High Mobility Oxide and Novel Dual-Gate Pixel Structure Application to Gaming Notebook LCDs

Jiandong Guo, Xibin Shao, Zhangtao Wang, Yanping Liao, Zhonghao Huang, Taiye Min, Xiaoyuan Wang, Kunkun Gao, Huan Zhou, Xu Wu, Haipeng Zhu

BOE Technology Group Co., Ltd., Beijing, China

Abstract

A novel dual gate pixel structure disrupts the vertical periodicity of pre-charged and non-pre-charged pixels in sky blue image, which is sensitive to human eyes. Combined with high mobility oxide technology, it can solve the problem of vertical stripes caused by insufficient charging at WQ 165Hz, ensuring the display quality.

Author Keywords

High mobility, novel dual gate, charge, cost-effective, metal com.

1. Introduction

The general pursuit of high cost-effective gaming notebook has become a trend in the coming years. There are two technologies that can achieve cost reduction to improve cost-effectiveness by reducing the number of ICs, while the main specifications such as resolution, refresh rate, response time etc. still meeting the need of gaming products. One is mux technology by reusing one data channel for two columns of pixels in order through a set of TFT, but it will experience a significant forward shift in the long-term operating casing decrease in driving capability. So it is suitable for LTPS with high mobility (100cm^2/Vs) to ensure sufficient driving capability of mux TFT. The other is dual gate technology by doubling the number of gate lines while reducing the number of data lines. It is used in a-Si (1cm^2/Vs) and traditional oxide (10cm^2/Vs) process, but difficult to support higher resolutions above QD and larger refresh rates above 120Hz due to the relatively slow charging speed. It may cause periodic vertical stripes in sky blue image, which is sensitive to human eyes.

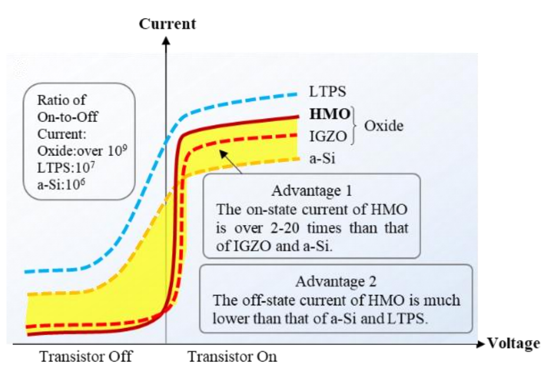


Figure 1. The advantages of HMO Oxide compared with a-Si and LTPS

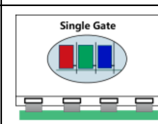
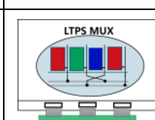
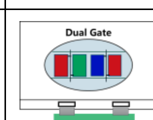
This paper reports that we used a novel dual gate pixel structure with high mobility oxide (HMO for short, 20cm^2/Vs) process to solve vertical stripes in sky blue image. It disrupts the vertical periodicity of pre-charged and non-pre-charged pixels by swapping the opening order of red and green pixels, and reduces the brightness difference between pixels by increasing mobility of TFT devices to improve charging rate. The |NBTIS| and PBTS of TFT devices measured less than 2V, it can still maintain good image quality performance over long-term use. In addition, as shown in Figure 1, high mobility oxide TFT devices have lower off state currents, performing better than LTPS and a-Si at low frequencies of less than 40Hz, making it compatible with office needs, dual-use, and more cost-effective [1-2].

2. HMO Dual Gate Gaming Technology

2.1. HMO Dual Gate Advantage

As shown in Table 1, we conducted a thorough and detailed review and analysis of the advantages and disadvantages of various technologies based on the WQHD platform. Compared with single gate and LTPS mux technologies, HMO dual gate gaming technology can support 30-165Hz in terms of refresh rate, which is medium and still meets the current mainstream gaming notebook needs. By optimizing the layout design, the L/R/U/D panel border can meet the requirements of 1.9/1.9/1.9/5.0mm. In terms of process, it is as the same as traditional oxide and does not require the additional mask process, making it simpler than LTPS. In addition, the source driver is only needed 2 pieces, which is lower in cost. At the same time, the PCB size can be made smaller due to the reduction in the number of ICs, which is beneficial for the overall design and more aesthetically pleasing. Therefore, it is more competitive and widely applicability to develop HMO dual gate gaming technology.

