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

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Abstract

21.6" a-Si:H TFT array for direct conversion X-ray detector with 2480 by 3072 pixel is successfully developed. To obtain good X-ray image quality, novel structure, storage on BCB structure, is proposed. The structure reduces the parasitic capacitance of data line, one of the main sources of signal noise. Also, the structure shows higher failure resistance against defects than that of the old design.

Introduction

Digital image technology has been giving birth to a revolution of medical system especially in the parts of diagnosis, remote inspection, image archiving and retrieval. Recently, it is possible that X-ray projection area for radiology benefits from amorphous silicon (a-Si:H) technology. There are some reasons why the direct digital X-ray detector in the projection area needs a-Si:H TFT array. One is that for the direct replacement of X-ray film plate flat panel detectors are required, the other is that a-Si TFT array can be in harmony with amorphous selenium (a-Se), one of the adequate x-ray photo-conductor and above all, the a-Si:H TFT technology is available to the large detection area.[1],[2],[3],[4]

We have developed 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 old one in electrical characteristics and manufacturing.

The operation of detector

Figure 1 shows the schematic cross sectional view of 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 top electrode and the ground plane of the TFT array are collected by CCE (Charge Collecting Electrode) and charge the storage capacitor of active matrix array. 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 data line.
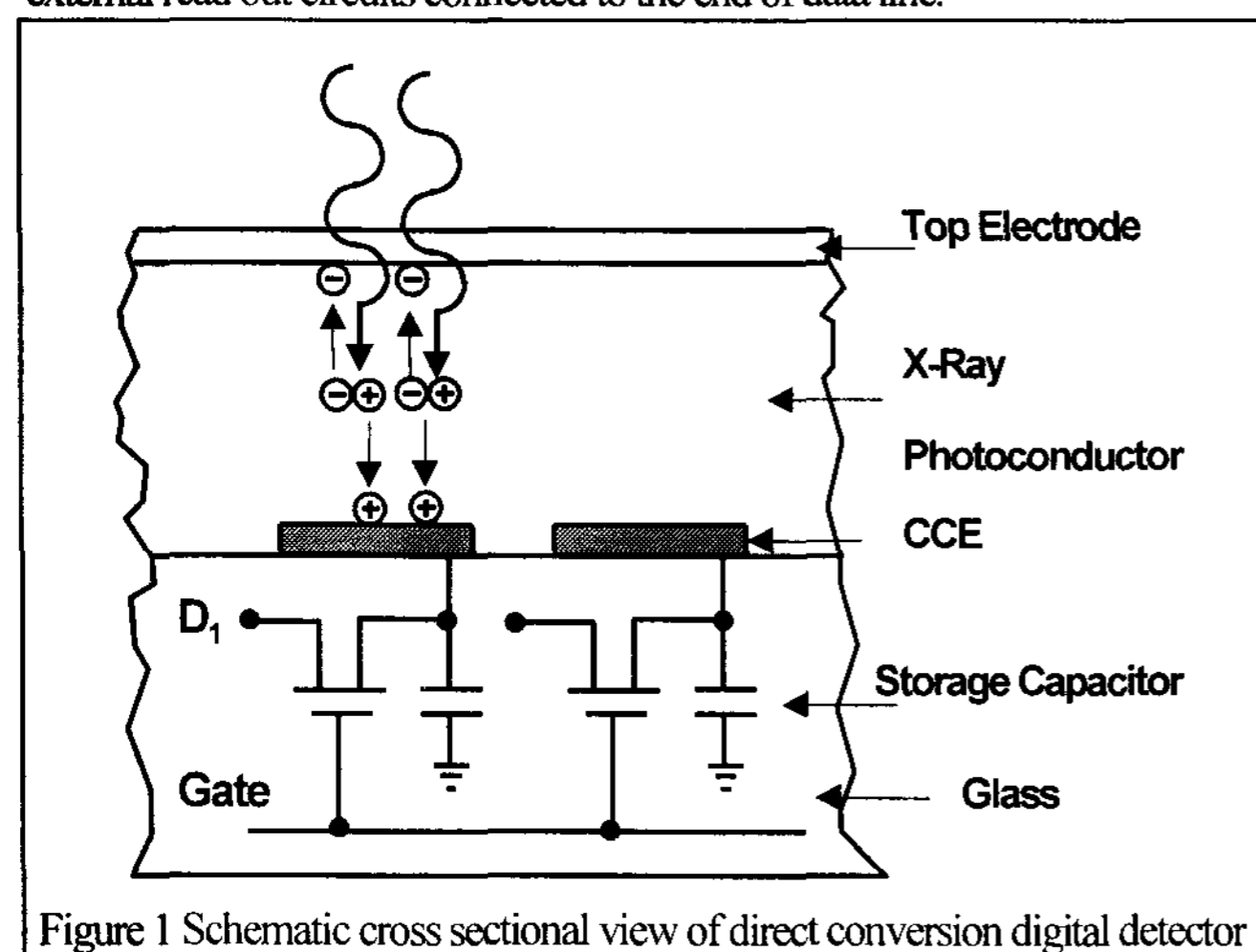

