Structural and Electrical Characterization of $Hf_{0.5}Zr_{0.5}O_2$ Thin Films Crystallized by Rapid Thermal Annealing

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Background incl. aims
High-k dielectric thin films such as HfO_2, ZrO_2 and $Hf_{0.5}Zr_{0.5}O_2$ for semiconducting memory devices was selected as model systems. Metastable orthorhombic phase of $Hf_{0.5}Zr_{0.5}O_2$ (HZO) has ferroelectricity and has been the potential materials to next generation nanoscale electronic devices based on its superior physical scalability. In order to increase the ferroelectricity of HZO, understanding the basic generation mechanism of ferroelectric crystalline phases is crucial and is investigated structurally and electrically in this study.

Methods
10 nm thick $Hf_{0.5}Zr_{0.5}O_2$ films were deposited using atomic layer deposition (ALD) on 200 nm thick TiN electrodes as the top and bottom was crystallized by post-metal rapid thermal annealing (RTA) in the temperature range from 400 to 900℃. The crystalline phase of HZO was determined with high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) in TEM (JEOL, ARM-200F). The capacitance-voltage (C-V) characteristics were obtained by Agilent E4980A. Electrostatic Force Microscopy (EFM) and piezoresponse force microscopy (PFM) imaging was performed using NX-10 (Parks systems) on the HZO surface without the top electrode.

Results
From GI-XRD analysis results, the HZO samples annealed at 600 and 700 ℃ showed the higher orthorhombic phase and was consistent with the C-V measurement (Figure 1). The orthorhombic phase is confirmed with HR-STEM. The amplitude and phase images of EFM clearly showed the presence of ferroelectricity at the 600 ℃ RTA-treated sample. The C-V measurement showed that the dielectric constant was 8.8e-18 F/μm for a thickness of 10 nm and an area of $3.14e^4$ μm^2.

Conclusion
We investigated the basic generation mechanism of ferroelectric hafnia crystalline phases as a function of RTA temperature. We found that the higher ferroelectricity was shown from the samples annealed at 600 and 700 ℃ and that orthorhombic phases were dominant on the sample annealed at 600 ℃.

Graphic:

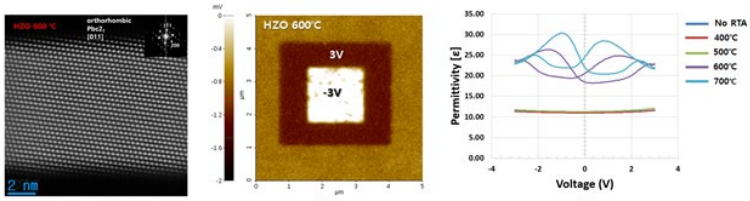

Figure 1. (a) HR-STEM image, (b) EFM image and (c) C-V curve of $Hf_{0.5}Zr_{0.5}O_2$ thin films.

Keywords:

$Hf_{0.5}Zr_{0.5}O_2$, Ferroelectricity, HR-STEM, EFM

Reference:

[1] Geun Taek Yu et al., New Physics: Sae Mulli, Vol. 71, No. 11, November 2021, pp. 890~900
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