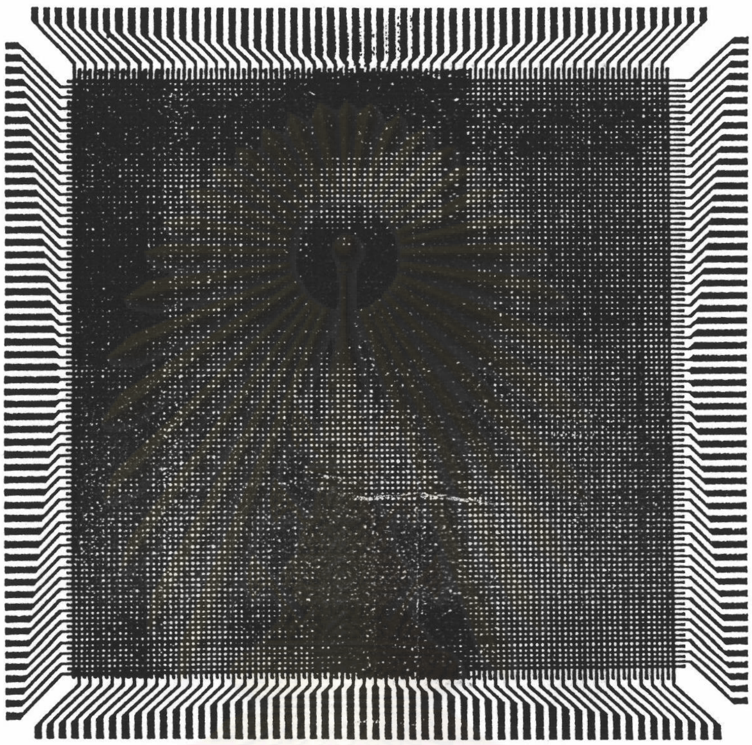

Figure 7.13 Design of a high resolution dot matrix amorphous TFLED display with a pixel area of 0.3 x 0.3 mm^2 and spacing distance of 0.3 mm.

cut-off frequency of the light intensity output of the a-SiC:H TFLED display isabout 500 kHz. Since the conventional scanning frequency of the TV or computer display is the order of several kHz to several ten kHz, it is clarified in this work that the amorphous dot matrix TFLED display can be operated by the scanning mode.

Figure 7.12 shows examples of the packages of the amorphous TFLED dot matrix display. It is seen that the amorphous TFLED display is a smart flat panel display.

Figure 7.13 shows another design of a high resolution dot matrix amorphous TFLED display with a pixel area of 0.3 x 0.3 mm^2, spacing distance 0.3 mm.

7.4 Summary

Large area dot matrix amorphous TFLED displays have been proposed and fabricated for the first time. The dot matrix amorphous TFLED display consists of a number of grid ITO electrodes deposited perpendicularly to a number of grid Al electrodes. Two versions of the dot matrix display; version No.1 with screen area of 4 x 4 cm^2, pixel area of 2 x 2 mm^2; version No.2 with screen area of 8 x 8 cm^2, pixel area of 1 x 1 mm^2, have been demonstrated.

It has been clarified that there is no cross talk in the display, and the minimum spacing distance between the adjacent two ITO or Al electrodes can be as small as the order of μm. The dot matrix amorphous TFLED can be operated in a scanning mode at the frequency as high as 500 kHz.

References

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