Table 1. The advantages of Dual Gate compared with Single Gate and LTPS Mux

Item	Single Gate	LTPS Mux	Dual Gate
Diagram			
Resolution	2560*1600	2560*1600	2560*1600
Refresh rate	20~240Hz	40~144Hz	30~165Hz
Process	Oxide 8mask	LTPS 9mask	HMO 8mask
Pixel	Column	Column+ Mux	DG Zigzag
Border	1.9/1.9/1.9/5.0	1.9/1.9/1.9/5.0	1.9/1.9/1.9/5.0
IC	4 EA	3 EA	2 EA
PCB	Large	Medium	Small
Price	High	Medium	Low

2.2. Novel Pixel Structure of Dual Gate

As shown in Figure 2(a), the traditional dual gate pixel structure is typically applied to low resolution (HD and FHD) and low refresh rate (60Hz) products. It is now necessary to improve to high resolution (QHD) and high refresh rate (165Hz). The pixel charging time has been reduced from 10.4 and 7.7μs to only 1.8μs, so the charging rate has decreased from 99% to below 90%. In common Windows or blue-green mixed images, the risk of vertical stripes has increased. As shown in Figure 3(a), the green and blue pixels are non-pre-charged in one column and pre-charged in the other column, exhibiting a clear periodicity. The

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brightness of non-pre-charged pixels is lower and pre-charged pixels due to insufficient charging, visually presented as vertical lines. To tackle this issue, we proposed a novel pixel structure by swapping the opening order of red and green pixels. As shown in Figure 2(b), the green pixels are always switching on before red pixels in each row. As shown in Figure 3(b), it is similarly analyzed the pre-charged and non-pre-charged pixels of the novel dual gate structure, the vertically periodic difference between the adjacent columns of blue-green mixed color pixels has been disrupted. Combined with high mobility oxide technology, the charging rate of non-pre-charged pixels has been improved to 95% above, greatly reducing the risk of vertical stripes.

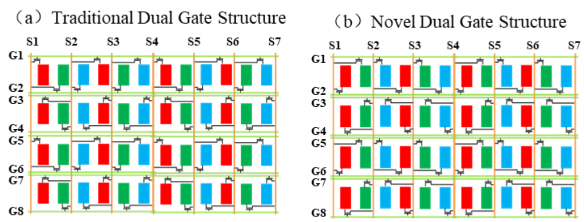

Figure 2. Novel pixel structure compared with traditional pixel structure of dual gate

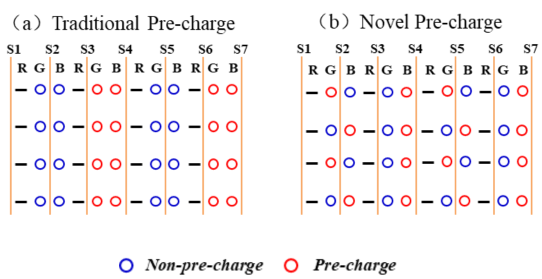

Figure 3. Pixel pre-charge under blue and green mixed color

2.3. Pixel optimization For Dual Gate Gaming

As shown in Figure 4(a), it is a schematic diagram of the traditional a-Si dual gate pixel design. To reduce the coupling pull of the gate signal line on the pixel ITO electrode signal, the TFT is usually set outside the gate line, which requires a winding design for the gate. In Figure 4(b), it is a schematic diagram of novel dual gate pixel design, with ITO1 as the com electrode and ITO2 as the pixel electrode. ITO1 covers all positions except for the pixel via. which can shield the coupling of the gate signal line to the pixel ITO2. Therefore, the TFT can be set between the two gate traces, and the gate does not need to be wound, reducing impedance by more than 10%. In addition, the metal common electrode lines inside the display screen usually use horizontal and vertical gate layers, and ITO2 cross line connection is required at the TFT gate line position. We propose using a vertical SD layer for the metal common electrode lines to fully utilize the dark area in the middle of the pixel, which can improve pixel light efficiency by about 2%. At the same time, a third layer of metal compatible design can be added, located directly above the data line without affecting the transmittance, as shown in the schematic diagram of the process stack structure in Figure 5. Metal3 is directly deposited on Com ITO1, which can further reduce the com impedance and improve the stability of com voltage. Due to only thin PAS2 layer separating ITO2 and Metal3, the Metal3 design needs to avoid the pixel ITO2 crossover position to prevent ITO2 disconnection caused by height difference. Based on the specific characteristics of the dual gate pixel structure, it needs to adopt only a 1/6 sub-pixel period of Metal3 design. In addition, Metal3 can use HTM Mask with ITO1 to save factory exposure capacity.

