Defect engineering in the ultra-wide band gap semiconductor α-Ga_2O_3

Supervisors

Dr. Javier García Fernández, Prof. Dr. Øystein Prytz, Prof. Dr. Holger von Wenckstern

Number of Candidates

1

Backgrounds of Candidates

The candidate preferentially has an interest in materials properties, with some laboratory experience. Experience with characterization techniques such as transmission electron microscopy (TEM), scanning electron microscopy (SEM) or X-ray diffraction (XRD) are desirable. An interest in thin film growing methods, such as pulsed-laser deposition (PLD) is advantageous.

Preferred project period

June-September 2025

Project Descriptions

With an ultra-wide band gap of up to 5.3 eV [1], the α-polymorph of gallium oxide (Ga_2O_3) has garnered significant interest for high-power applications, transparent conductive thin films, and solar-blind photodetectors [2]. Its high breakdown field and the recent availability of the first commercial α-Ga_2O_3-based devices have further driven scientific interest in this material. The α-phase can be grown on readily available, cost-effective, and isostructural α-Al_2O_3 substrates. However, a major limitation is the high dislocation density, reaching up to 10^{10} cm^{-2}, which arises from the significant lattice mismatch with the substrate and the differing thermal expansion coefficients of α-Al_2O_3 and α-Ga_2O_3 [3], see schematic representation in Figure 1(a). This issue critically restricts the electron mobility in α-Ga_2O_3 thin films and devices.

In this project, we will explore two different strategies to minimize the strain generated at the α-Al_2O_3/α-Ga_2O_3 interface due to the lattice mismatch. Firstly, we will study sample growth with a buffer phase (α-Cr_2O_3) with lattice parameters intermediate between the two phases (Figure 1(b)). A second sample with a vertical compositional gradient α-$(Al_xGa_{1-x})_2O_3$ as a buffer layer (Figure 1(c)) were the lattice parameter change gradually will be also studied. Both cases will be compared to an initial sample of pure α-Ga_2O_3 on α-Al_2O_3 in order to study the influence of the buffer layer on the crystal quality and defects in α-Ga_2O_3.

In this project, the student will investigate in detail the thin films deposited on wafers by TEM as the main characterization method located in the NORTEM [4]. Different aspects to be studied are: the thickness of the layers, the crystallographic relationship between the substrates and the layers, the defects present in the sample, the chemical composition, etc.

The student will be introduced to sample preparation for TEM, and analysis of the TEM results. Depending on the student's ability, the TEM can be operated by the supervisors or by the student with the supervisors present.

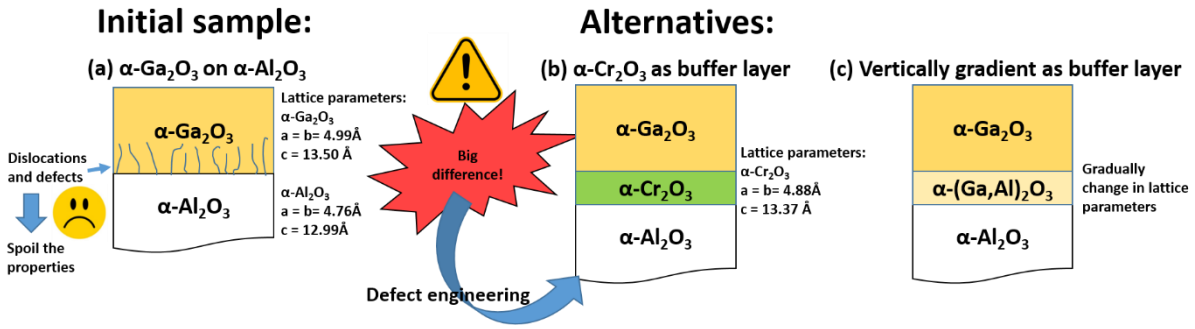


Figure 1. (a) Initial sample growth of pure α-Ga_2O_3 on α-Al_2O_3 with the presence of defects. Alternative planned samples: (b) sample with α-Cr_2O_3 as a buffer layer, and (c) sample with α-$(Al_xGa_{1-x})_2O_3$ as a buffer layer.

References

[1] A. Hassa, M. Grundmann, and H. von Wenckstern, J. Phys. D: Appl. Phys. 54, 223001 (2021)

[2] J. Zhang, J. Shi, D.-C. Qi, L. Chen, and K. H. L. Zhang, APL Mater. 8, 020906 (2020)

[3] K. Kaneko, H. Kawanowa, H. Ito, and S. Fujita, Jpn. J. Appl. Phys. 51, 3 (2012)

[4] https://www.mn.uio.no/fysikk/english/research/nortem/