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Reduction of the Sensitivity Non-Uniformities in a 2-Million Pixel CCD Imager Overlaid with an Amorphous Silicon Photoconversion Layer

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A new model for sensitivity non-uniformities in a 2-million pixel CCD imager overlaid with an amorphous silicon photoconversion layer, has been proposed. The origin of that phenomenon has been clarified with this new model.

As a results of analysis and improvement for pixel structure in the imager, much higher sensitivity uniformities has been realized and better quality pictutre for HDTV have been achieved.

1.INTRODUCTION

Recently, there has arisen an urgent need for a solid state image sensor adapted to the HDTV camera system. To answer the requirment for the HDTV camera system, horizontal limiting resolution must be over 1000 TV lines. Therefore, to obtain so much horizontal limiting resolution, there must be 4 or 5 times as many pixels as in conventional solid state imager. However, the imager area cannot be enlarged, because of the optical format regulation, so that the unit pixel area has to be sacaled down. However, when pixel area is reduced, the signal charge quantity is dcreased and bandwidth is expanded. Consequently, the imager S/N ratio degraded. Therefore, to improve the S/N ratio, the apperture ratio must be increased to increase the siganl charge. So, the authors have previously reported that a 2-million pixel CCD imager, overlaid with an amorphous silicon (a-Si) photoconversion layer for HDTV, resulted in high sensitivity and high resolution.[1)] However to find applications, much higher uniformity in sensitivity is reaquired for imagers.

So far, the origin of sensitivity non-uniformities has not been clarified. The authors eliminated causes for sensitivity non-uniformities, such as variation in electrode area, and non-uniformities in a-Si layer film characteristics. However, the sensitivity non-uniformities still remaind.

In this work, a new model for determining sensitivity non-uniformities has been proposed and analyzed. Also, the origin of that phenomenon has been clarified.

2.DEVICE STRUCTURE

A cross section of a unit pixel in this imager is shown in Fig.1. The incident light generates signal charges (electron). The signal charges are collected at the pixel electrode by voltage applied between transparent electrode(ITO) and pixel electrodes, and the signal charges are storaged at storage diodes. When the storage period is terminated, the signal charges are transfered to vertical buried chanel CCD (V-CCD) resister. Afterwards, the signal charges are transfered in V-CCD. This imager contains no isolation structure between pixels, so the aperture ratio is almost 100%.

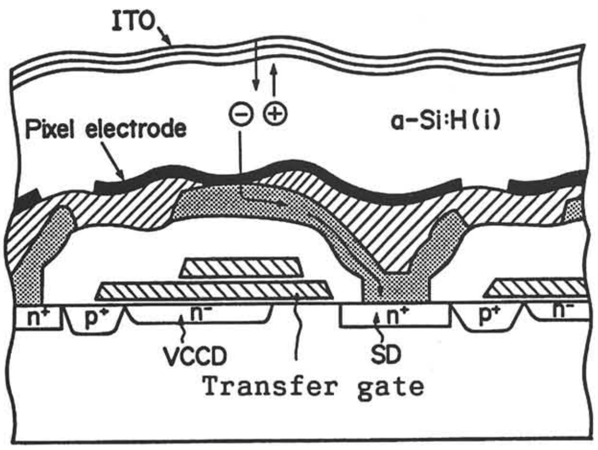
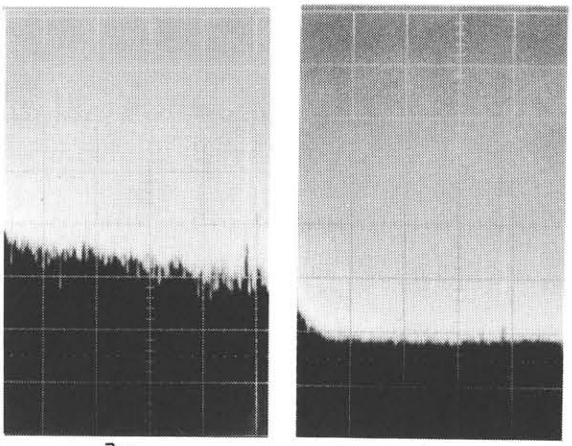


Fig.1 Unit Pixel Cross Section.

3.ANALYSIS and DISCUSSION

The sensitivity non-uniformities have been evaluated as follows. A uniform light is applied incident to this imager vertically, the scanning line in a reporoduced monitor is selected. The signal outputs from individual pixels have been measured. In Figs.2a and 2b, the signal outputs from individual pixels are shown.

As shown in Fig.2a, the output variation for individual pixels is very large. On the other hand, the vatiation indicated in Fig.2b is small, compared with that in Fig.2a. These variations in signal output are due to the non-uniformities in sensitivity. Therefore, sensitivity non-uniformities are defined as the difference between the maximum output and minimum output.



