Process and reactor design optimization by computational analysis of the MOVPE of III-V compounds in multi-wafer Planetary Reactors

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The MOVPE (Metal Organic Vapor Phase Epitaxy) of III-V compounds for the manufacturing of e. g. LEDs (Light Emitting Diodes), lasers and solar cells has truly turned into a mass production technology. This paper summarizes latest hardware and process improvements in order to enhance reactor productivity for large scale Planetary Reactor® configurations accommodating 8x4”, 12x4”, 18x3”, up to 49x2” substrates in one fully loaded reactor chamber. The design changes of the reactor chamber and of crucial components, in particular at the gas injector area, are guided by predictive modeling of flow, heat transfer and thin film deposition. Various measures are implemented that lead to increased precursor utilization efficiency, reduced overall gas consumption, improved uniformity, and a more robust process window. The extensive use of modeling provided for a substantial reduction of development time. Data obtained from the redesigned chambers provided in turn for model validation.

The Planetary Reactor® concept addresses today’s productivity driven requirements very well. It features a central gas inlet with separate supply of group-III and group-V source gases with the substrates located on an annular region symmetrically around the inlet. Individual substrate rotation as well as main rotation ensure uniformity of layer properties by rotational averaging of radial reactant depletion [1]. This reactor setup provides for wafer processing at high throughput with excellent uniformity and reproducibility of electrical and optical layer properties.

The MOVPE process model includes mixed convective flow, heat transfer for the gas flow as well as for the solids, radiative transfer involving semitransparent materials, gas phase transport and reaction kinetics of reactant species and solid layer deposition from the gas phase on the surface of substrates, reactor components and walls. Model accuracy for the prediction of MOVPE growth rates of III-V compounds like GaAs, InGaP and AlGaAs has already been demonstrated in previous publications [2, 3] and is confirmed throughout this work by comparison of measured layer thickness profiles with computational results.

Design improvements address the reduction of heat load into the reactor center in order to avoid unnecessary deposition at the area upstream of the substrates and to warrant a deposition free gas injector, further the layout of the central gas deflection without causing disturbances of the flow pattern, thus ensuring stratified gas flow and symmetric distribution in angular direction, and the precise definition of the gas injector size and geometry. In figure 1 the accumulated effect of these measures on the group-III precursor species utilization efficiency (defined as the ratio of precursor molar flux contribution to layer growth on the substrates over total input flux) is exemplified for the 49x2” reactor configuration.

Outstanding process results were obtained as exemplified here for the 12x4” configuration: AlGaAs DBR stop band center uniformity on wafer of 0.5% standard deviation, peak PL wavelength uniformity of AlGaInP double heterostructures of ± 0.7 nm standard deviation on wafer and ± 0.85 nm from wafer to wafer at a target waferlength of 600 nm, all with 3mm wafer edge exclusion, and growth rates of GaAs as high as 17 µm/h with excellent surface morphology expressed by XRD peak width could be achieved.

[1] P. M. Frijlink, J. Crystal Growth 93 (1988) 207.
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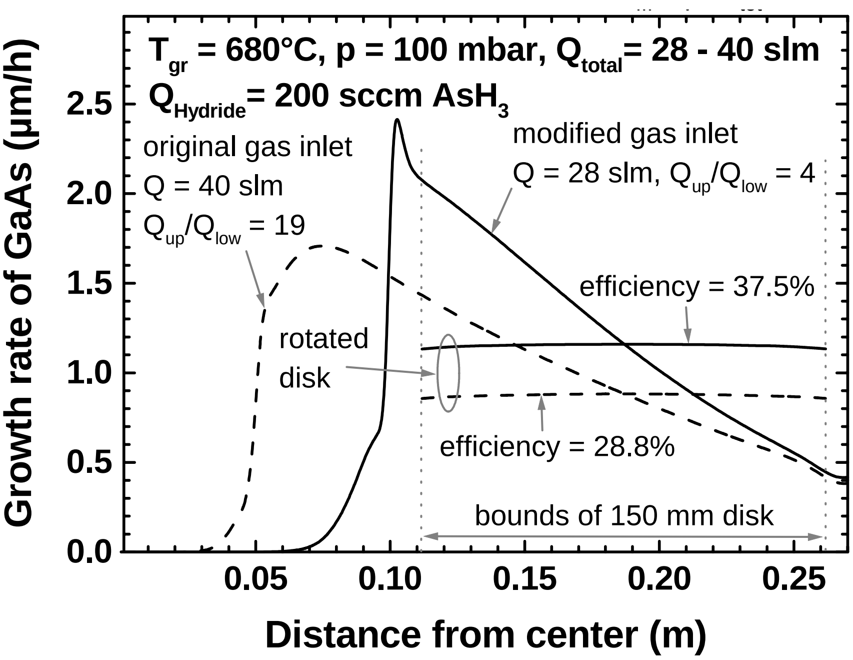

Figure 1. Computed GaAs growth rate distribution in the 49x2" Planetary Reactor® showing the effect of various changes of gas inlet design and process conditions on the group-III precursor efficiency.