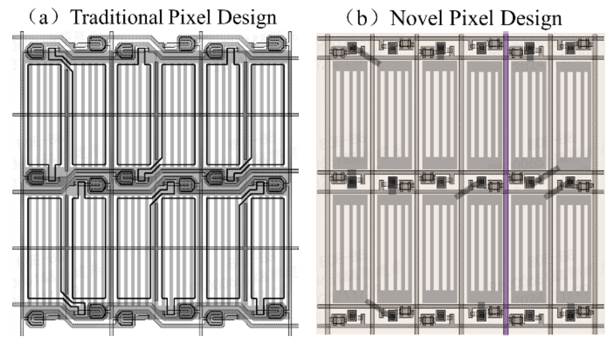

Figure 4. Pixel design schematic of HMO compared with a-Si

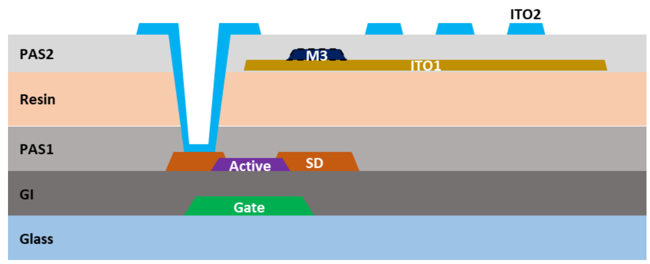

Figure 5. Cross section schematic of Device

2.4. Process Experiment

High mobility is achieved by adding rare metals to semiconductor materials to increase the content of conductive ions. In Figure 5, the HMO TFT devices were fabricated with the following layers. In the first step, a gate electrode was deposited and patterned using a wet etching process. Then, a gate insulation (GI) layer was deposited by PECVD. High mobility oxide (HMO) material was deposited using DC-Plus Sputter and patterned by wet etching process after gate insulation deposited. Source/drain (SD) electrodes were formed through DC sputtering and patterned using wet etching. Following that, a passivation layer (PAS1) was grown through PECVD. After that, an organic resin was coated and patterned. Subsequently, com ITO and Metal3 were deposited and patterned, and an anther passivation layer (PAS2) prepared by PECVD was used as the device protection layer and patterned. Finally, a pixel ITO was deposited and patterned.

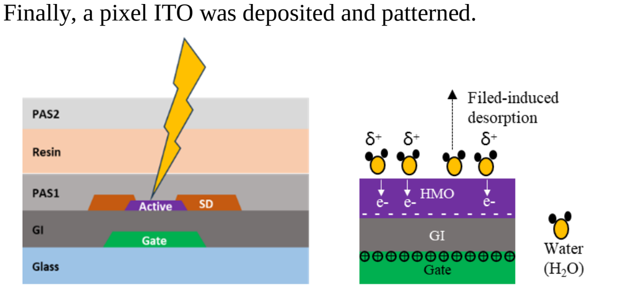

Figure 6. The Influence of Water Invasion on TFT Devices

With the increase of mobility, the carrier concentration and oxygen vacancy density of oxide TFT devices increase. As shown in Figure 6, if water vapor gradually penetrates the insulation layer and enters the TFT device during the production process or long-term use, it will cause hydrolysis of the semiconductor material and weaken the stability of the device. Therefore, for high mobility oxides, it is necessary to optimize the film-forming process conditions of PAS1 and PAS2, improve the density of the insulation layer, enhance the water oxygen barrier ability, reduce water vapor penetration, and ensure stable performance of TFT devices. [3-4]

3. Results and Discussion

Figure 7 shows the transfer characteristic curve of the HMO 8 mask BCE device. Three representative points of G8.5 Glass were tested. The TFTs exhibited a mobility of 24.3 cm2/Vs, a SS of 0.32 V/dec, and a Vth of 1.2 V. From the Figure 7, it is evident that the device demonstrates excellent uniformity, high on-state current and lower off-state current performance. It excellently meets the requirements of dual gate gaming products.

