Influence of Hollow Cathode Gradient Diffuser in PE-CVD for SiO_2 on Performance and Reliability of IGZO TFTs

Yuhao Zhai[1],Wei Huang, Xiaobo Hu, Yupei Wang,Jinming Li,Jun Zhang, Qifeng Jiang, ,Conglong Zhang,Yifeng Yang

zhaiyuhao@tcl.com

[1]TCL China Star Optoelectronic Technology Co., Ltd. Guangdong, China

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Abstract

As display technology becomes more demanding in terms of size, resolution and refresh rate, high mobility thin film transistor(TFT) arrays is the focus of current research.In this work,The hollow cathode gradient (HCG) diffuser has been testified to be advantageous for the preparation of high performance devicees by comparison with the normal hollow cathode effect(HCE) diffuser. The mobility of the device prepared under HCG diffuser condition is 11.3cm/V, SS is 0.17V/dec and Vth shift is 0.5V. In addition, PBTS and NBTIS results also showed good stability of the device. These results indicate that HCG diffuser is beneficial to the development of high mobility display devices.

1. Introduction

Thin film transistors (TFTs) with oxide semiconductors have obtained more and more attention due to their easy fabrication process,good scalability and profemance [1], [2]. TFT with top gate (TG) self-aligned (SA) structure is the focus of recent researches for the implementation of ultra-high resolution display. However, there are some difficulty in the treatment of high mobility TG oxide TFTs such as metallization, the control of threshold-voltage (Vth) about short channels [3], gate insulator (GI) deposition process [4], film quality, and passivation. Among these, the GI film is most critical in controlling Vth and ensuring high stability. A high quality GI of SiO2 is necessary for TG TFTs to protect active layer away from deteriorating due to the hydrogen (H) incorporation into the active layer [4] or the free carrier source which is formed in the surface of the active layer. Hence,obtaining a high quality GI is one of the main means to improve the performance of TFT devices. Plasma enhanced chemical vapor deposition (PECVD) is used to deposite thin films at a low temperature with a high deposition rate. In conventional, the SiO2 is deposited by PECVD with HCE structutre, however, the uniform reliability of GI film prepared under PECVD with HCE structure is poor. This phenomenon is not expected to be observed in TG TFT devices. In this study,in order to obtain more excellent performance of the device, we focused on the equipment parts structure study of the fabrication of porous SiO2 film by PECVD, i.e. optimized diffuser structure, substituting HCG diffuser for conventional HCE diffuser. And finally,we proposed a novel and yet practical approach for producing a high-quality detector-grade porous SiO2 film. Our results strongly support the idea that the porous SiO2 film produced by HCG PECVD can meet the requirements of high performance TG TFTs devices.

2. Experiment

The SiO2 film are deposited on the glass substrate by the PECVD, and the diffuser structure is the only variable in the whole experiment .The schematic diagrams of these two difference diffuser are shown in Figure 1.Figure 1(a) is the structure of the HCE diffuser,and Figure 1(b) is the structure of the HCG diffuser. As can be seen from the figure 1(a), for the HCE structure, the cone of the edge region and the central region are the same.And HCG diffuser with deeper cone at the position of the edge is shown in 1(b).Figure 1(c) and 1(d) are the simulative thickness mapping of films prepared with HCE and HCG structures, respectively.From these figures it is clearly that HCG structure is more conducive to the formation of high homogeneity films.

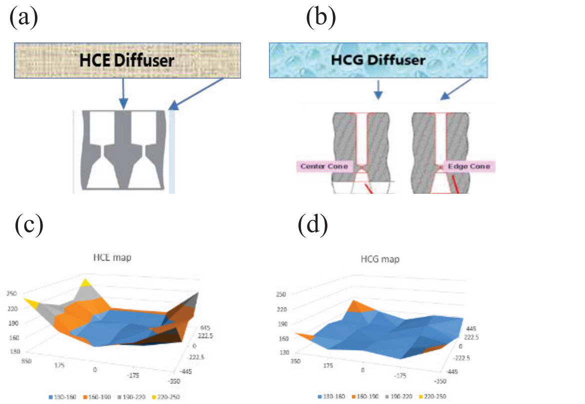
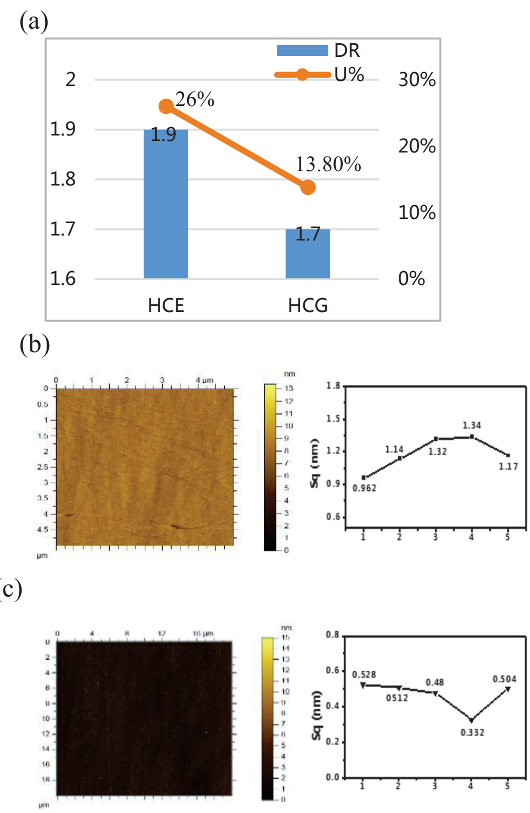


Fig. 1 Schematic diagram of (a) cone structure of HCE diffuser, (b) cone structure of HCG diffuser,(c) thickness mapping of HCE diffuser film, (d) thickness mapping of HCG diffuser film.