2a 2b

Figs.2 Signal wave form photographs

Various device structures have been fabricated and non-uniformities have been evaluated. As a result of evaluations, it has been clarified that the sensitivity non-uniformities have been correlated with a pixel electrode structure and the voltage applied between ITO and pixel electrodes. Therefore, a new model for sensitivity non-uniformities has been proposed, as follows.

Although the a-Si layer has high resistivity, when light falls on the layer, the carriers generated reduce the layer resistivity, and the carriers are able to diffuse in the a-Si layer. As a result, the quantities of signal charges, storaged in the storage diode, were varied and imger sensitivity degraded.

The equivalent circuit for this imager is shown in Fig.3. The upper gate corresponds to the ITO, and source/drain means individual pixel electrodes. When individual channel potentials under the transfer gate are not equal, leakage currents flow between source and drain.

The potentials for storage diodes were determined at the channel potential under the transfer gate, when the gate is turned on. So, if the potential under the transfer gate has been varied, the carriers were able to move between pixels. The potential variations have seemed to occur due to the short channel effect of the transfar gate.

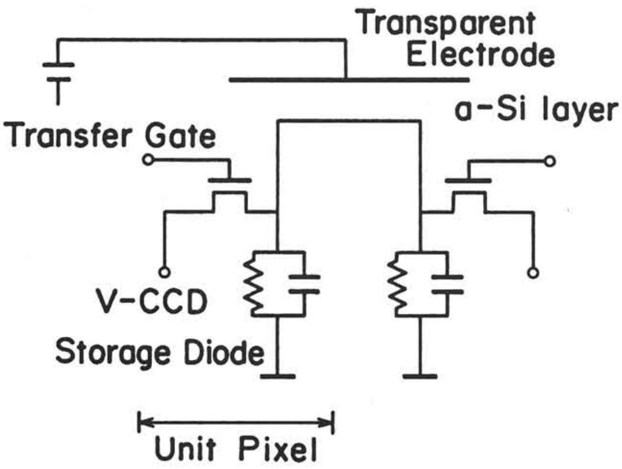


Fig.3 Equivalent circuit for unit pixel.

The potential variations under the transfer gate have been evaluated with test elements and the number of carriers moving between pixels has been calculated with simulations. Fig.4 shows the results of these simulations. It was clarified that a channel, along which signal charges can flow, is formed between the side wall of a pixel electrode and the wall of an adjacent pixel electrode along the insulating layer. The conductance of this channel is modulated by the pixel electrode structurte and the voltage applied between ITO and pixel electrodes. With these simulations, the quantitiy of signal charges flowing between pixel electrode in a field period (1/60 sec) have been calculated.

In Figs.5, 6 and 7, non-uniformities dependence on the pixel electrodes thickness, gap length between pixel electrodes, and applied voltage between ITO and pixel electrode are shown. As shown in Fig.4, as the pixel electrode thickness was reduced, the channel conductance was reduced and sensitivity uniformities was improved. As indicated in Fig.5, as the voltage increased, the channel depth was reduced and channel conductance fell.

As Fig.6 shows, as the gap length (corresponds to channel length) increases, resistivities of the channels between pixel electrodes were increased, so that sensitivity non-uniformities were improved.

In these figures, the calculated values and measurement values agree very well with each other.

As discussed above, it is concluded that non-uniformities in sensitivitity values for this imager occurred mainly due to the leakage currents flowing between one pixel electrode and an adjacent electrode. Consequently, the sensitivity quanties of each pixel were varied, so that the imager sensitivity has been degraded.

4 CONCLUSION

In a 2-million pixel CCD imager, overlaid with an amorphous silcon photoconversion layer, sensitivity non-uniformities has been analyzed and reduced. A new model for determining the sensitivity non-unifommities has been proposed and analyzed with sumulations. This phenomenon has occured mainly due to the leakage currents flowing from the side wall of the pixel electrode and the side wall of adjacent pixel electrodes, along the insulating layer. By optimizing the pixel electrode structure, much higher sensitivity uniformities have been realized and good quality pictures for HDTV have been achieved.

