TERNARY AMORPHOUS OXIDE SEMICONDUCTOR MATERIAL TOWARD 3D-INTEGRATED FERROELECTRIC DEVICES

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Interest in transistor-based ferroelectric memory (FeFET) using ferroelectric HfO_2[1] as a candidate for next-generation memory devices has been growing, and FeFETs with a three-dimensional stacked structure (3D-FeFET) have been proposed[2]. Recently, amorphous oxide semiconductors (AOS) such as In-Ga-Zn-O have been mentioned as a candidate channel material, and it is expected to suppress the characteristic degradation caused by the formation of interface layers, which is a problem with Si-based materials [3]. deposition (ALD) technology is required to apply AOS to 3D-FeFETs. Conventional AOS are mainly quaternary, and have been designed for display applications that require low-temperature deposition. Therefore, there is insufficient accumulated knowledge on the effects of high temperature heat treatment (≥500ºC) on electrical properties and reliability, and the AOS composition should be reviewed for 3D-FeFET applications. In addition, deposition of composite oxide films by ALD method is technically challenging, and it is inferred that a ternary system with reduced constituent elements from a quaternary system is promising. In this study, with the aim of realizing an AOS that can be implemented in 3D-FeFETs, we evaluated the effect of the additive element X in the ternary In-X-O on the thermal stability of the amorphous phase and electrical properties. In addition, HfO_2-based ferroelectric devices using In-X-O as a semiconductor layer were fabricated and their operation was verified.
Figure 1 shows the transfer characteristics of a FET with RTA-treated ternary AOS as the channel. Heat treatment in a high-temperature nitrogen atmosphere causes oxygen to desorb from the AOS, which may increase the carrier density. The figure shows that the threshold voltage can be controlled near 0 V by using an In-Ga-O (IGO) system. It was also confirmed that the amorphous phase of IGO is maintained up to 600ºC, and excellent electron transport properties, represented by a field-effect mobility of 25 cm2/Vs and an S value of 69 mV/decade, were obtained [4].
It has also been reported that AOS can act as a cap material to induce the ferroelectric phase of HfO_2 [3]. In this study, we crystallized $Hf_{0.5}Zr_{0.5}O_2$ (HZO) using IGO as a cap material and fabricated a capacitor with an IGO/HZO/TiN structure. Figure 2 shows the polarization characteristics of the capacitor using IGO and HZO. The clear ferroelectricity was confirmed, indicating that IGO can be used as a cap material. From the above, we found that IGO is promising as a ternary AOS with high affinity to the ferroelectric HfO_2 process.

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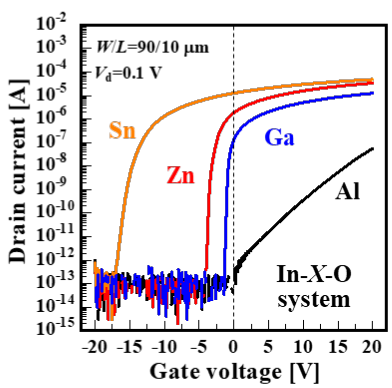

Fig. 1 Transfer characteristics of FET with various In-X-O channels after annealing at 500°C in N₂.

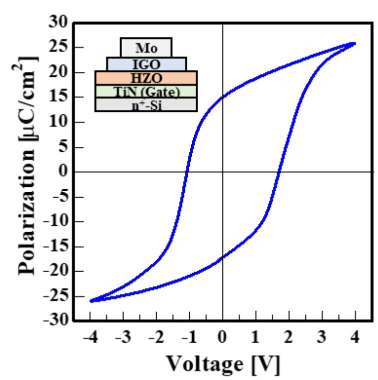

Fig. 2 Polarization-voltage characteristics of metal-ferroelectric -semiconductor capacitor based on IGO and HZO.