Figure 1 Schematic cross sectional view of direct conversion digital detector

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. For the sake of obtaining a good quality of X-ray image, it is also very important for the external read out circuits to have low noise gain. The noise gain (Gn) of the external read out circuit is given as (1).

$$Gn = 1 + (Cco + Cs + Cp) / Cfb \quad (1)$$

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

Cfb : feed back capacitance of read our circuit of X-ray detector

Cco : cross over capacitance between gate line and data line

Cs : overlap capacitance between source and CCE

Cp : parasitic capacitance between data line and pixel electrode

If Cfb is fixed, the noise gain depends on various capacitors in the active matrix array. Cco and Cs are mainly determined and constricted by design rule and conventional process of fabrication. For example, Cco is determined by the line width of gate and data and Cs is also determined according to the channel width of TFT. However, we could improve Cp characteristics by reforming the vertical structure of device.

Figure 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 we call the previous device as Storage under BCB (SUB) and the new structure as Storage on BCB (SOB) respectively. And 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

(a) Storage under BCB structure
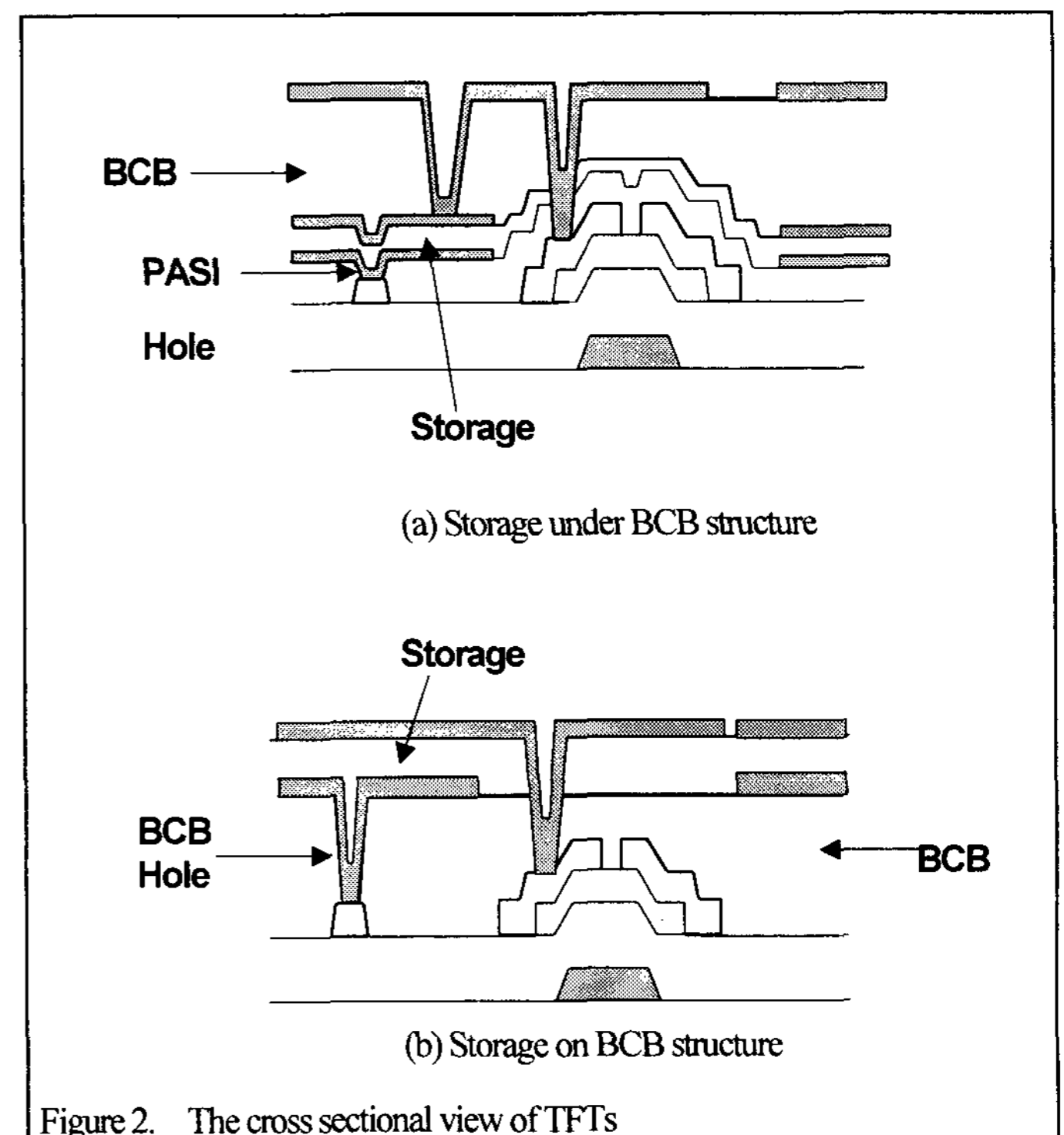
(b) Storage on BCB structure

