

Novel Structure of 21.6 inch a-Si:H TFT Array for the Direct X-ray Detector

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Abstract

A 21.6" a-Si:H TFT array for direct conversion X-ray detector with 2480 by 3072 pixels is successfully developed. To obtain X-ray image of satisfactory quality, a novel structure with a storage electrode on BCB is proposed. The structure reduces the parasitic capacitance of data line, which is one of the main sources of signal noise. Also, the structure shows greater resistance to failure than that of the conventional design.

Keywords: X-ray, a-Si:H TFT, detector, BCB, noise gain, parasitic capacitance

1. Introduction

Digital image technology has given birth to a new revolution of medical systems especially in diagnosis, remote inspection, image archiving and retrieval. But X-ray projection area in various medical systems lags behind in digital image technology. Now, it has become possible that X-ray projection area for radiology benefits from amorphous silicon (a-Si:H) technology. There are some reasons to why the direct digital X-ray detector in the projection area needs a-Si:H TFT array. One is that there is a need of flat panel detectors for the direct replacement of X-ray film plate, the other is that a-Si TFT array can be in harmony with amorphous selenium (a-Se), which refers to one of the adequate x-ray photoconductors and above all, the a-Si:H TFT technology is available to the large detection area.[1],[2],[3],[4]

We have developed a 21.6" large area a-Si:H TFT array for a direct digital X-ray detector panel and embodied the new device structure superior to the conventional one in terms of its performance, electrical characteristics and manufacturing.

2. Operation of Detector

Fig. 1 shows a schematic cross sectional view of a direct conversion digital detector. When a-Se layer is irradiated by X-ray, EHPs (Electron Hole Pair) are generated. Holes accelerated by several kV between the top electrode and the ground plane of the TFT array are collected by CCE (Charge Collecting Electrode) and the storage capacitor of active matrix array are charged. When the gate channel of TFT is open, discharging currents flow through the channel and the charges are converted directly into the digital signal by the external read out circuits connected to the end of the data line.

