Low Temperature Ferroelectric Oxide TFTs for Display Application

Samiran Roy, Md Mehedi Hasan, and Jin Jang*

E-mail: jjang@khu.ac.kr

Advanced Display Research Center, Department of Information Display, Kyung Hee University, Dongdaemun-gu, Seoul 02447, South Korea

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ABSTRACT

We review the oxide TFTs with ferroelectric gate insulator (GI) for display application. The HfZrO layer with bottom ZrOx and top AlOx interlayers used for GI for ZnO and IGZO TFTs shows excellent ferroelectric properties We focus on how to make ferroelectric IGZO TFTs with a large memory window at low temperatures for display application. The HfZrO, covered with ZrOx and AlO_x, shows a high memory window.

1 INTRODUCTION

Recently, HfO_2-based ferroelectrics attract great attention because of many advantages such as large polarization, large memory window, wide band gap, and compatibility with the CMOS process. [1] Ferroelectric thin film transistors (FE-TFTs) have drawn a great deal of attention as memory devices, because

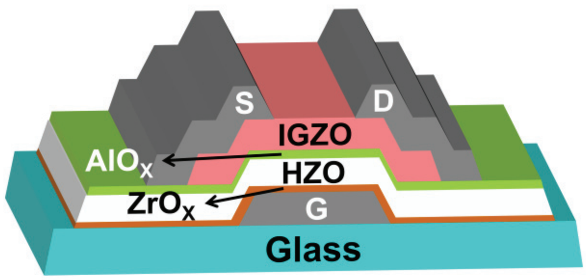

Figure 1. Schematic cross-sectional view of the IGZO with a ferroelectric stacked gate insulator HZO.

of the increasing demand for wearable systems. [2-4] Most of the ferroelectric HfZrO (HZO) thin film transistors (Fe-TFTs) have been reported by using TiN capping electrodes and different active layers.[5] The capping layer should be removed after the crystallization process for active layer deposition. This increases the process steps. We found that the ferroelectricity of the hafnia films can be improved using stack layers, which also would be compatible with

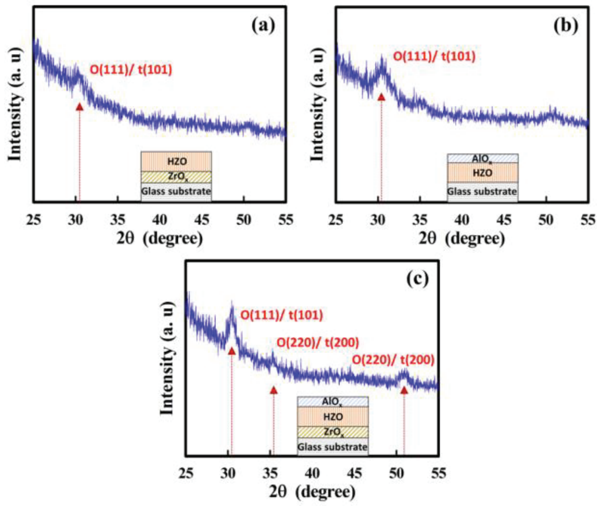

Figure 2. GI-XRD spectra of (a) ZrOx/HZO, (b) HZO/AlOx, and (c) ZrOx/HZO/AlOx films, respectively. All samples were annealed at 650 ^{0}C for 3 min in N_2 environment.[20]

flexible substrates. [6-10] **Table I** summarizes the reported FE-TFTs using HZO as the GI. T. Lu et al report ferroelectric HfZrO-based synaptic transistor with the sputtered α-InGaZnO as active layer shows memory window of 1 V. [11] C. Sun *et al. fabricated HZO-based BOEL compatible* α-InGaZnO FeTFTs with a large memory window of more than 3 V by using sputtering.[21] Here, we report FE-TFTs on glass substrate using ZnO/IGZO active layer for display applications with low temperatures. We used spray pyrolyzed stacked HZO with ZrOx and AlOx showing excellent ferroelectricity and a large memory window.

TABLE.1: Summary of the FE-HZO TFTs reported in the literature.

