Fabrication of ferroelectric gate thin film transistors using CSD Y-HZO and sputtered HZO with sputtered ITO channel

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【Introduction】

Ferroelectric HfO_2-based materials have attracted much attention since the discovery of ferroelectricity [1]. Metastable orthorhombic phase (o-phase) is responsible for ferroelectricity in HfO_2 whose stability is important for device applications. In this work, ferroelectric gate thin film transistor (FGT) with sputtered indium-tin-oxide (ITO) channel have been fabricated using solution derived Y-doped Hf-Zr-O (HZO) and sputtered HZO films.

【Experiments】

Y-HZO film was prepared by chemical solution process (CSD) using the source solution consisting of $Hf(acac)_4$, $Zr(acac)_4$ and $Y(acac)_3$ in propionic acid (PrA) [2]. Y composition is 5%. CSD Y-HZO was fabricated by procedure reported previously and crystallized at 800°C in vacuum [3]. On the other hand, sputtered HZO film was deposited on TaN bottom electrode by co-sputtering [4]. Crystallization was done at 700 °C in N_2 for 10 min using rapid thermal annealing (RTA). To confirm the ferroelectricity, Pt top electrode was deposited by sputtering for metal-ferroelectric-metal (MFM) structure.

To fabricate metal-ferroelectric-semiconductor (MFS) structures for bottom-gate FGTs, 10-nm-thick ITO layer was deposited by sputtering at room temperature, followed by annealing at 600 °C in N_2 for 15 min. Then, Pt source and drain electrodes are patterned by the lift-off process and the device area was isolated by wet etching.

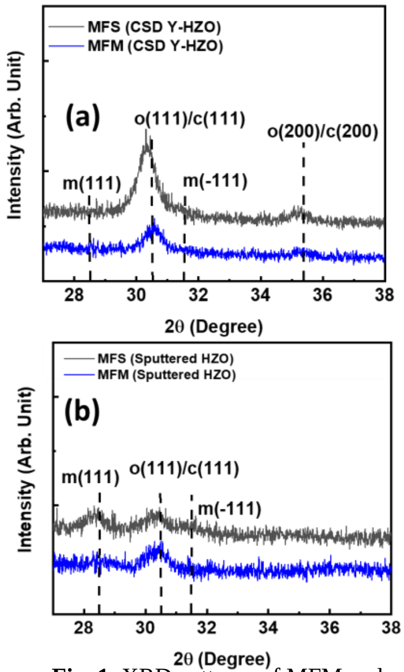

Fig. 1. XRD patterns of MFM and MFS structures with (a) CSD Y-HZO (b) sputtered HZO.

【Results and Discussion】

At first, we confirmed ferroelectric properties for both CSD Y-HZO and sputtered HZO MFM structures before the FGT fabrication. Figure 1 depicts XRD patterns of MFM and MFS structures using (a) CSD Y-HZO and (b) sputtered HZO films. The CSD Y-HZO samples show a diffraction peak around 30.5° which suggests the formation of o(111)/c(111), where o and c mean orthorhombic and cubic phases. It is worth noting that Y-HZO films show negligible diffraction peak from monoclinic-phase (m-phase). On the other hand, intensity of the diffraction peak from m-phase increased for MFS structure with sputtered HZO after 600 °C re-annealing. The diffraction peak around 30.5 includes diffraction from 222 of bixbyite structure of ITO. It was found from polarization-electric field (P-E) and capacitance-voltage (C-V) measurements that CSD Y-HZO shows stable ferroelectricity whereas sputtered HZO reveals paraelectric nature in the MFS structure after 600°C re-annealing. Figure 2 shows transfer curves of FGTs with CSD Y-HZO (black solid line) and sputtered HZO (red solid line). The FGT with CSD Y-HZO shows clear typical n-channel transfer curve with a counter-clockwise hysteresis loop due to ferroelectric nature of Y-HZO, whereas no transistor operation was observed for the FGT with sputtered HZO. This is because the sputtered HZO became paraelectric and cannot deplete the ITO channel with high carrier concentration. FGTs with as-deposited and 400 °C annealed ITO channels will be presented at conference.

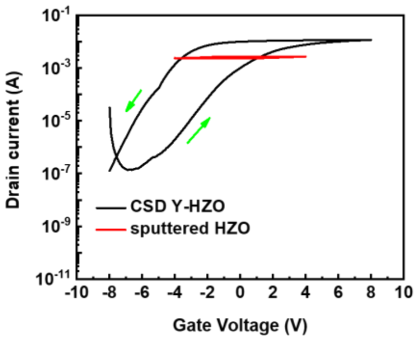

Fig. 2. Transfer curves of FGTs with CSD Y-HZO and sputtered HZO

【Conclusion】

ITO channel FGTs were fabricated using CSD Y-HZO and sputtered HZO films, and significant difference in stability of ferroelectricity was found. Sputtered HZO, which showed good ferroelectric properties for MFM capacitors, has turned to paraelectric after the FGT fabrication and no transistor operation was obtained. On the other hand, CSD Y-HZO remained ferroelectric after the FGT fabrication and transfer curves with hysteresis due to ferroelectric gate insulator was observed.

【References】

[1] J. Müller et al., Nano Lett.,**12**, 4318 (2012). [2] Mohit et al Jpn. J. Appl. Phys., **59**, SMMB02 (2020).
[3] Mohit et al., Jpn. J. Appl. Phys. **59** SPPB03 (2020). [4] S.Migita et al., Jpn. J. Appl. Phys. **57** 04FB01 (2018).