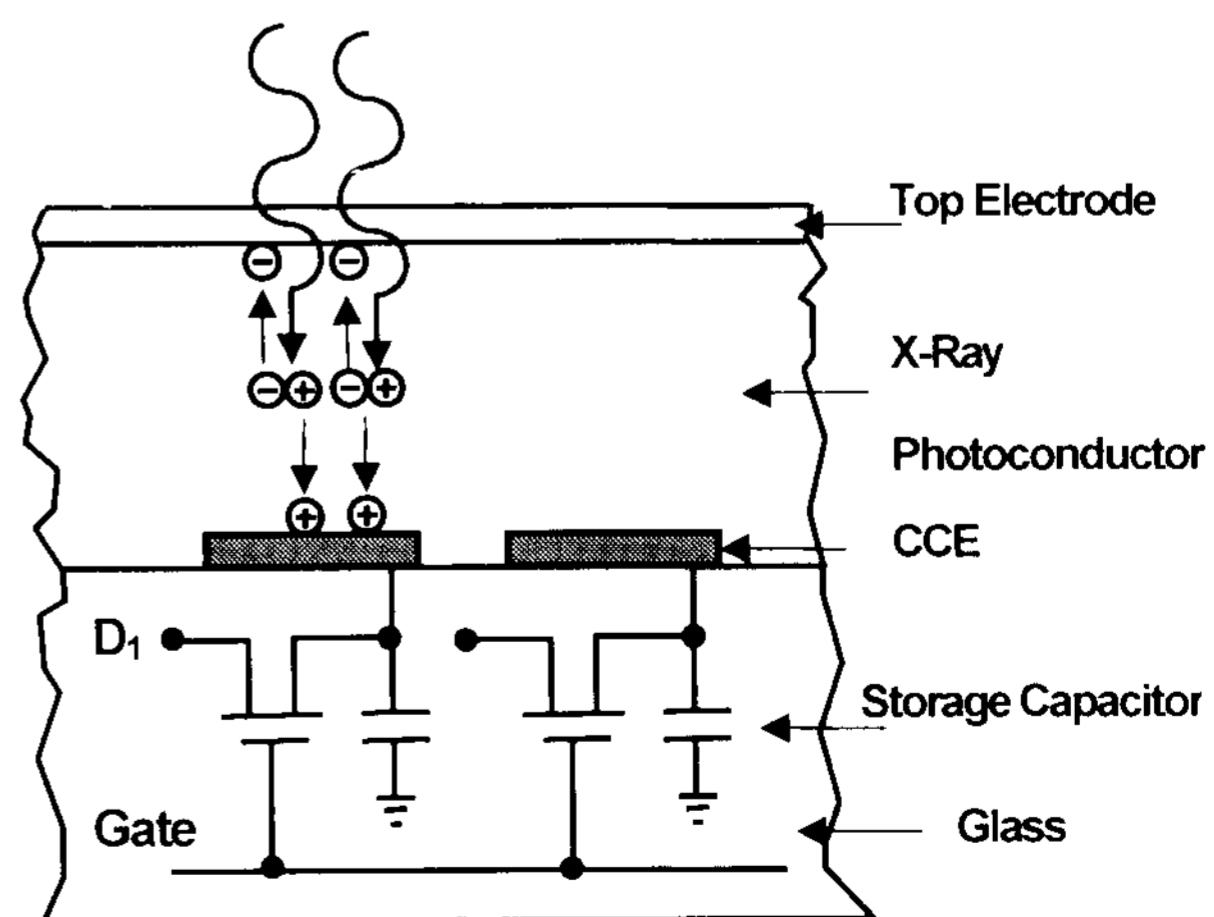


Fig. 1. Schematic cross sectional view of a direct conversion digital detector

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3. Device Design

There are several important parameters of device design, which are low on resistance and high off resistance of TFT, large storage capacitor for charge collection and small parasitic capacitor to reduce cross talk. To achieve a X-ray image of good quality, it is also very important for the external read out circuits to have low noise gain. The noise gain (G_n) of the external read out circuit is given as :

$$G_n = 1 + (C_{co} + C_s + C_p) / C_{fb}$$

G_n : noise gain of external read out circuit of X-ray detector

C_{fb} : feed back capacitance of read our circuit of X-ray detector

C_{co} : cross over capacitance between gate line and data line

C_s : overlap capacitance between source and CCE

C_p : parasitic capacitance between data line and pixel electrode

If C_{fb} is fixed, the noise gain depends on various capacitors in the active matrix array. C_{co} and C_s are mainly determined and constricted by design rule and conventional process of fabrication. For example, C_{co} is determined by the line width of gate and data. Also C_s is determined according to the channel width of TFT. However, we could improve C_p characteristics by reforming the vertical structure of device.

Fig. 2 compares the cross-sectional view of previous device (a) and new device (b). There are some differences between these two devices. One is the construction of storage capacitor. According to the location of the storage capacitor the previous device is referred to as Storage under BCB (SUB) and the new structure as Storage on BCB (SOB), respectively. The other is that the new device has the advantage in manufacturing process in terms of the simplification of the process, that is one PECVD, one sputtering, and one photo lithography process can be eliminated by adopting SOB structure. This unique structure of SOB is effective in reducing the value of C_p , which is due to the fact that insulating layer on data line of SOB has lower dielectric characteristics and is thicker than that of SUB. We have calculated and compared the C_p of SUB and that of SOB

through simulation..

Fig. 3 shows that the new device has lower parasitic capacitance than the previous device design. This means that the new device structure has good immunity to cross talk, thus reducing the noise gain of read out circuit, effectively.