5 REFERENCES

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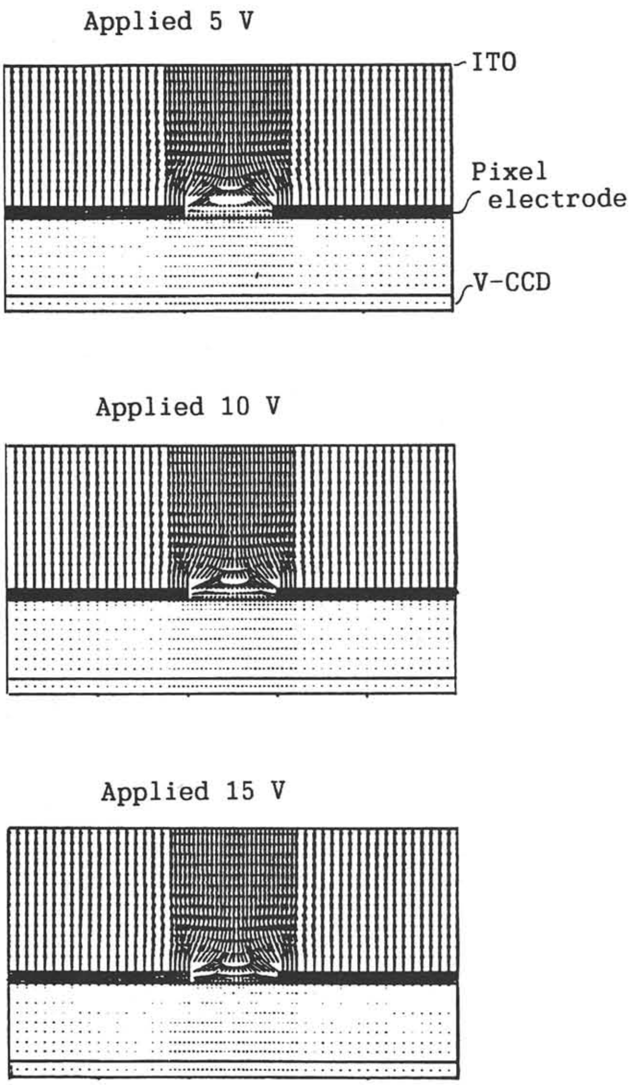

Fig.4 Simulation results

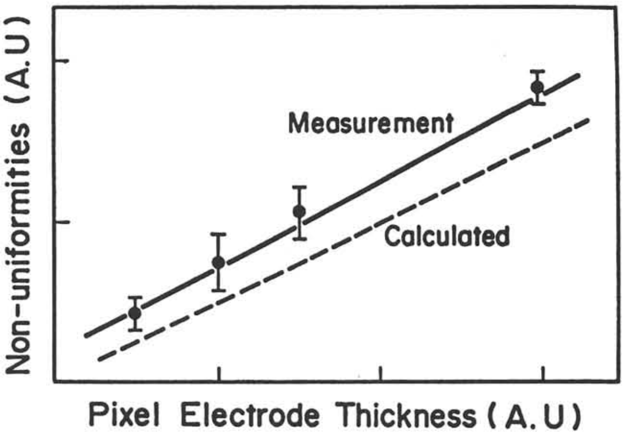

Fig.5 Relationship between non-uniformities and pixel electrode thickness.

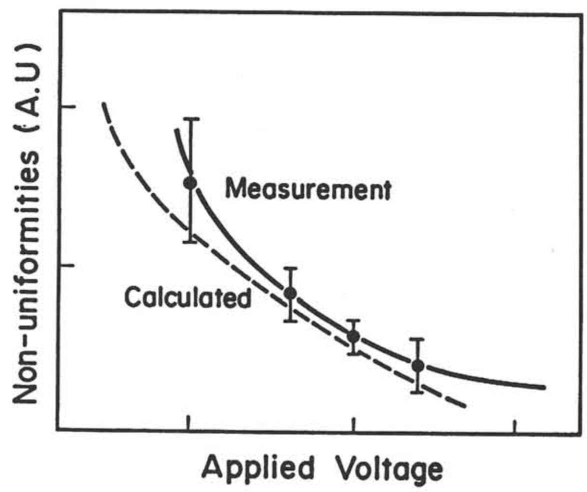

Fig.6 Non-uniformities bias dependence. The bias is applied between ITO and pixel electrode

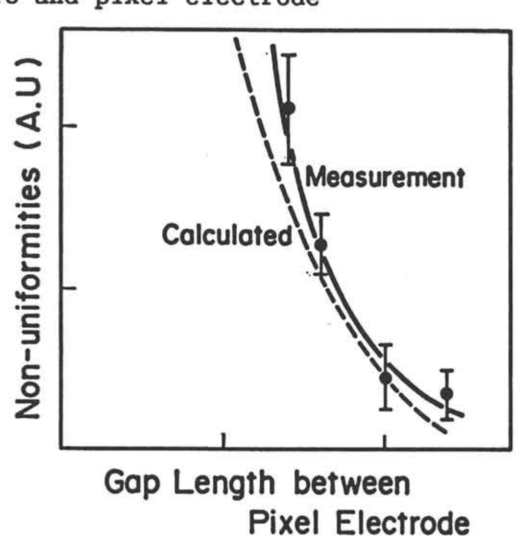

Fig.7 Gap length vs. non-uniformities.