Confined Lateral Overgrowth of Epitaxial InP Layers by Chemical Beam Epitaxy

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Recently, tunnel field-effect transistors (T-FET) have received considerable attention as a promising candidate for next-generation logic devices beyond metal-oxide-semiconductor FETs. T-FETs offer a fast transition between *on* and *off* device states with low power consumption. However, since charge carriers must "tunnel" through the bandgap of the transistor source, T-FETs tend to suffer low *on*-state current, which in turn slows device operation. In an attempt to mitigate the issue with low *on*-state current by increasing the tunnel probability, a confined hetero-junction T-FET has recently been proposed [1].

Here, we demonstrate lateral overgrowths of epitaxial InP thin layers inside three-dimensional confined structures defined by SiO_2 walls in chemical beam epitaxy on InP substrates for the development of high-performance III-V hetero-junction T-FETs. Figure 1 shows a schematic of substrate structure, growth process, and a resulting top-view scanning-electron micrograph.

Suppression of undesired parasitic nucleation on SiO_2 surfaces and growth of high-quality InP layers inside the confined structure are strongly influenced by surface chemistry and chemical reactions between precursor molecules and surfaces. Dependencies of structural properties of InP layers on growth parameters such as substrate crystallographic orientation, direction of lateral growth, growth temperature, and V/III ratio are discussed. Technical challenges in the substrate preparation procedures and characterization of thin layers formed inside confined structures are also addressed. Success of confined epitaxial lateral overgrowth would pave a pathway toward the monolithic three-dimensional integration of semiconductor hetero-structures for advanced electronic and photonic device technologies.

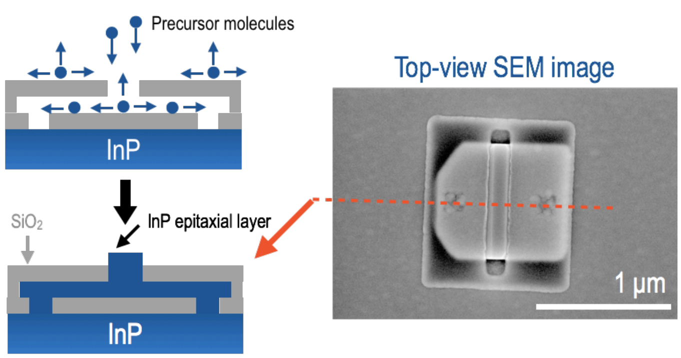

Figure 1 The confined structure is defined by SiO_2 horizontal and vertical layers. Precursor molecules, trimethyl-indium and thermally cracked phosphine enter into the structure through the feed hole in the center and arrive onto the two seed holes where the growth initiates. Top-view SEM image confirms the epitaxial growth inside the confined structure.

[1] P. Long et al., IEEE Electron. Dev. Lett. **37**, 345(2016).

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High-resolution Cross-Sectional Transmission Electron Microscopy

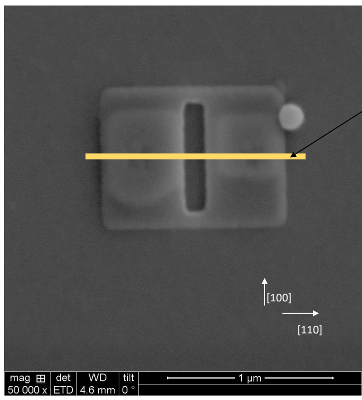

Figure S1 Top-view SEM image showing the section used for cross-sectional TEM analysis.

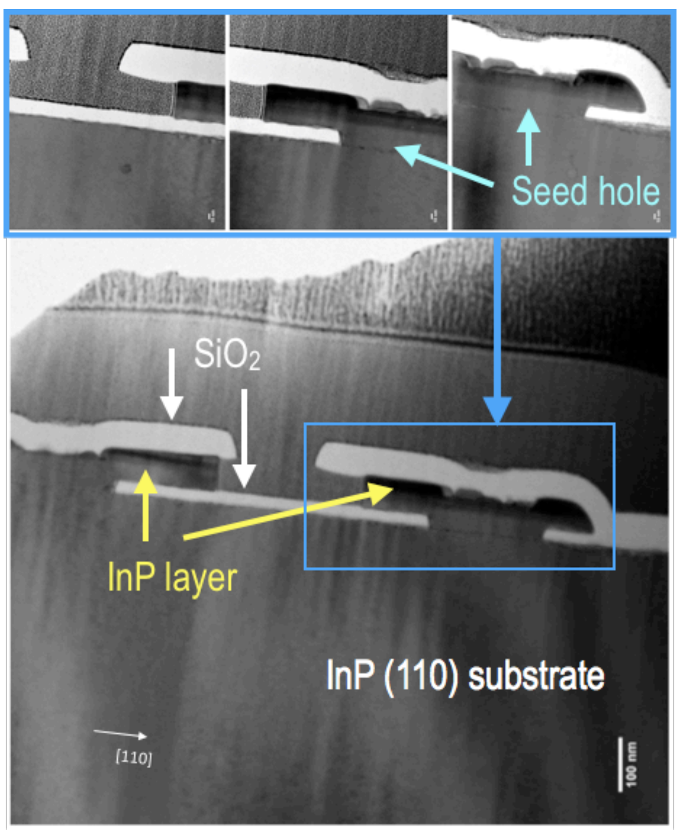

Figure S2 Cross-sectional TEM images of epitaxial InP layers grown inside the confined structure. Growth fronts toward the feed hole show the desired vertical facet. The depth of seed hole (i.e. thickness of bottom SiO_2 layer) is 20 nm and the height of tunnel is 50 nm.