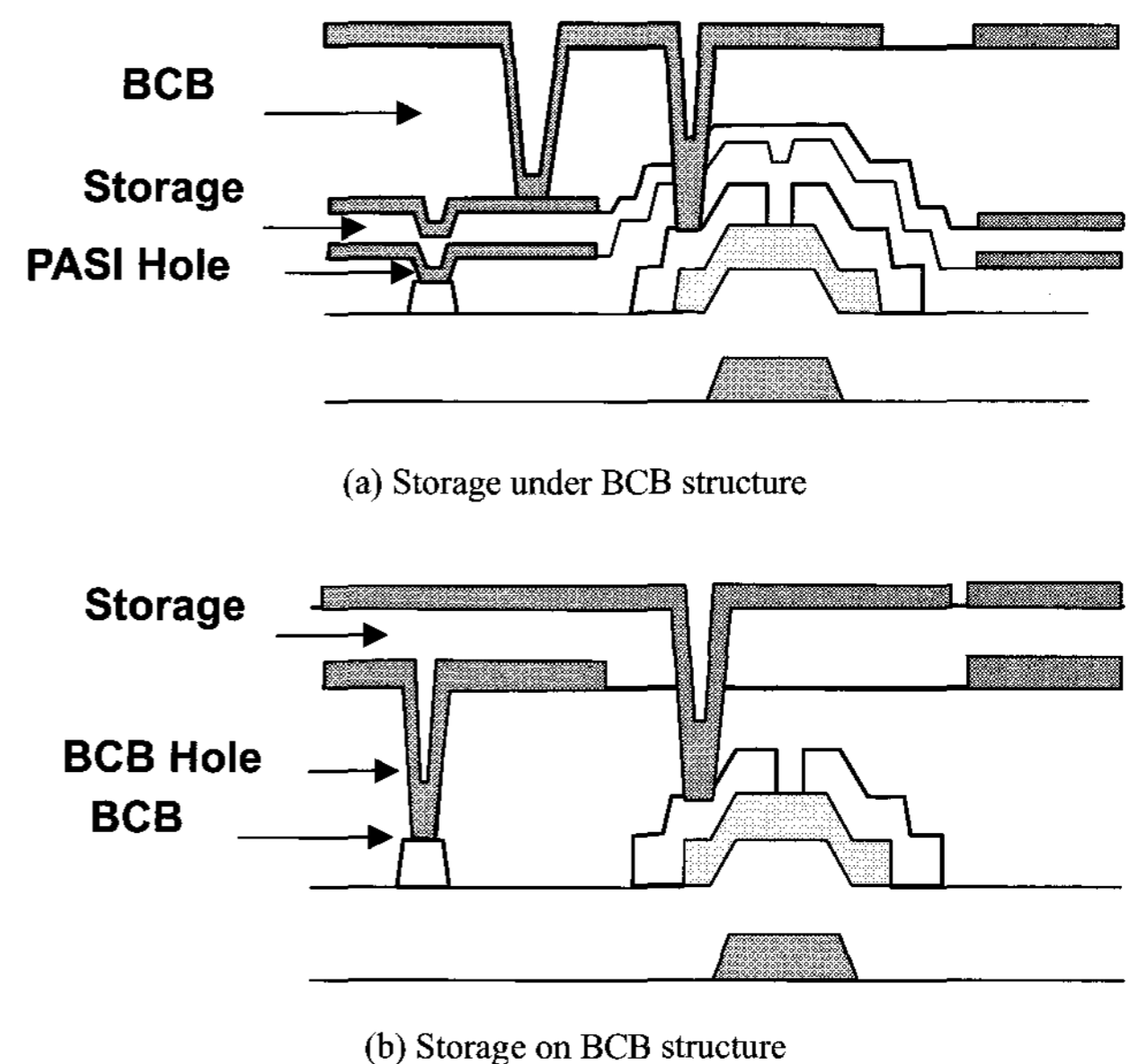


Fig. 2. The cross sectional view of the TFTs

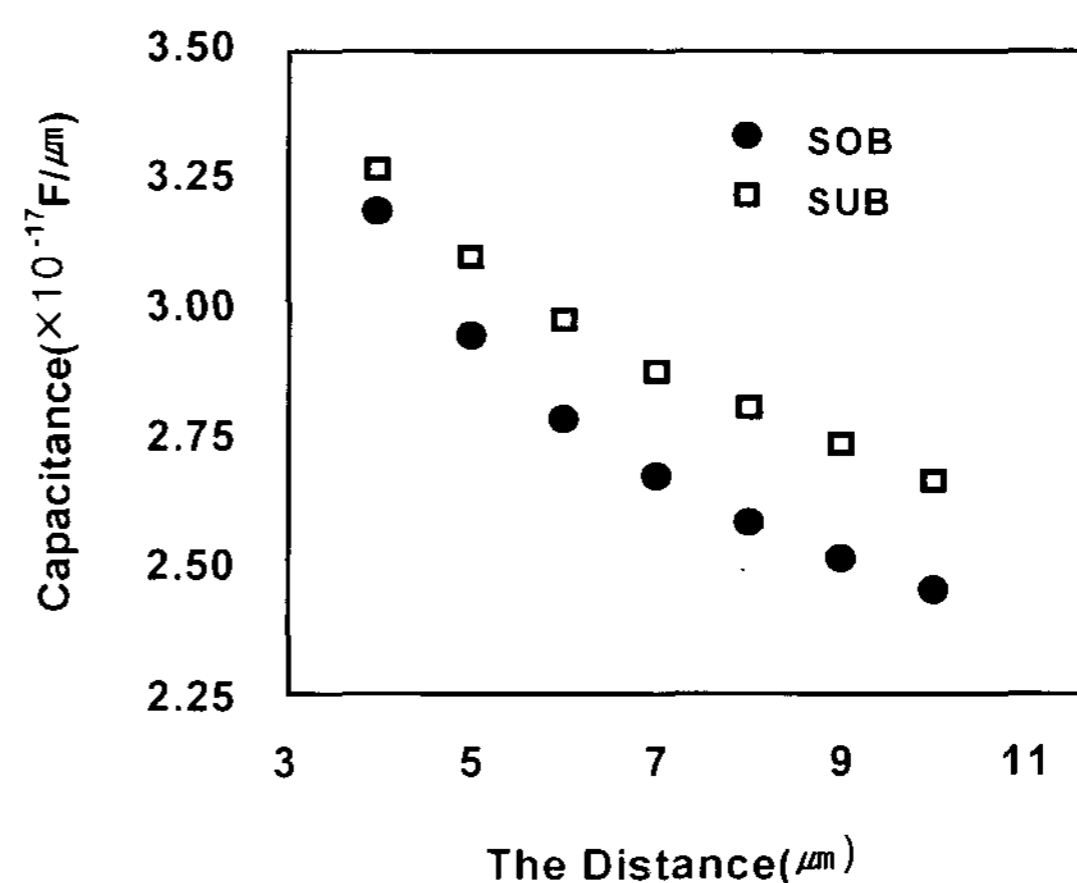


Fig. 3. C_p with varying the distance between data line and storage electrode.

4. Device Fabrication

The new device is manufactured using the following sequence. Gate metal is deposited and gate line is patterned as the 1st layer. Three layers of gate insulator, a-Si and n+(phosphor doped) a-Si are deposited and then

n⁺/a-Si are patterned. After patterning the data and common (COM) lines, n⁺ of back channel is etched off. After BCB layer is coated and cured, contact holes of BCB are formed using reactive ion dry etching. ITO layer is deposited and patterned on BCB for the storage electrode (STG). STG makes contact to the COM line via the contact holes. After silicon nitride is deposited for storage capacitor, the charge collecting electrode (CCE) is formed by using ITO. The storage capacitor is made of silicon nitride inserted between STG and CCE.