3 RESULTS

In order to verify the uniformity of the film prepared by the HCG diffuser is the same with simulation results, we chose the same recipe to prepare two samples and measured the uniformity of the film layer using Nanometer,the results are shown in Figure 2(a).Comparing these two measurements,the U% decreases from 26% to 13.8% and the deposition rate dropped slightly,from 1.9 to 1.7. As we know that the deposition rate plays a decisive role in the homogeneity, the quality of the film is berrer with the slower the deposition rate. The surface AFM pictures and the statistical graph of the roughness on the diagonal of HCG film and HCE film displayed in Figure 2(b) and 2(c) are used to illustrate this conclusion.Observed this two figures,all of this two films have a great surface topography .However, the change trend of roughness is just the opposite and the change is more uniform in HCG mode. The $\Delta Sq(\Delta Sq=|SqISO-SqSample|)$ of this two films are 0.126 and 0.589, respectively. The difference ofΔSq clearly indicate that HCG structure is more favorable for the growth of highly homogeneous films . In addition, we analyzed the influence of different process parameters on deposition rate and homogeneity, the results are summarized in Figure 2(d). From left to right, there are diagrams of influence of power variation on deposition rate and U%,variation of deposition rate and U% with pressure,the change of deposition rate and U% with spacing variation and the effect of N2O / SiH4 ratio on deposition rate and U%. Both HCG and HCE mode show the same trend of deposition rate and U% with process parameters. But, with HCG mode, the change of deposition rate and U% is smaller(10-18) than HCE mode, the smaller U% fluctuation is beneficial to the development of high performance IGZO devices. This is due to the structural differences between HCG and HCE diffusers. When the gas is piped in, it will dissociate in the diffuser due to electric field/wave action as shown in Figure 2(e). HCE diffuser has the cones of the same depth. The standing wave effect makes the power density in the centre area is higher than the edge area.And the thickness distribution of CVD films is positively correlated with the power density,therefor, the film appears thick at the edges and thin in the centre. The deeper cones structure at the edge of the HCG diffuser optimizes the thickness difference,this is because the deeper cone increases the path of electron oscillation, reducing the power density at the edge range, which will result in the decrease of the difference of film thickness,increasing the U%.



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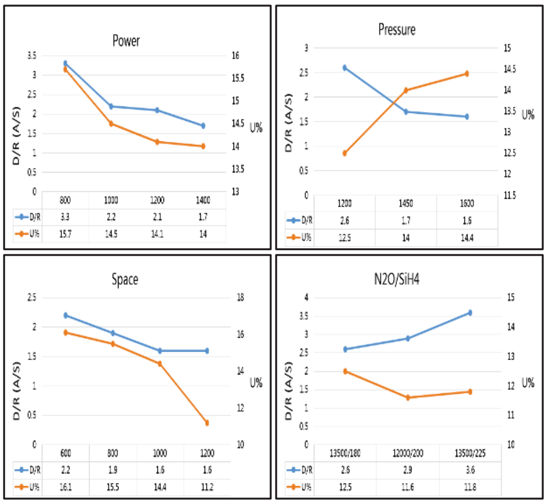

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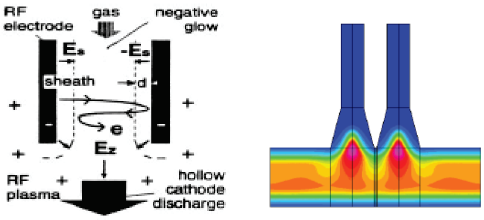
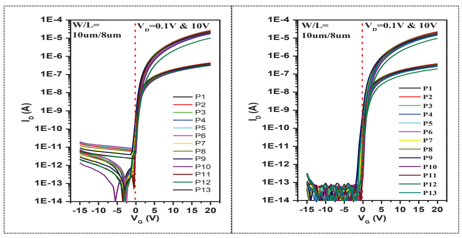


Fig. 2. (a) Deposition rates and U% in two diffuser modes.(b) surface morphology andΔSq of HCG diffuser film.(c) surface morphology andΔSq of HCE diffuser film.(d) diagram of the relationship between deposition parameters and deposition rate and U%.(e) diagram of gas dissociation in a cone.

