

Growth and Characterisation of GaAsSb:C/GaInAs:Si Tunnel Junctions for InP-based Longwavelength VCSEL

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Recent progress on InP-based longwavelength Vertical-Cavity-Surface-Emitting Lasers (VCSELs) with laser emission at 1.55 μm and modulations bandwidths as high as 17 GHz give these devices an auspicious market position as low-cost and low-power light sources for data traffic in access networks like passive optical networks (PON) [1]. One key-element of these laser diodes is an MBE grown structured tunnel junction consisting of p -Ga_{0.47}In_{0.53}As:C and n -Ga_{0.47}In_{0.53}As:Si with doping levels around $1.5 \times 10^{20} \text{cm}^{-3}$, which serves as current aperture (necessary for single mode operation) and as an electron-to-hole converter (the tunnel junction is reversely biased). The difficulty to realize such a structure with a large scale growth technique like MOVPE is a sufficient

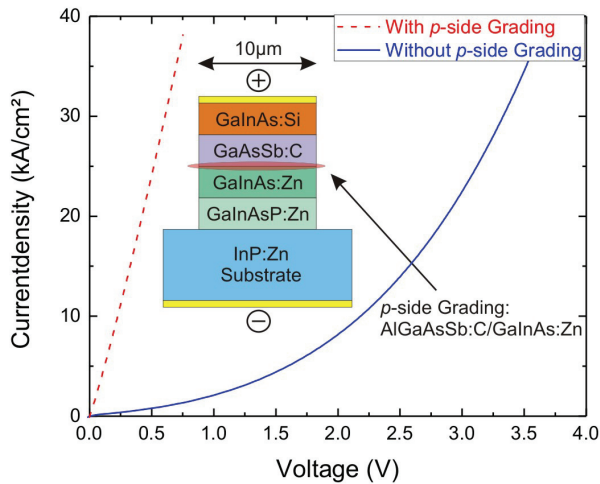


Figure 1: U-I-characteristics of grown tunnel diodes with a dry etched mesa diameter of 10 μm .

high p -doping of GaInAs with a segregation stable dopant like carbon [2]. However, this obstacle can be circumvented by using carbon doped GaAs_{0.51}Sb_{0.49} instead of Ga_{0.47}In_{0.53}As, where hole concentrations around $1.0 \times 10^{20} \text{cm}^{-3}$ have been reported [3] and in combination with n -Ga_{0.47}In_{0.53}As a more favourable type-II band alignment is given [4]. In this work the MOVPE growth and the electrical performance of GaAsSb:C/GaInAs:Si tunnel diodes with mesa diameters from 5-12 μm on InP substrate are presented and the influence of AlGaAsSb:C/GaInAs:Zn grading layers for the reduction of band discontinuities are discussed. The structures were grown with an Aix 200/4 MOVPE system at a pressure of 150 mbar and with a total gas flow of 10 l/min. As carrier gas H₂ was used. For group-III incorporation trimethylgallium (TMGa), trimethylindium (TMIn) and trimethylaluminium (TMAI) were employed. Arsine (AsH₃), phosphine (PH₃) and trimethylantimony (TMSb) served as group-V supply. Silane (SiH₄), dimethylzinc and carbontetrabromide (CBr₄) were used as dopant sources. The layers were characterized with room- and low-temperature photoluminescence (PL), x-ray diffraction (XRD), van-der-Pauw measurements and in-situ reflectance by using a Laytec "EpiTT" system. The tunnel junction test structures were grown on zinc-doped exact orientated InP wafers and consisted of GaInAsP:Zn grading layers, 100 nm GaInAs:Zn (both grown at 650°C), 30 nm GaAsSb:C, 5-10 nm GaInAs:Si (both grown at 500°C) and finally 40-45 nm GaInAs:Si (grown at 600°C). All layers were nearly lattice matched to InP, the n -doping density of the GaInAs:Si layers was adjusted to $2-5 \times 10^{19} \text{cm}^{-3}$. Whereas the first layers have a p -doping of $1.0 \times 10^{18} \text{cm}^{-3}$, a p -doping of $5.0 \times 10^{19} \text{cm}^{-3}$ inside the GaAsSb layer could be realized by using CBr₄, which was measured with 100-200 nm thick GaAsSb:C layers grown on semi-insulating InP:Fe substrates. The etching effect of CBr₄ was equalised by increasing the V/III ratio from 1 to 1.2 and by decreasing the AsH₃/TMSb ratio. In this way GaAsSb:C layers with defect-free surfaces could be grown. To reduce the large valence band-offset of 430 meV between the GaInAs:Zn and GaAsSb:C layer, which restrains the hole transport, an 20nm thick Al_{0.4}GaAs_{0.53}Sb:C/GaInAs:Zn digital alloy grading layer was added. Since the decomposition of TMAI is very low at 500°C, the grading layers were grown at 550°C.

As shown in Figure 1, the electrical performance is drastically enhanced by this grading layer and it should be noted that the structure with p -grading (see Fig. 1) was directly grown after the first sample without p -grading, with the same switching sequence between GaAsSb:C and GaInAs:Si. A measured value of $8 \times 10^{-6} \Omega \text{cm}^2$ for the specific sheet resistance indicates, that this tunnel junction would be suitable for InP-based longwavelength VCSELs.

References:

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