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Green Color PCEL Device Stacked with n-i-n a-SiC Photoconductor on ZnS:TbOF TFEL

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Green Color PCEL(photoconductor electroluminesecent) devices have been developed. A series of technical data on the fabrication processes and operational device characteristics will be reported. The systematic operational data shows that memory margin ΔV, luminance L_{mid} and threshold voltage $V_{on/off}$ are strongly dependent on the operating frequency and an anomalous low operational voltage points has been found. The mechanism of these anomaly will be explained by cell impedance variation with the photoconductive modulation in an optoelectronic self-feedback system in the multilayered structure. On the basis of these analyses, a new concept of optimum design will be proposed and discussed.

1. Introduction

Among the various flat panel display devices such as liquid crystal display (LCD), plasma display panel (PDP), electroluminescent (EL) panel have a number of attractive features. That is; a) a high resolution, b) excellent visibility, c) large area flat panel display and d) low power consumption. In the meanwhile, a remarkable progress has also been seen in the amorphous silicon alloy technologies. The significance of this material innovation is that one can control electrical, optical and optoelectrical properties by changing atomic compositions in the mixed alloys. In consequence, a variety of optoelectrical devices such as a-SiC:H/a-Si:H heterojunction solar cells, a-Si thin-film transistor for LCD have been developed, based on new electronic materials. We have combined above two technologies and developed a new type of green color imaging display having image storage function. Although the principle of imaging memory function is similar to that of the ordinary PCEL (photo-conductive electroluminescent) device and the SEBIC (Sustained Electron Bombardment Induced Conductivity) device, the present device has some significant merits in not only its production process for cost reduction but also device performance.

2. Fabrication of the PCEL device

Figure 1 shows a cross-sectional view of PCEL device. On a glass substrate coated with indium tin oxide (ITO) transparent electrode, insulating layers of a-SiNx:H(2000Å) were deposited at 250℃ by rf-plasma CVD method. The ZnS:TbOF emitting layer (6000Å) was deposited by an electron-beam evaporation method at 350℃ and annealed at 500℃ in the vacuum for an hour. The n-i-n a-SiC PC layers were deposited on this EL structure by rf-plasma CVD at 250℃. During the deposition of i- and n- PC layers, the gas flow rate was kept at a ratio of $[CH_4]/[CH_4]+[SiH_4]=60\%$ and $[CH_4]+[SiH_4]=60$[sccm]. The n-layer of PC cell was prepared by feeding PH_3 into the gas mixture of CH_4 and SiH_4.

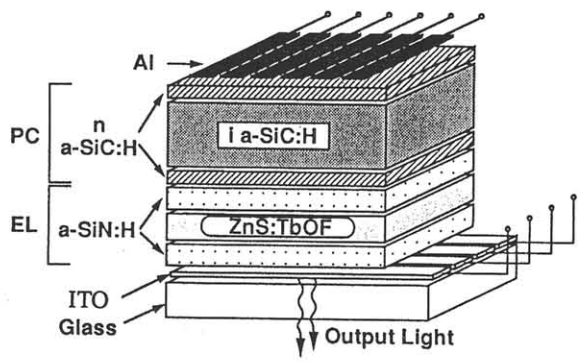


fig. 1 Cross-sectional structure of the PCEL device.

3. Device performance of PCEL device

EL devices with no PC layers show the maximum luminance of 370cd/m^2 and 1350cd/m^2 at 1KHz and 5KHz, respectively. On the other hand, the maximum luminance of the PCEL device reveals around 200cd/m^2 at 5KHz. By a I-V measurment, it was found that the i-layer of the PC cell has an order of magnitude

of 10^{-12} [S/cm] and 10^{-7} [S/cm] in the dark conductivity and the photoconductivity, respectively. It should be noted that the difference between these conductivities is somewhat large, compared with that of the i-layer prepared at the other gas flow rate. The optical band gap of the i-layer was measured by the absorption spectrum analysis and found to be around 1.81 eV. On the other hand, the conductivity of the n-layer ranges from 10^{-4} [S/cm] and 10^{-3} [S/cm] depending on the flow rate of PH_3.

