PROCESS DESIGN OF MIGRATION-ENHANCED MOCVD GROWTH OF AlN AND AlGaN

Karolina German[1], Tadas Malinauskas[1], Arūnas Kadys[1]

[1]Vilnius University, Faculty of Physics, Institute of Photonics and Nanotechnology, Lithuania
karolina.german@ff.stud.vu.lt

III-nitride semiconductor membranes are promising for flexible and hybrid electronic and optoelectronic systems, enabling lightweight, transferable GaN-based devices. Graphene and van der Waals interfaces offer a route to detachable nitride layers. However, fundamental limitations restrict their practical implementation. In particular, pure remote epitaxy of GaN through graphene cannot be realized under conventional MOCVD due to graphene degradation in ammonia- and hydrogen-rich environments. GaN nucleation on graphene is difficult, leading to a low density of islands and necessitating thick overgrowth for coalescence, which is incompatible with thin membrane concepts. Low-temperature AlN provides an alternative nucleation layer with improved coverage on graphene, but shifts the growth toward a van der Waals–dominated regime limited by gas-phase parasitic reactions and reduced adatom mobility. This motivates the development of migration-enhanced MOCVD (ME-MOCVD).

This work aims to design and optimize ME-MOCVD growth of AlN and AlGaN layers for thin membrane applications. The process relies on temporal separation of metal-organic (MO) precursors (TMA, TMG) and ammonia (NH_3) exposure, combined with intermediate purge steps to suppress parasitic gas-phase reactions. Nitridation pulses of 10 s were used, while TMA and TMG were supplied either simultaneously or separately in 2 s pulses, followed by a 2 s purge after each MO and NH_3 exposure. This process design temporally separates precursor supply from surface reactions, thereby enhancing adatom mobility.

AlN and AlGaN layers were grown at 750 $^\circ\mathrm{C}$ and 100 mbar, with growth rates of $\sim$ 1.1 $\mathrm{\AA/s}$ for AlN and 1–1.4 $\mathrm{\AA/s}$ for AlGaN. For AlN growth, TMA flows of 35 and 17 $\mu\mathrm{mol/min}$ were used. The AlGaN composition was controlled by varying TMG flow from 8.4 to 38 $\mu\mathrm{mol/min}$ and TMA flow from 17 to 3.9 $\mu\mathrm{mol/min}$. The resulting AlN thickness was $\sim$ 105 nm, while AlGaN layers reached $\sim$ 250–340 nm. With a 16 s growth cycle, the growth per cycle corresponds to $\sim$ 6 AlGaN monolayers, exceeding typical optimal values and indicating the need for growth-rate reduction.

Finally, X-ray diffraction confirms crystalline, single-phase, c-axis-oriented AlN and compositionally tunable AlGaN layers. This study demonstrates that ME-MOCVD provides a viable and scalable pathway toward III-nitride membrane technology within conventional MOCVD, supporting flexible and hybrid electronic and optoelectronic systems.

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