Research on the Crystal Phase and Microstructure of Pure Phase ε-Ga_2O_3 Film by Plasma Enhanced Atomic Layer Deposition

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As a new type of third-generation semiconductor material, ε-Ga_2O_3 has higher symmetry and lower anisotropic crystal structure, which bring it strong spontaneous polarization, ferroelectric properties and piezoelectricity [1–3]. Therefore, the strong polarization effects in ε-Ga_2O_3 make it promising for applications both in electronic and piezoelectric devices [4]. At present, a large number of epitaxial technologies have been widely applied in the growth of Ga_2O_3 films. However, when ε-Ga_2O_3 grown on α-Al_2O_3 substrate, β- or α-Ga_2O_3 phases are observed directly above the substrate interface [5–7]. Therefore, there are difficulties in the high-quality and phase-pure ε-Ga_2O_3 film growth. Here, we have successfully grew phase-pure ε-Ga_2O_3 film without β phase on 2-inch c-plane sapphire using plasma enhanced atomic layer deposition (PEALD) for the first time. The obtained film phase was identified preliminarily as ε-Ga_2O_3 phase by XRD. We has characterized the crystal quality, impurities and defects of film by XPS and SIMS, which there were almost no carbon impurities in film, especially in the interface between film and substrate, showing a gallium-rich state. Besides, the pure ε-Ga_2O_3 with [002] preferred orientation and the epitaxial relationship have been confirmed by high-resolution transmission electron microscope (HR-TEM) results. The interface between ε-Ga_2O_3 and sapphire is polycrystalline Ga_2O_3 without β phase, due to the lattice mismatch between ε-Ga_2O_3 and substrate, this polycrystalline Ga_2O_3 layer works as a stress relaxed layer for the growth of the upper ε-Ga_2O_3 layer. This research will help to understand the mechanism of ALD growth high quality and pure phase ε-Ga_2O_3 film for further applications.

References

[1] F. Mezzadri et al. Crystal Structure and Ferroelectric Properties of ε-Ga2O3 Films Grown on (0001)-Sapphire. Chem. 55 (2016) 12079. .

[2] Y. Arata et al. Heteroepitaxial growth of single-phase ε-Ga2O3 thin films on c-plane sapphire by mist chemical vapor deposition using a NiO buffer layer. CrystEngComm 20 (2018) 6236-6.

[3] San-Dong Guo , Hui-Min Du. Piezoelectric properties of Ga2O3: a first-principle study. Eur. Phys. J. B (2020) 93: 7.

[4] Z. Chen et al. ε-Ga2O3: An Emerging Wide Bandgap Piezoelectric Semiconductor for Application in Radio Frequency Resonators. Adv. Sci. 2022, 2203927

[5] H. Nishinaka et al. Incorporation of indium into ε-gallium oxide epitaxial thin films grown via mist chemical vapour deposition for bandgap engineering. CrystEngComm, 2018, 20, 1882.

[6] M. Kracht et al. Tin-Assisted Synthesis of e-Ga2O3 by Molecular Beam EpitaxyPhys. Rev. Appl., 2017, 8, 054002.

[7] Y. Kajita et al. Observing the microstructure of a (001) κ-Ga_2O_3 thin film grown on a (−201) β-Ga_2O_3 substrate using automated crystal orientation mapping transmission electron microscopy. CrystEngComm, Vol. 24, p. 3239, 2022