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Growth Optimizations of MBE-Grown InAlAs on InP

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The $In_{0.52}Al_{0.46}As$ ternary lattice-matched to InP is of great importance for many electrical and optical devices utilizing heterostructures. The material quality of MBE-grown InAlAs, however, leaves much to be desired primarily because it suffers from alloy clustering and high reactivity of aluminum with impurities. Consequently, a great care must be taken in order to obtain the optimal InAlAs as required for specific device applications.

Our target device application is MBE-grown 1.55 μm InGaAlAs laser diodes in which InAlAs cladding layers can take up more than 80 percent of the entire epi layer. In order to determine the optimal MBE growth conditions for InAlAs in such application. we grew a number of InAlAs samples under different growth conditions and characterized them by double crystal x-ray diffraction, Hall measurements, and photoluminescence (PL). Our MBE machine is a Riber 2300 equipped with an EPI valved As cracker. For this study. only tetramer As_4 was used and the growth rate of InAlAs was fixed at 0.65 μm per hour.

We first investigated the window of growth conditions that allow the As-stable growth by measuring under different amounts of As overpressure the transition temperature at which RHEED from InAlAs changes from As-stable 2x to group-III-stable 4x patterns. The range of As Beam Equivalent Pressure (BEP) investigated was from 5×10^{-6} to 1.8×10^{-5} Torr as measured by the flux ion gauge. The corresponding transition temperatures were from 490 °C for low As to 553 °C for high As as measured by a calibrated pyrometer.

Within this window, we took three different growth temperatures. 455. 505. and 535 °C (Sample H1, H2, and H3. respectively) at high As overpressure with BEP = 1.6×10^{-5} Torr. and two different temperatures, 455 and 505 °C (Sample L1 and L2, respectively) at low As overpressure with BEP = 7.9×10^{-6} Torr, and grew 0.65 μm thick InAlAs samples with Si doping concentrations of about 5×10^{16}. All the samples have mirror-like morphology with very few defects observed under the microscopic inspection.

Double crystal x-ray diffraction measurements show that alloy clustering is more severe for samples grown at higher temperature or lower As overpressure. For instance. Sample L2 has the x-ray full-width-at-half-maximum (FWHM) of 47 arc seconds. whereas Sample H1 has 32 arc seconds. The theoretical limit for the x-ray FWHM for the layer structure investigated is about 30 arc seconds as determined from the simulation.

Both 10 K PL FWHM and 77 K mobility show that InAlAs quality is better at higher growth temperature if sufficient As overpressure is maintained. For instance, Sample H2 has a PL FWHM of 17.3 meV and a mobility of 1608 cm^2/V-s, whereas Sample H3 has a larger PL FWHM of 20.4 meV and a lower mobility of 947 cm^2/V-s. This is believed due to the combined effects of high growth temperature that reduces impurity incorporation and high As overpressure that reduces alloy clustering and As vacancies. Detailed analyses of these material characterization will be presented as well as their impacts on device performances.