Ferroelectric Oxide for Display Application

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ABSTRACT

We review the oxide TFTs with ferroelectric gate insulator for display application. The HfZrO, in between ZrO_x and AlO_x, shows the ferroelectric properties. We used this material for ZnO TFTs on glass. In this talk we will focus on how to make ferroelectric materials at low temperatures for the application to flexible ferroelectric electronics.

1 Introduction

Recently, HfO_2-based ferroelectrics attract great attentions because of many advantages such as large polarization in ultrathin, wide gap thin films, which can be compatible with CMOS process.[1] Ferroelectric thin film transistors (FE-TFTs) as memory devices have drawn a great deal of attention, because of the increasing demand for embeddable and wearable systems.[2] Most of the ferroelectric HfZrO (HZO) TFTs have been reported using vacuum deposition technique, and the ferroelectricity is induced by TiN capped layer. The capping layer should be removed for active layer deposition. This increases the process step and cost of fabrication. Table I summarizes the reported FE-TFTs using HZO as the gate insulator (GI).

We report a ferroelectric thin film transistor on glass substrates by cost effective, solution process. We found that the ferroelectricity of the hafnia films can be improved using stack layers, which would be compatible to flexible substrate

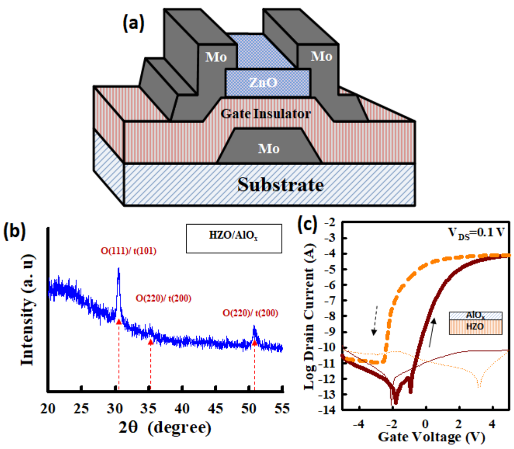

Fig. 1 (a) Schematic cross-sectional view of the fabricated ZnO TFT with a ferroelectric gate insulator. (b) GI-XRD spectra of HZO/AlO_x films on glass. (c) Transfer characteristics with hysteresis and corresponding leakage current of spray coated ZnO TFTs on stack HZO/AlO_x gate insulator.

2 Result and Discussion

We fabricated the ZnO TFTs on the glass substrate using HZO/AlO_x GI with bottom-gate, top-contact structure shown in Fig.1 (a). The detail of solution synthesis process appears elsewhere.[19] For HZO/AlO_x-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.

Fig. 1(b) represents the GI-XRD pattern of the HZO/AlO_x on glass substrate. A clear and distinct peak at 30.4° could be seen for the HZO/AlO_x film, which is believed to be due to the induced ferroelectricity in HfO_2 based film.[19-20] It is reported that AlO_x has the suitable thermal expansion coefficient (CTE) to induce

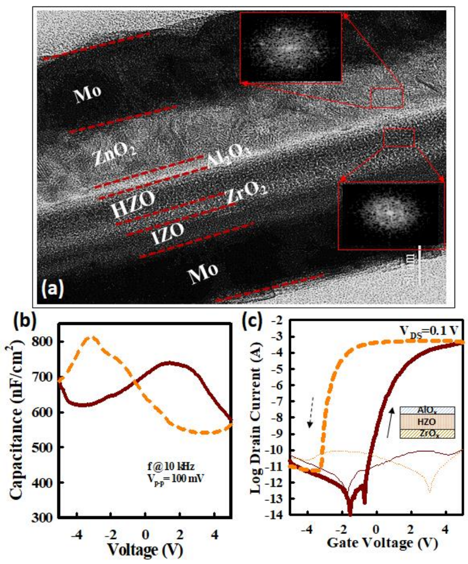

Fig. 2 (a) Cross-sectional transmission electron microscope (TFM) image of spray coated ferroelectric $ZrO_x/HZO/AlO_x$ gated ZnO TFT, inset of figure (a) shows the fast Fourier transform of ZnO and HZO, respectively, which confirm the c-axis grain growth of ZnO and polycrystalline structures of HZO. (b) Capacitance-voltage characteristics of $ZrO_x/HZO/AlO_x$ from MIM structure. (c) Transfer characteristics with hysteresis and corresponding leakage current of spray coated ZnO TFTs on stack $ZrO_x/HZO/AlO_x$ gate insulator.