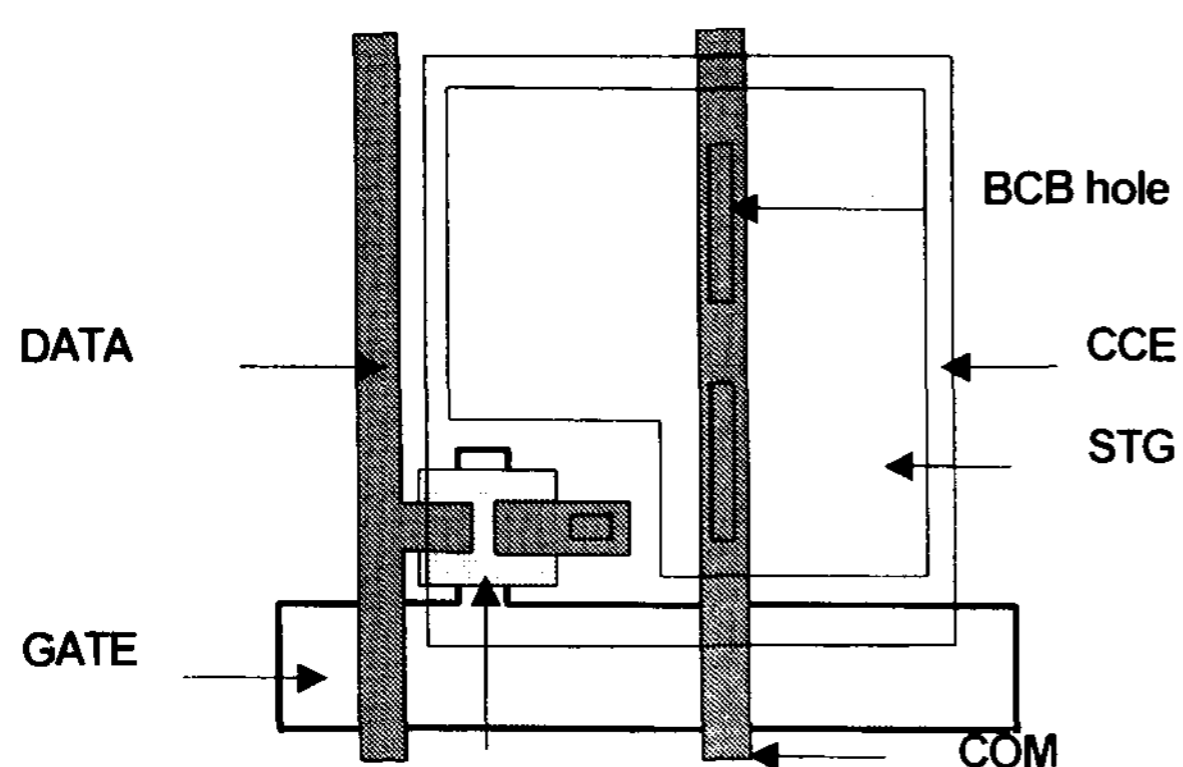


Fig. 4. Schematic diagram of a unit pixel(139x139 μm)

Through these sequence of process, we successfully fabricated the new a-Si:H TFT for a direct X-ray detector panel. The pixel size is 139x139μm, the total number pixel is 2480(gate) x 3072(source) and the diagonal size of the TFT array is 21.6". Figure 4 shows the schematic

diagram of unit pixel fabricated. Typically, the on resistance of TFT, R_{on} , is less than $2.9 \times 10^7 \Omega$ (at $V_{gs}=+7V$, $V_{ds}=+10V$) whereas off resistance, R_{off} , is greater than $3.7 \times 10^{14} \Omega$ (at $V_{gs}=-5V$, $V_{ds}=+10V$).

5. Summary

21.6" full size X-ray detector with a novel SOB structure has been fabricated. The SOB structure shows a good X-ray Image because it reduces the parastic capacitance of data line, which is one of the main source of signal noise. The SOB structure is simpler than the SUB structure. The typical value of storage capacitance is 2.1pF, which is a suitable value to obtain good X-ray image.

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