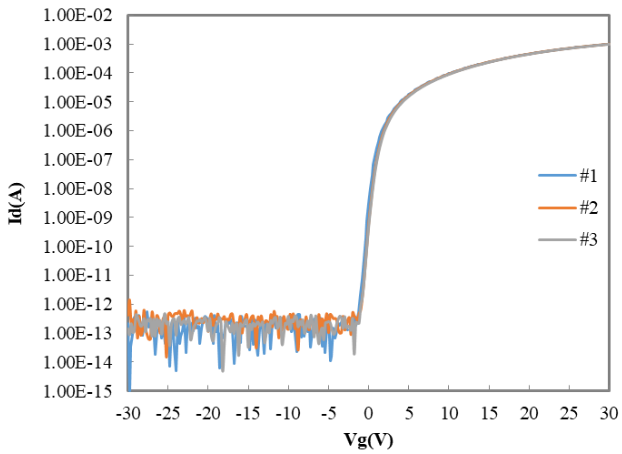

Figure 7. I-V transfer characteristics of HMO TFT

Table 2 compares the main characteristics of the traditionally prepared IGZO and HMO TFTs. It can be observed that the HMO device exhibits more than two times improvement in mobility and significant enhancement in stability, particularly with regards to NBTIS and PBTS characteristic.

Table 2. The TFT parameters of HMO compared with IGZO

Item	IGZO	HMO
Vth	2.0 V	1.2 V
SS	0.6 V/dec	0.32 V/dec
Mobility	10 cm^2/Vs	24.3 cm^2/Vs
⊿ Vth of PBTS	3.0 V	1.81 V
⊿Vth of NBTIS	-3.0 V	-1.24 V

Figure 8 (a) and (b) shows the Vth shift of HMO BCE TFT under NBTIS and PBTS respectively. The NBTIS |ΔVth| is less than 2V (TFT W/L = 6/5 μm, VGS = -30 V, VDS = 0 V, 60℃, 5000 nit, 3600 sec), while PBTS ΔVth is also less than 2 V (TFT W/L = 6/5 μm, VGS = 30 V, VDS = 0 V, 60℃, 0nit, 3600 sec). The excellent stability of the HMO TFT is due to innovative material system development. It is known that metal oxide materials typically achieve high mobility by increasing the proportion of indium in the material. But it often leads to a reduction in the material's band gap and easily forms numerous oxygen vacancies (VO) during device preparation, resulting in a deterioration of NBTIS properties. We introduced additional metal elements into high indium material systems. These elements absorb light through charge transfer transitions and subsequently return to their regular states through non-radiative transitions. This method not only achieves their high mobility characteristics, but also enhances the light stability of oxide materials [4~5].

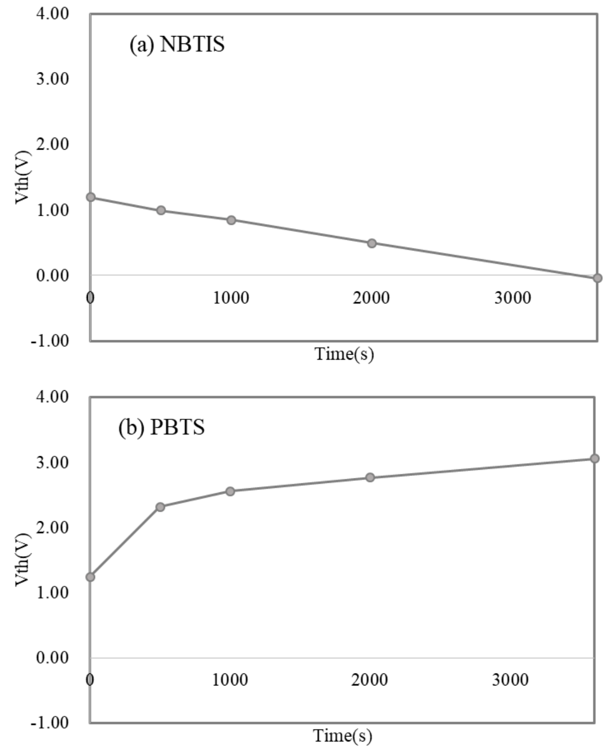

Figure 8. Vth shift of NBTIS (a) and PBTS (b)