In order to further prove the effect of HCG diffuser mode on device performance. The TFT devices in two diffuser modes were prepared and their mobility, Vth and SS were characterized respectively.Both samples with Mo as the LS and the thickness is 150nm.Then buffer SiO2 above it was deposited by HCG and HCE mode with the same process conditions. After 320 ℃ CDA annealing treatment for 1h, IGZO of 40nm thickness was used as active layer by PVD sputtering. To reduce the defects in IGZO and improve the performance of the device,the samples were treated 1h in a CDA atmosphere at 250℃ after sputting IGZO layer. Next GI layer was deposited, and the only difference between the two samples was the structure of the diffuser. After the same subsequent process, its electrical properties were characterized and shown in the following. Figure 3(a) and 3(b) are I-V graphs of samples prepared under HCE and HCG diffuser modes, respectively. The left graphs in 3(a) and 3(b) is the measurement result after PLN, and the right one is the I-V curve with the Bank process. Observed the curves in the figures and extract the relevant data about SS and Vth. The obtained results are summarized in the table 1.And the mobility is also displayed in this table,which is characterized by μ-PCD. The data in the table shows that the properties of PLN and Bank are basically the same in a single mode.However, the mobility in HCG mode is about 11.5cm/V approximately twice as much as that in HCE mode,which is 6.5cm/V.At the same time,comparing the Vth and SS of the two mode,not only the Vth in HCG mode is closer to 0V,but also the SS is smaller than it with HCE mode.All of this results indicates the films prepared in HCG mode have better electrical properties. On the other hand, the stability of the devices is also a fouces. Figures 3(c) exhibits the transfer Id-Vg characteristics of HCG modes under DC positive bias temperature stress (PBTS) and negative bias temperature illumination stress (NBTIS), respectively. The DC electrical stress conditions are Vg=±30 ,Vs,d=0 V and T=60℃ for 3600s.TheVth shift under PBTS and NBTIS are 0.28V and -1.87V. The transfer Id-Vg characteristics of HCE modes under DC positive bias temperature stress (PBTS) and negative bias temperature illumination stress (NBTIS) are exhibited in Figure 3(d). The DC electrical stress conditions are Vg=±30 ,Vs,d=0 V and T=60℃ for 3600s.The Vth shift under PBTS/NBTIS are 0.28V/-1.87V and 0.20V/-1.09V with HCG and HCE diffusers. By comparing Vth shift in the two modes, it can be clearly seen that there is no significant difference between them under PBTS, while NBTIS has a greater influence on the film preparated in HCG mode. This can be illustrated by the thickness of the film.

(a)



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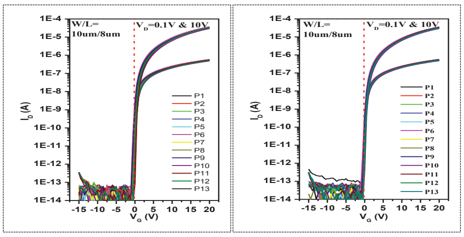

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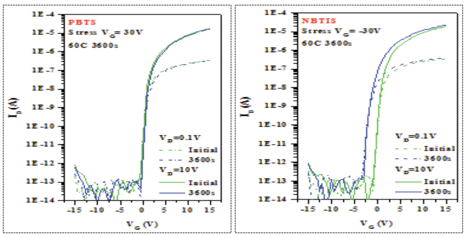

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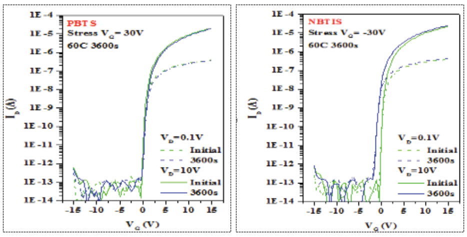

Figure 3

(a) I-V graphs of samples prepared under HCE diffuser.

(b) I-V graphs of samples prepared under HCG diffuser.

(c)the PBTS and NBTIS of the sample prepared under HCE mode.

(d) the PBTS and NBTIS of the sample prepared under HCG mode.

Table 1 The electrical performance of the samples with HCE and HCE diffusers.

Diffuser structure	HCE mode		HCG mode	
process	PLN	Bank	PLN	Bank
Mobility(cm/V)	6.5	6.5	11.5	11.3
SS(V/dec)	0.23	0.21	0.17	0.17
ΔVth(V)	1.25	1.2	0.78	0.5

4. Conclusion

The devices under differet diffuser mode had been preparated . The U% has been illustrated by roughness, ΔSq of the film preparated with HCG diffuser is 0.126, which is lower than it(0.589) with HCE diffuser. It demonstrates the PECVD with HCG diffuser facilitates the growth of highly homogeneous films. At the same time, the electrical properties of these devices have been analyzed.Under HCE mode the mobility of the device is 6.5V/cm, SS is about 0.2V/dec and Vth shift is 1.2V.And under HCG mode the mobility of the device is 11.3V/cm, SS is 0.17V/dec and Vth shift is 0.5V. The results further indicate that HCG diffuser is not only beneficial to the generation of high uniformity films, but also can improve the performance of the device. Therefore, HCG diffuser provides a new idea for the preparation of high performance oxide thin film semiconductor, which is beneficial to the development of AMOLED and other flat panel displays.

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