Table 1 Summary of the FE-HZO TFTs reported in the literatures.

Bottom electrode	HZO deposition technique	Crystallization technique	TFT channel material	Channel deposition technique	Memory Window (V)	S/D electrode
Tin (Ref. 3)	ALD	RTA(430 °C) in N_2 covered with TiN	C_{60}	Thermal evaporation	N/A	Al
TiN (Ref. 4)	ALD	RTA(500 °C) in N_2 covered with a-GeSn	GeSn	Physical vapor deposition	1.6 V	Ni
TiN (Ref. 5)	ALD	Flash lamp (375 °C) in N_2	WO_x	RF sputtering	N/A	W
P++Si (Ref. 6)	ALD	RTA (500 °C) in N_2	WS_2	Exfoliation	~2.5 V	Ti/Au
TiN (Ref. 7)	ALD	Annealing free	MoS_2	Exfoliation	~1.3 V	Ti/Au
P++Si (Ref. 8)	ALD	RTA (500 °C) in N_2	ITO	RF sputtering	N/A	Ni
P++Si (Ref. 9)	ALD	RTA (400 °C) in N_2	ITO	RF sputtering	N/A	Ni
TiN (Ref. 10)	ALD	RTA(400 °C) in N_2 covered with IZO	IZO	RF sputtering	~3 V	Mo
TiN (Ref. 11)	ALD	RTA(500 °C) in N_2 covered with TiN	IGZO	RF sputtering	~1 V	Mo
P+Si (Ref. 12)	ALD	RTA(500 °C) in N_2 covered with TiN	IGZO	RF sputtering	~1 V	Mo
TiN (Ref. 13)	ALD	350 °C furnace annealing	IGZO	RF sputtering	N/A	Mo
TiN (Ref. 14)	ALD	RTA(400 °C) in N_2 covered with TiN	IGZO	RF sputtering	~2 V	Mo
TiN (Ref. 15)	ALD	RTA(500 °C) in N_2 covered with TiN	IGZO	RF sputtering	~1 V	Mo
TiN (Ref. 16)	ALD	RTA(400 °C) in N_2 covered with TiN	IGZO	RF sputtering	~2 V	Al
TiN (Ref. 17)	ALD	RTA(400 °C) in N_2 covered with IZO	IZTO	RF sputtering	~1 V	Mo
TiN (Ref. 18)	ALD	Annealing free	IZO	RF sputtering	~1.2 V	ITO
Mo (Ref. 19) *[Our work]	Spin coating	Furnace annea. (450 °C) in N_2	ZnO	Spray pyrolysis	~2.15 V	Mo
Mo (Ref. 20) *[Our work]	Spray pyrolysis	RTA (650 °C) in N_2	ZnO	Spray pyrolysis	~3.5 V	Mo

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

ferroelectricity in HfO_2 based film.[20] Anticlockwise hysteresis with a memory window (MW) of 1.95V, confirms the induced ferroelectricity in HZO/AlO_x GI in ZnO TFT.

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. Fig. 2 (a) shows the cross-section TEM images of the fabricated of ZnO TFTs with ZrO_x/HZO/AlO_x GI. Ferroelectric behavior, bowknot feature hysteresis, could be seen in the capacitance-voltage (C-V) characteristics [Fig.2 (b)]. A large MW of ~3.2V could be obtained from the ZrO_x/HZO/AlO_x based TFT, as shown in Fig. 2(c). The improved ferroelectricity in HZO could originate from the different CTE of bottom ZrO_x and top AlO_x layer with HZO.[20]

3 Conclusion

We have developed loe 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 than 450 °C so that the current flexible substrate technique could be utilized.

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