

Title: Selective Area Regrowth of Self-Aligned, Low-Resistance Ohmic Contacts on InGaAs

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As electronic device areas scale with each generation by 1:4, resistances must remain constant, so contact resistivities must scale by 1:4. The high dopant concentrations achievable by molecular beam epitaxy (MBE) provide a method for creating low-resistance ohmic contacts; however, line-of-sight deposition and low desorption of atomic species may hinder the self-alignment of such regrowth. Careful control over growth conditions makes MBE a suitable technique for creating self-aligned, low resistance ohmic contacts to InGaAs.

Samples were grown by solid source MBE lattice matched to semi-insulating InP with layer structure as follows from the substrate: 400 nm InAlAs, 3 nm of Si-doped 2 and $3 \times 10^{19} \text{ cm}^{-3}$ InAlAs, and 25 and 15 nm of InGaAs, respectively. 300 nm of SiO_2 and 20 nm of Cr were deposited by PECVD and e-beam evaporation. A combination of electron beam and photolithography followed by ICP dry etching was used to define dummy spacer pillars. Oxidation and oxide removal of exposed InGaAs was done with UV o-zone and a dilute 10 H_2O :1 HCL dip. Samples were heated to 420 °C and treated with thermally cracked hydrogen ($\approx 1 \times 10^{-6}$ Torr) for 40 minutes prior to regrowth. 70 nm of 5×10^{19} Si-doped InAs was grown on the exposed InGaAs regions with quasi-migration enhance epitaxy (MEE) at 500 °C with V:III beam equivalent pressures of 4.0, 5.6, and 8.0. After regrowth, shorts over the dummy pillar were removed, and samples were metalized with lifted-off e-beam evaporated Ti/Pd/Au and mesa isolated. Contact resistances were extracted by transmission line measurements (TLM).

RHEED images during regrowth showed 4x2 surface reconstructions for regrowths with V:III ratios of 4.0 and 5.6 indicating a group In-rich surface reconstruction. SEM of regrowths at V:III ratios of 4.0 and 5.6 showed no faceting and fill-in to the dummy pillar edge. AFM showed roughened surfaces possibly due to high Si incorporation and lattice mismatch between InGaAs and InAs. Regardless of the V:III ratio during growth, 25 nm thick InGaAs channels showed contact resistances of 190 $\Omega \mu\text{m}$ while 15 nm thick InGaAs showed contact resistances of 105 $\Omega \mu\text{m}$. Metal-semiconductor contact resistances were 2.1 $\Omega \mu\text{m}$. Local electrode atom probe shows that the regrowth carries some of the Ga along with it creating a varying InGaAs alloy concentration throughout the regrowth.