Carbon doping of AlGaAs using CBr_4 in a nitrogen environment

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Carbon is a valuable p−type dopant in MOVPE grown GaAs and AlGaAs since it enables high doping levels, low electrical compensation, improved hole mobility while showing a low diffusion coefficient and no reported memory effect. However, epitaxial design must take into account the reduction of the growth rate of GaAs and AlGaAs which is significant even at moderate doping levels.

When CBr_4 is used as precursor in a hydrogen environment, different etching mechanisms were proposed for GaAs and AlAs, while the growth rate of AlGaAs cannot be described by a linear combination of the two binaries (1). When nitrogen was used as a carrier gas, a reduction in the growth rate of GaAs was also reported (2). However, the formation of HBr and hence the etching rate of GaAs may be affected if the carrier gas changes from hydrogen to nitrogen. Further work is clearly needed to clarify the influence of the carrier gas. Beside being an intrinsicaly safer process, MOVPE in a nitrogen environment has clear advantages with respect to material purity and unifomity.

We have therefore undertaken to study the influence of CBr_4 doping on the growth rate and the alloy composition of AlGaAs alloys over the full alloy range at different substrate temperatures (650−800°C), V/III ratios (20−200), using nitrogen as a carrier gas. The growth rate of undoped GaAs and AlGaAs ("nominal" growth rate) was calibrated using reflectivity measurements on GaAs/AlGaAs superlattice structures and adjusted to 1 micron/hour. Dedicated AlGaAs:C/GaAs:C heterostructure samples were then grown and examined using transmission electron microscopy (TEM). Due to the lattice contraction of AlGaAs:C, the Al content cannot be directly derived through the lattice parameter as measured by X−ray diffraction. Therefore the Al content was measured by Energy dispersive electron Spectroscopy (EDS). The free carrier concentration was derived using C−V profiling.

TEM dark field contrasts show a systematic increase in the nominal Al content between undoped and C doped AlGaAs layers for doping levels close to 3e18 cm−3. A reduction in the growth rate of AlGaAs is also observed and varies with growth temperature and V/III ratio. At a growth temperature of 640°C, a V/III ratio of 180 and a nominal Al fraction of 40%, the growth rate is reduced by 29% and the Al content increases by 20%.

These results allow the accurate tailoring of the growth conditions of AlGaAs:C for applications in light−emitting diodes or lasers . They provide additional insight in the etching mechanisms related to the use of CBr4 and in the influence of the carrier gas.

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