Figure 2 shows the dependence of the memory margin ΔV on the i-layer thickness of the a-SiC PC cell. As illustrated from this figure, increases with increasing i-layer thickness of a-SiC PC cell. However, an optimum thickness for ΔV exists around at 2μm. This result may be due to the depth of penetration of green-color emission from the EL cell. The i-layer above 2μm will work only as a high resistive layer.

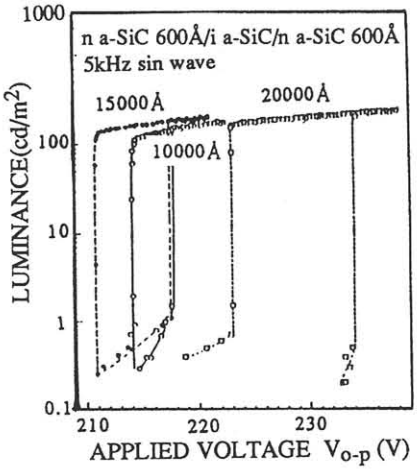


fig. 2 Luminance-Voltage characteristics in PCEL devices having various thickness of i a-SiC photo-conductor layer.

Figure 3 shows the dependence of ΔV on the PH_3 flow rate during the deposition of the a-SiC n-layer. One finds that ΔV is very sensitive to the PH_3 flow rate, whereas the conductivity of the n-layer rises up simply with increase of the PH_3 flow rate to 40[sccm], saturated at the PH_3 flow rate of more than 40[sccm]. Provided that the increase of the n-layer conductivity results to the increase of ΔV to some extent, the use of μc-SiC with high conductivity and wide band gap as n-layer will lead to better result.

The dependence of ΔV and luminance L_{mid} in the middle of V_{on} and V_{off} on the thickness d of a-SiNx insulator have been plotted in Fig. 4. When d is small, the maximum luminance L_{max} of the EL device with no PC layers L_{max} and the threshold voltage (not shown in Fig. 4) are lower, while L_{mid} is higher and ΔV has the

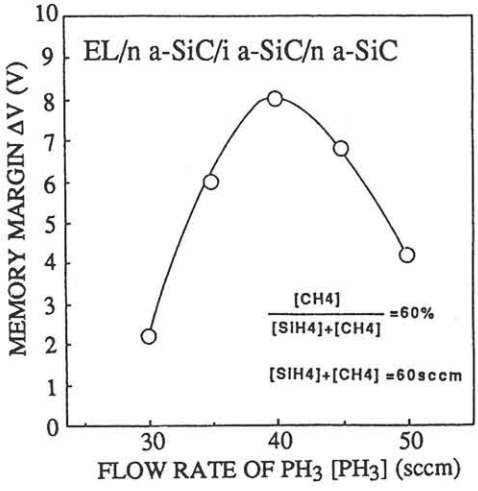


fig. 3 Dependence of memory margin ΔV upon the flow rate of PH_3.

maximum value at around 200Å thickness of a-SiNx. It should be noted that the EL devices with no dielectric interlayer or semi-insulating Y_2O_3 layer in place of the SiNx insulator, didn't have the memory effect in the L-V characteristics, although they have the same maximum luminance as the EL devices with SiNx insulator and their threshold voltage is higher than that of the EL devices with no PC layers. If the a-SiNx with very thin thickness of below 100Å or semi-insulating Y_2O_3 insulator is used as a dielectric interlayer, electrons can be injected directly between the PC layer and the EL layer by the tunneling and the defect conduction, resulting in no hysteresis effect of the PCEL device. Thus, it is concluded that the memory effect needs the blocking of free electrons between the PC layer and the EL layer.

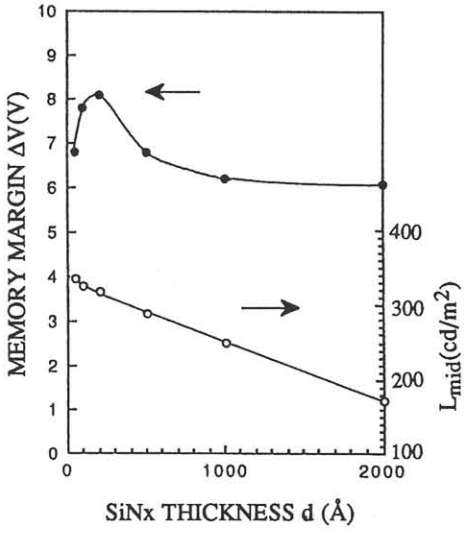


fig. 4 Dependence of memory margin ΔV and L_{mid} upon the thickness of dielectric interlayer SiNx.