Figure 2. The cross sectional view of TFTs

photo lithography process can be eliminated by adopting SOB structure. This unique structure of SOB is effective in reducing the value of Cp, 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. By simulation, we have calculated and compared the Cp of SUB and that of SOB.

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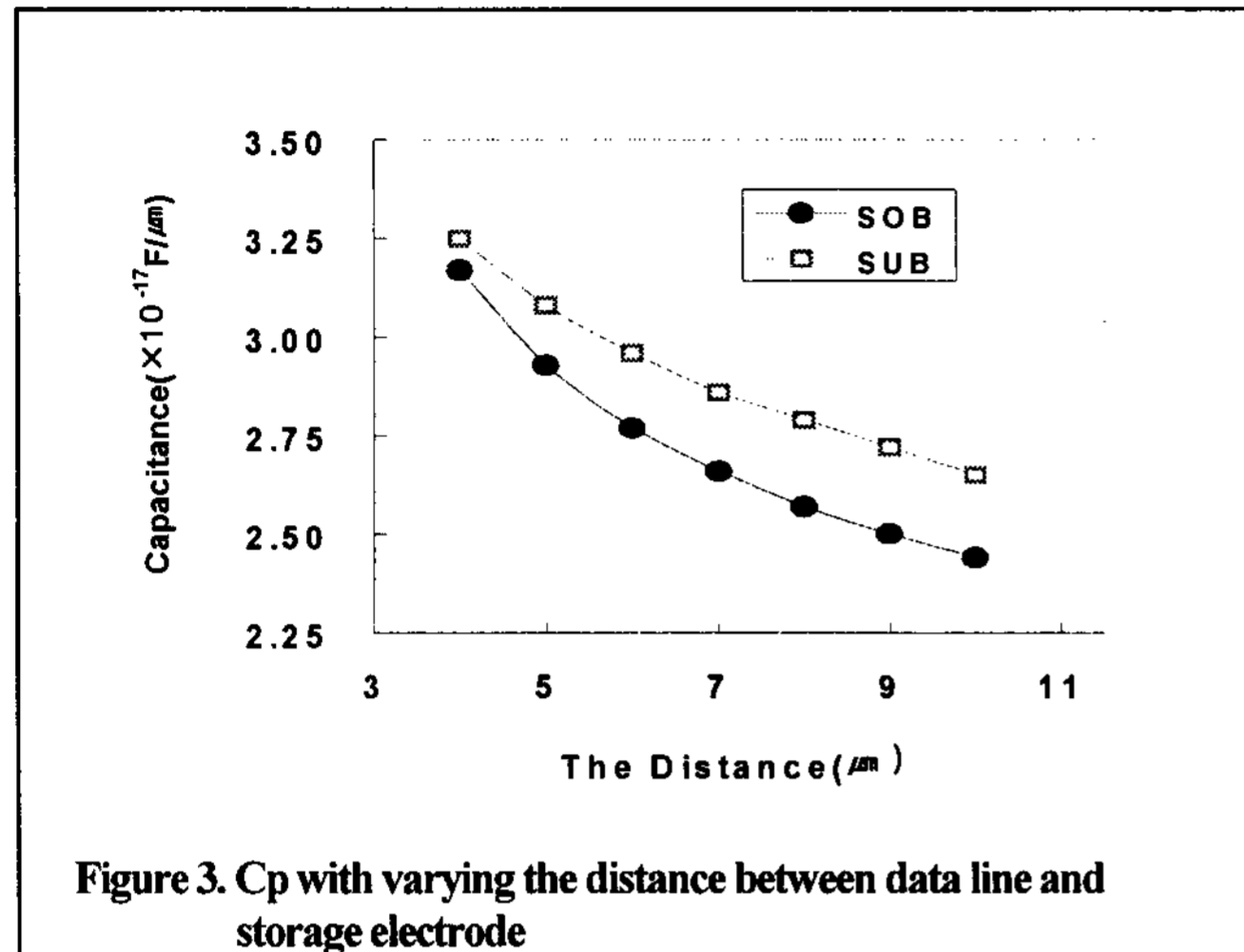

