κ-Ga_2O_3 thin films and related heterostructures grown by Suboxide-MBE and conventional MBE

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The wide-bandgap semiconductor Ga_2O_3 is considered a promising material for high-power electronic devices, benefiting essentially from its large bandgap and the associated high breakdown field strength. The five polymorphs of Ga_2O_3 also exhibit unique material properties [1]. Widely investigated is the thermodynamically stable monoclinic β-Ga_2O_3, from which bulk substrates are commercially available [2], and precise n-type doping that enables high carrier mobilities has been established [3]. However, the primary focus of this contribution is on the metastable orthorhombic κ-Ga_2O_3. Due to its crystal structure, it is assumed to possess a spontaneous polarization along the c-axis, which makes the realization of high sheet carrier densities at heterointerfaces feasible [4].

In this study we focus on two key aspects of κ-Ga_2O_3 growth, the stabilization of the metastable polymorph and the realization of heterostructures. Here, we initially demonstrate the growth of the κ-phase and discuss the phase stabilization and the growth process using suboxide-MBE (S-MBE) as a novel MBE technique and conventional MBE (C-MBE), both combined with the use of the known additive tin [5,6]. The growth regimes in which a phase transformation from β-Ga_2O_3 to κ-Ga_2O_3 occurs are identified and characteristics of the obtained layers are compared.

Additionally, we focus on the growth of Ga_2O_3-based heterostructures using both growth techniques (S-MBE and C-MBE). The study examines the combination of different polymorphs in superlattice heterostructures, specifically β-Ga_2O_3/κ-Ga_2O_3. This provides through scanning transmission electron microscopy insights into the atomic arrangement of both polymorphs at the interfaces. Furthermore, κ-Ga_2O_3/κ-$(Al,In,Ga)_2O_3$ heterostructures are studied and the strain state in κ-Ga_2O_3/κ-InGaO/κ-AlGaO heterostructures is investigated [7], since fully strained structures are promising candidates for the realization of carrier accumulation at heterointerfaces.

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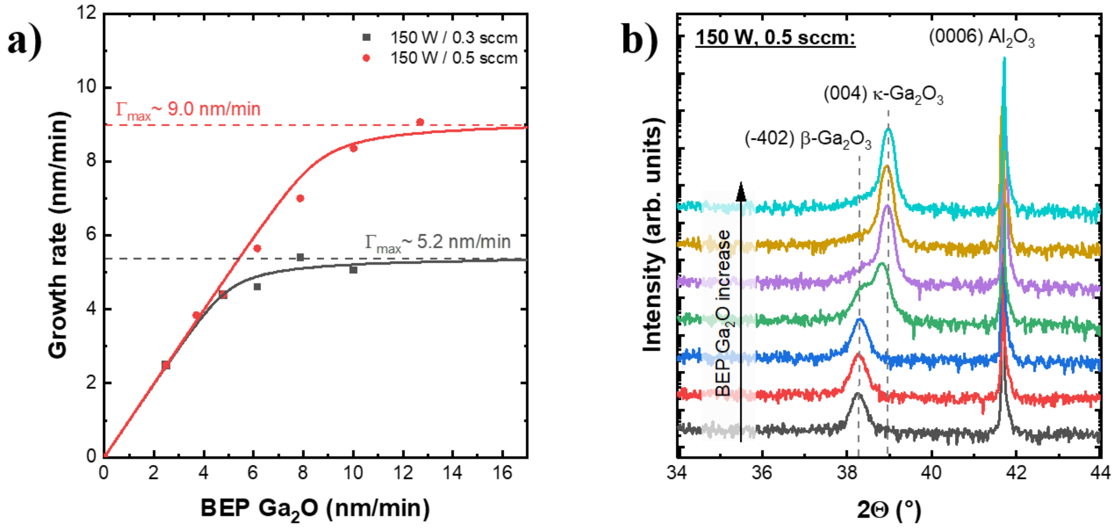

Fig. 1: a) Ga_2O_3 growth rate as a function of gallium suboxide (Ga_2O) flux. For both series grown at different plasma settings, the adsorption-controlled regime with a constant growth rate is reached, indicating the single-step growth mechanism of κ-Ga_2O_3 when using S-MBE. b) XRD spectra of the series grown at 150 W and 0.5 sccm revealing the phase transition from β- to κ-Ga_2O_3 when increasing the Ga_2O flux.

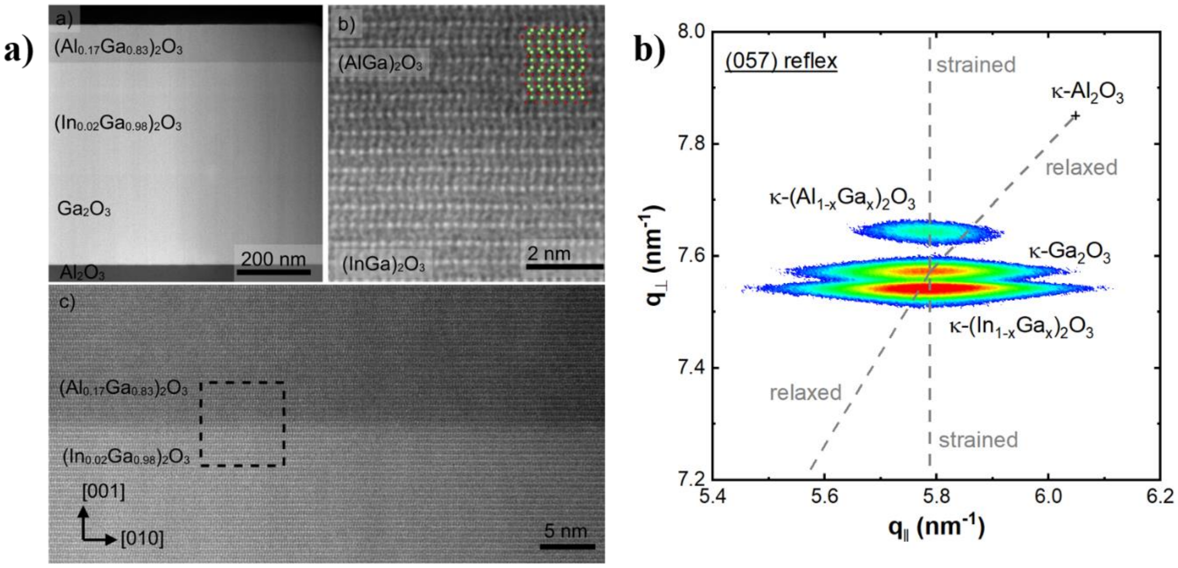

Fig. 1: a) STEM images of a κ-Ga_2O_3/κ-$(In,Ga)_2O_3$/κ-$(Al,Ga)_2O_3$ heterostructure, showing a sharp distinct transition between the κ-$(In,Ga)_2O_3$ and κ-$(Al,Ga)_2O_3$ layer. b) The corresponding reciprocal space map of the heterostructure displayed in a) indicates the pseudomorphic growth throughout the layer sequence [7].