Crystal phase analysis of HZO thin film using ACOM-TEM

HZO ($Hf_{0.5}Zr_{0.5}O_2$) is receiving a lot of attention as memory applications because of its ferroelectricity even in the thin film. Only orthorhombic crystals show ferroelectricity, so it is important to understand which crystalline phases are contained in HZO to determine the dielectric properties. This paper introduces an example of using ACOM-TEM to evaluate the crystalline phase ratio and other properties of HZO thin films.

1. Cross-sectional analysis of HZO thin film

ACOM-TEM: Automated crystal orientation and phase mapping in TEM (product name : ASTAR)
Ferroelectric memory: FE-FET (Ferroelectric field effect transistor), etc.

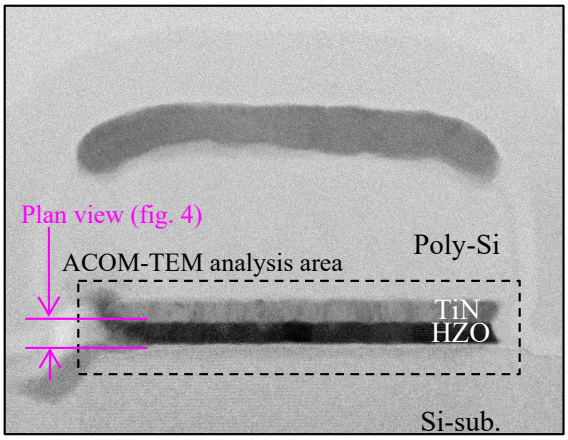


Fig. 1 Cross-sectional BF-STEM image of the transistor

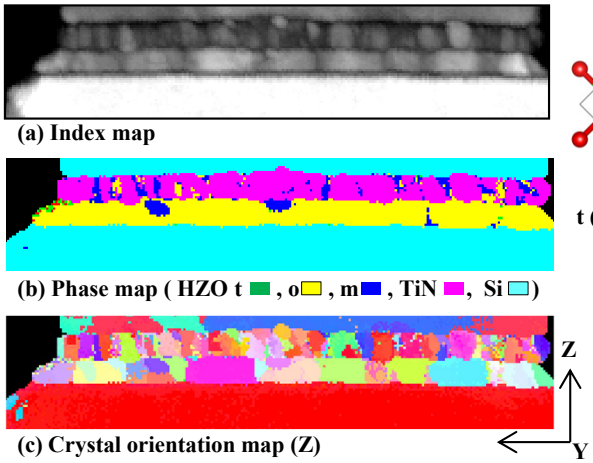


Fig. 2 Maps obtained by cross-sectional ACOM-TEM analysis

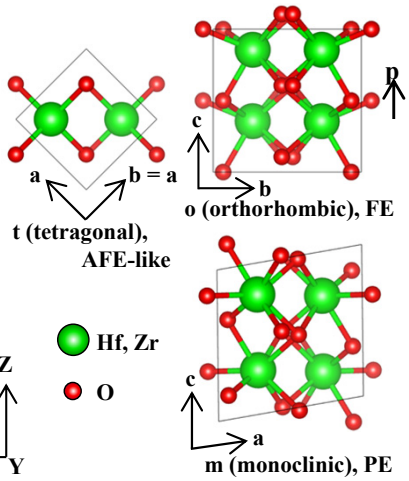
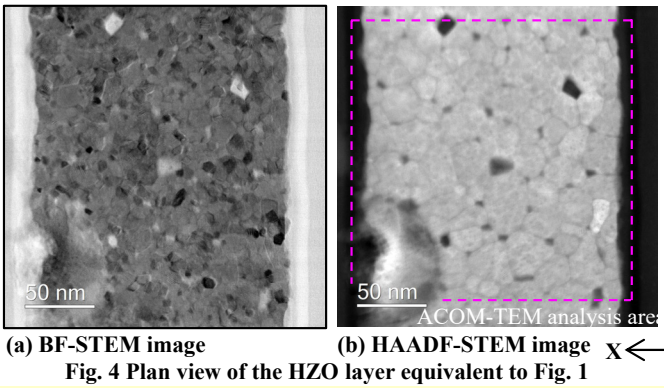


Fig. 3 Crystal phases of HZO

Fig.1 shows the cross section of a ferroelectric gate transistor. Fig. 2(b) shows the results analyzed as mainly ferroelectric orthorhombic crystals.
Fig.3 shows the crystal phase types of HZO: tetragonal (t), orthorhombic (0), and monoclinic (m).