Bottom electrode	HZO deposition technique	Crystallization technique	TFT channel material	Channel deposition technique	Memory Window (V)	S/D electrode	Ref.
TiN	ALD	RTA (500 °C) in N_2 covered with TiN	IGZO	RF sputtering	~1 V	Mo	[11]
P+Si	ALD	RTA (500 ^{0}C) in N_2 covered with TiN	IGZO	RF sputtering	~1 V	Mo	[12]
TiN	ALD	350 ^{0}C furnace annealing	IGZO	RF sputtering	~1.8	Mo	[13]
TiN	ALD	RTA(400 °C) in N_2 covered with TiN	IGZO	RF sputtering	~2 V	Mo	[14]
TiN	ALD	RTA(500 °C) in N_2 covered with TiN	IGZO	RF sputtering	~1 V	Mo	[15]
TiN	ALD	RTA(400 °C) in N_2 covered with TiN	IGZO	RF sputtering	~2 V	Al	[16]
TiN	ALD	RTA(400 °C) in N_2 covered with IZO	IZTO	RF sputtering	~1 V	Mo	[17]
TiN	ALD	Annealing free	IZO	RF sputtering	~1 V	Mo	[18]
Mo	Spin coating	Furnace annealing (450 ^{0}C) in N_2	ZnO	Spray pyrolysis	~2.15	Mo	[19]
Mo/IZO	Spray pyrolysis	RTA (650 ^{0}C) in N_2	ZnO	Spray pyrolysis	3.2	Mo	[20]
W	ALD	RTA(400 °C) in N_2 covered with W	a-IGZO	RF sputtering	~3.2 V	W	[21]
TiN)	ALD	RTA(400 °C) in N_2 covered with Ti/Al	IGZO	RF sputtering	~1.1 V	TiN	[22]
TiN	ALD	RTA(500 °C) in N_2 covered with TiN	a-IGZO	RF sputtering	~2.19 V	Mo	[23]
TiN	ALD	RTA(500 °C) in N_2 covered with TiN/W	a-IGZO	RF sputtering	~2 V	Ti/Pt	[24]
Mo	ALD	FMA in N_2 covered with W	Al-doped IZTO	RF sputtering	~1.76 V	Mo	[25]
Mo	Spray Pyrolysis	RTA(500 °C) in N_2	IGZO	RF sputtering	~1.0 V	Mo	[26]
P+Si	ALD	RTA (400 ^{0}C) in N_2	IO/ITO	RF sputtering	~1.5 V	Mo	[27]

ALD= Atomic layer deposition, RTA=Rapid thermal annealing, N/A=Not applicable

2 RESULT AND DISCUSSION

We fabricated ferroelectric HZO based bottom-gate, top-contact structure TFTs with ZnO/IGZO active layers on the glass substrate as shown in Fig.1 using solution process. The detail of solution synthesis process appears elsewhere.[19]

Fig. 2a-c represents the GI-XRD pattern of the HZO thin film stacked with ZrO_x and AlO_x on glass substrate for improving ferroelectricity. A clear and distinct peak at 30.4° could be seen for all the films, which is due to ferroelectricity. But for the two layers stack the peak intensity is less. To further improve the ferroelectric performance, we fabricated stack GI, using ZrO_x, HZO, and AlO_x, where all the layers were deposited by spray pyrolysis showing robust ferroelectricity as show in Fig 2c. Ferroelectric behavior, bowknot feature hysteresis, could be seen in the capacitance-voltage (C-V) characteristics (not shown here). For ZrO_X/HZO -based devices, films were deposited by spin coating and crystallized by annealing the films at 450 °C for 2 h in an N_2 furnace. The active layer of the ZnO (30 nm) was deposited by spray pyrolysis showing the memory window of 2.15 V. [19] A large MW of ~3.2V could be obtained from the ZrO_x/HZO/AlO_x based TFT, as shown in Fig. 3(c). The improved ferroelectricity in HZO could originate from the different CTE of bottom ZrO_x and top AlO_x layer with HZO. [20]

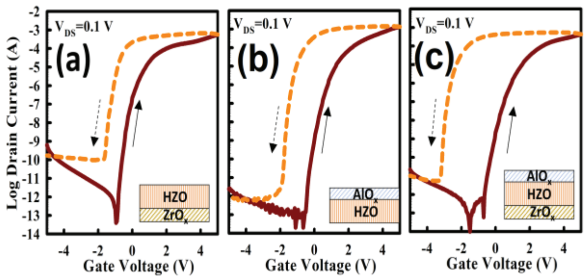

Figure 3. Transfer with hysteresis of IGZO/ZnO TFTs on spray coated (a) ZrOx/HZO, (b) HZO/AlOx, and (c) ZrOx/HZO/AlOx GIs, respectively. The TFT channel width and length are 50 and 10 μm, respectively for all devices.

3 CONCLUSION

We have developed low cost, ferroelectric HZO by using bottom ZrO_x and top AlO_x stack structure. The TFT on glass exhibits MW of 3.2 V, which is high enough for display application. The process could be done at less technique could be utilized.

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