Figure 5 shows the frequency dependence of the luminance, the threshold voltages, and ΔV of the PCEL. It is suggested strongly from this data that ΔV, the threshold voltage for switching on/off and the luminance under the voltage in the middle of V_{on} and V_{off} depend on the operating frequency. The mechanism of these anomaly will be explained by the cell impedance variation with the photo-conductive modulation in an optoelectronic self-feedback system in the multilayered structure. Full utilization of this characteristics, we could set an optimum operation frequency for the low threshold voltage device.

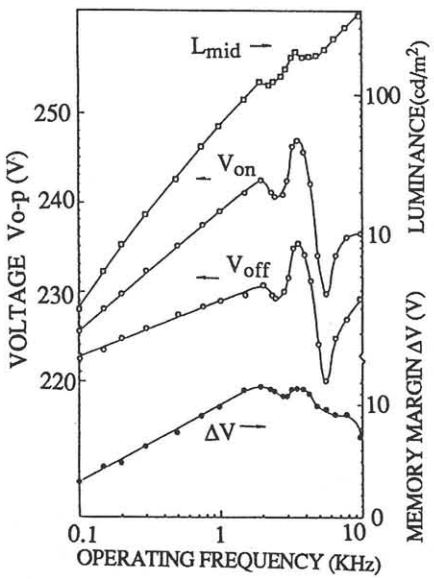
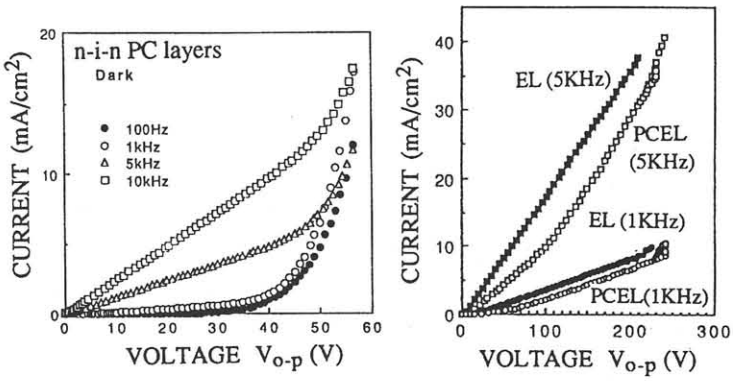


fig. 5 Dependence of the threshold voltage for switching on/off, memory margin and luminance under the voltage in the middle of V_{on} and V_{off} upon an operating frequency

Figures 6(a) and 6(b) show the I-V characteristics of the PC layers(glass/ITO/n a-SiC/i a-SiC/n a-SiC/Al) and the EL layer with no PC layers for the different operating frequency. The effective current of PC layers at a lower driving voltage increases with increasing an operating frequency due to the capacitance component by potential barrier of the i-layer. On the other hand, at a high driving voltage of above 50V the opposite phenomena that the current at a lower operating frequency flows more than that at a high operating frequency take place. In the PCEL device, as the PC layer is combined directly with the EL layer, the effective current of the PC layer flows the same as that of the EL layer. The change of the frequency dependent-current in PC layers like this manner of the cell impedance variation mechanism may result in the anomalous phenomena of the L_{mid}, V_{on}, V_{off} and ΔV, as shown in Fig. 5.



(a) (b)

fig. 6 I-V characteristics of the PC cell (a) and the EL cell (b) on the various operating frequencies.

4. Conclusion

Green color PCEL device stacked with n-i-n a-SiC photoconductor on ZnS:TbOF TFEL available for an image storager has been researched. From the obtained results, it has been found that memory margin of the important element to work efficiently as an image storager depends strongly on i-layer thickness or the n-layer conductivity of the a-SiC PC cell and an operating frequency. The maximum memory margin have ever been around 12V. However, further improvement in device performances is expected by controlling band gap and dark or photo-conductivity of i- and n-layer consisting of the a-SiC PC layers, matching I-V characteristics of the PC cell with that of the EL cell.

5. References

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