2. Plan-view analysis of HZO thin films



(a) BF-STEM image (b) HAADF-STEM image

Fig. 4 Plan view of the HZO layer equivalent to Fig. 1

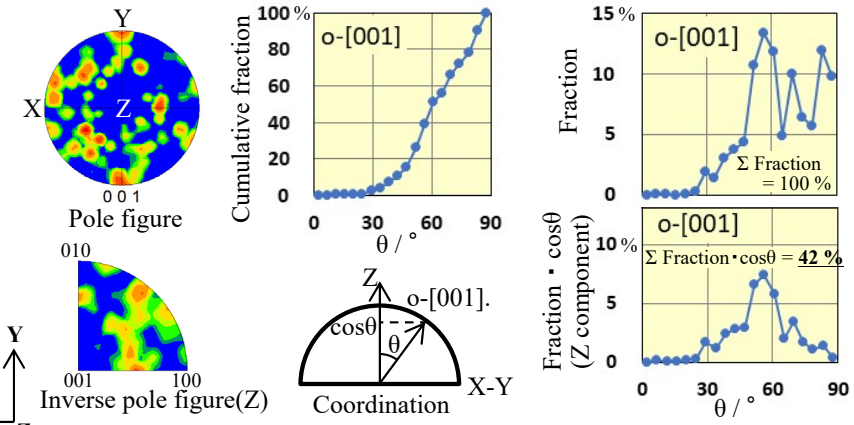
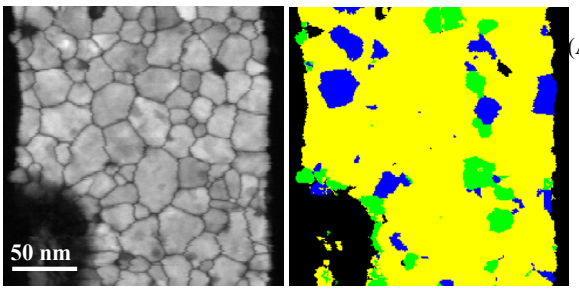


Fig. 6 Orientation analysis of o-HZO polarization axis [001] along Z

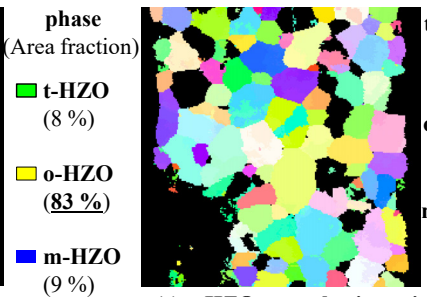
Voids are observed at the grain boundary triple point of the HZO thin film.

The orthorhombic polarization axis <001> is hardly aligned to Z. The total Z component is 42%.



(a) Index map

(b) Phase map



(c) o-HZO crystal orientation map (Z)

Fig. 5 Maps obtained using plan view ACOM-TEM analysis

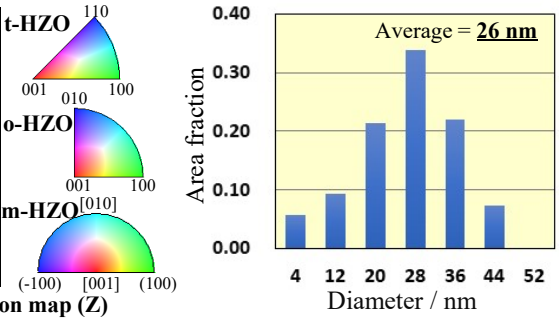


Fig. 7 Grain size distribution of o-HZO

Plan view analysis can provide more accurate results than cross-sectional analysis because more grains can be analyzed.
The orthorhombic crystal ratio is 83%, and the average grain size is 26 nm.

Toray Research Center, Inc. can fabricate TEM lamella of only HZO layer with a thickness of 10 nm taken from multi-stack structure and plan-view ACOM-TEM analysis can be performed.
Our techniques can reveal the crystal phase ratios (tetragonal, orthorhombic, monoclinic) of HZO.

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