

## GaAsSb:C / GaInAs:Si tunnel junctions with AlGaInAsSb:C grading for InP-based high-speed VCSELs

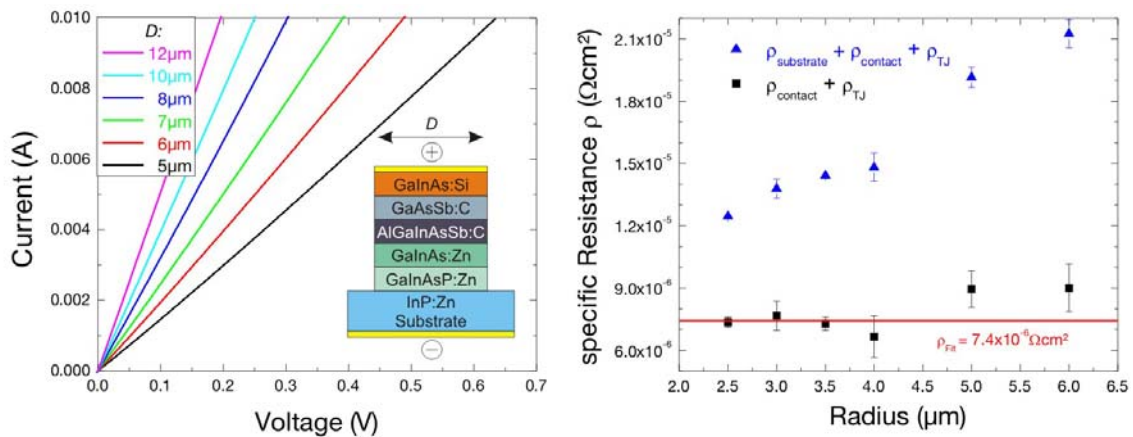
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### ABSTRACT

InP-based high-speed Vertical-Cavity Surface-Emitting Lasers (VCSELs) have reached modulation bandwidths of 35Gbit/s (BTB) and are therefore the key element to satisfy the unprecedented rise of data traffic. The main obstacle for the realization of such devices with a needed large scale growth technique like MOVPE is the growth of a low resistive tunnel junction (TJ), since the required high  $p$ -doping ( $5\text{-}10 \times 10^{19} \text{cm}^{-3}$ ) with carbon is hardly achievable with standard alloys as  $\text{Ga}_{0.47}\text{InAs}$  by MOVPE. By using  $\text{GaAs}_{0.51}\text{Sb}$  grown at  $500^\circ\text{C}$  a sufficient  $p$ -doping of  $5 \times 10^{19} \text{cm}^{-3}$  and in combination with  $n$ -doped  $\text{Ga}_{0.47}\text{InAs}$  ( $5 \times 10^{19} \text{cm}^{-3}$ ) also a more favorable type-II bandalignment could be achieved. To reduce valence-band offsets and, hence, the resistance of the structure  $\text{AlGaInAsSb:C}$   $p$ -doped grading layers consisting of  $\text{Al}_{0.48}\text{InAs}/\text{Al}_{0.5}\text{GaAsSb}$  and  $\text{Ga}_{0.47}\text{InAs}/\text{Al}_{0.5}\text{GaAsSb}$  were grown at  $550^\circ\text{C}$  (see Fig.1, left).



**Figure 1:**  $V/I$ -characteristics (left) and calculated specific sheet resistance (right) are shown.

The growth has been performed with an AIX 200/4 and standard precursors. For carbon doping  $\text{CBr}_4$  has been used. Fig.1 shows that with this design already a sufficient low spec. sheet resistance of just  $7 \times 10^{-6} \Omega\text{cm}^2$  could be reached. The growth of an inverted structure, on the other hand, with GaAsSb:C as toplayer revealed a resistance of only  $3.5 \Omega$  at a mesa diameter  $D$  of  $5 \mu\text{m}$ , which corresponds to a record low sheet resistance of  $7 \times 10^{-7} \Omega\text{cm}^2$ . Thus, with this tunnel junction the fabrication of InP-based high-speed VCSELs by MOVPE is now within reach.