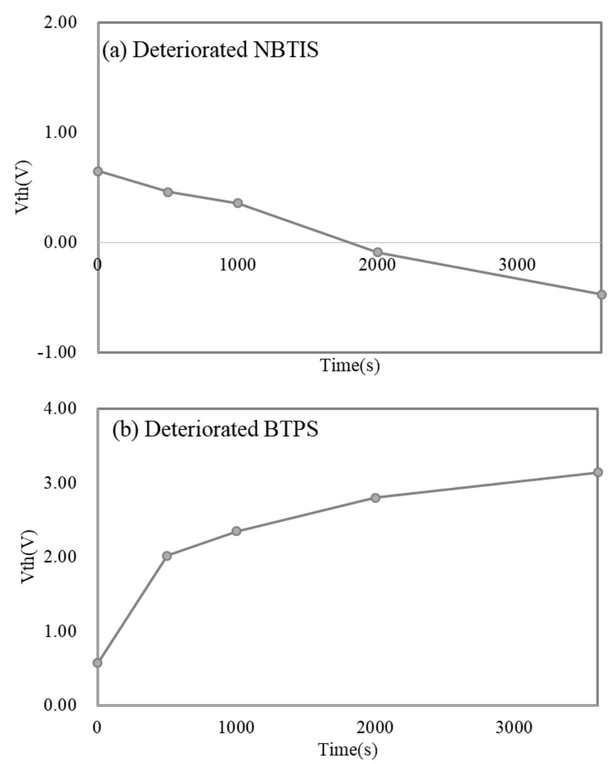

Figure 9. Vth shift of NBTIS (a) and PBTS (b) with water vapor at 85℃

Based on mentioned high mobility and stability TFT technology, to confirm the applicability of the HMO TFT in dual gate gaming products. We utilized it to produce WQHD 165Hz products combined with novel dual gate technology, and successfully passed strict image quality and reliability verification. Figure10 and Table3 show the picture of dual gate gaming notebook LCD display and the measured at least 5pcs main performance parameters, respectively.

Figure 10. WQHD 165Hz HMO Dual Gate Product

Table3. Panel specifications

Parameters	Specifications	Measured Ave.
Resolution	2560*1600	2560*1600
Pixel Density	189	189
Refresh Rate	165Hz	165Hz
TFT Mobility	20 cm^2/Vs	24 cm^2/Vs
Response Time	9 ms	8.5 ms
Contrast Ratio	1200:1	1280:1
Color Gamut	sRGB100%	sRGB100%

4. Conclusion

In this paper, a novel dual gate pixel structure with good image performance and com stability was used in notebook gaming LCD Displays, combined with high mobility and high stability oxide TFTs with |NBTIS| and PBTS less than 2V to improve charging speed. We optimized the TFT characteristic by modifying the parameters of PAS for this high mobility oxide material, enhancing the ability to hinder the invasion of water vapor, achieving good stability under high temperature and high humidity environments. Based on the WQHD platform, the maximum refresh rate can reach 165Hz, meanwhile other major specifications as same as single gate products. In the future, we will continue promoting this oxide TFT stability, as well as using dual gate technology in cost-effective product applications.

5. References

1. H. S. Seo et al. "Development of highly stable a-IGZO TFT with TiOx as a passivation layer for active-matrix display" SID' 10 Digest, 2010, 1132-1135

2. Zhuo Li et al. "The Technology of High-Mobility Oxide TFT for 14inch AMOLED Display" SID 2024 Digest, 2024, 1376-1377

3. Jae Kyeong Jeong et al. "Origin of threshold voltage instability in indium-gallium-zinc oxide thin film Transistors" Appl. Phys. Lett. 93, 123508 (2008)

4. Jie Huang et al. "High Mobility and High Light Stability Oxide Back-Channel-Etched TFT and Application to High-End LCD NB Production" SID 2024 Digest, 2024, 1414

5. Tai A H et al. Mobility enhancement of back-channel-etch amorphous InGaZnO TFT by double layers with quantum well structures [J]. IEEE Transactions on Electron Devices, 2019, 66(10): 4188-4192.