Figure 3. Cp with varying the distance between data line and storage electrode

Device Fabrication

The new device is manufactured following the process sequence as below. 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 pattering the data line and common (COM) line, 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.
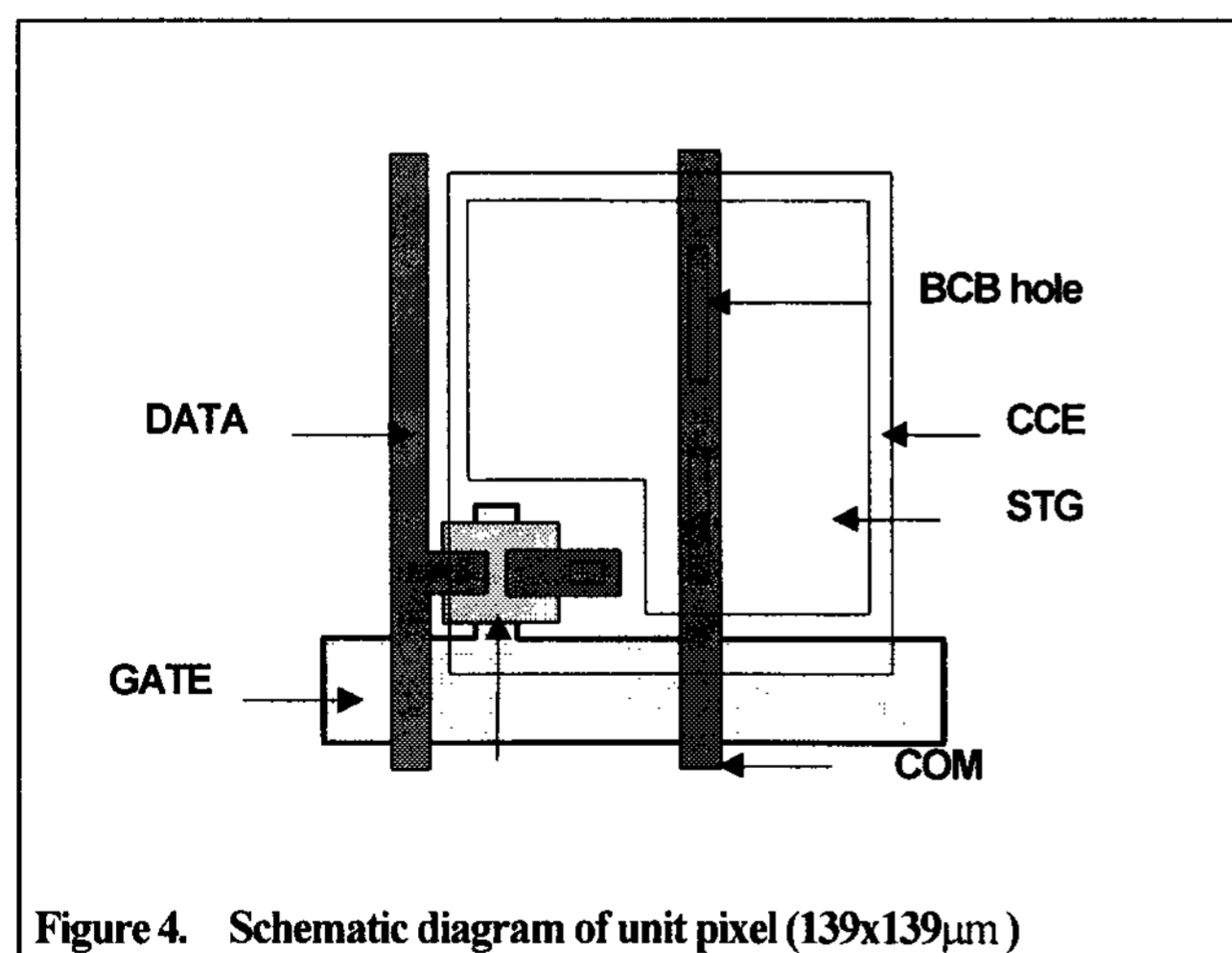

Figure 4. Schematic diagram of unit pixel (139x139μm)

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 μm μm, 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.

Summary

21.6" full size X-ray detector with novel SOB structure has been fabricated. Typically, the on resistance of TFT, R_{on} is less than $2.9 \times 10^7 \Omega$ (at Vgs=+7V, Vds=+10V), $1.4 \times 10^7 \Omega$ (at Vgs=+7V, Vds=+1V) and off resistance, R_{off} is more than $3.7 \times 10^{14} \Omega$ (at Vgs=-5V, Vds=+10V, +25V). The typical value of storage capacitance is 2.1pF which is suitable value for a good X-ray image.

References
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