Monolithic integrated InP distributed Bragg reflector (DBR) lasers on (001) silicon

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Silicon Photonics more and more is considered as a competitive platform for building complex photonic ICs, applicable in various fields, but the lack of a practical on-chip integrated compact, high-yield and electrically-driven laser source remains a major bottleneck. Due to its indirect bandgap, silicon itself is a poor light emitter. Therefore, new materials such as Germanium, III-V compounds and rare earth doped nanocrystals are being investigated and laser operation from hybrid III-V lasers [1], monolithic Germanium lasers [2] and monolithic III-V nanowire lasers [3] has been demonstrated. While III-V provides generally better performance, realizing monolithically integrated in-plane lasers that can be integrated with other waveguide circuits remains extremely challenging. In this paper, using a selective area growth technique originally developed for realizing next-generation ultrafast electronic transistors, we demonstrate a room temperature operating monolithic integrated in-plain InP DBR laser grown on a standard 300mm (001)-silicon substrate.

Conventional approaches for growing III-V compounds on silicon require a micrometers-thick buffer to cope with the large lattice mismatch and thermal expansion coefficient difference between silicon and III-Vs. In our work, InP waveguides were selectively grown inside narrow trenches defined by a Shallow-Trench-Isolation (STI) method [4] and V-groove etching. The transmission electron microscope (TEM) image shown in Fig. 1a shows that the InP-material is of high crystalline quality except for the 20nm buffer layer located at the InP-Si interface. Following the epitaxy, we defined first order Bragg gratings (165 nm period, 60 nm etching depth, and 50% Duty Cycle) on top of the diamond-shape InP-waveguides using electron beam lithography (EBL) and plasma etching. Next, the silicon substrate beneath the InP was removed using a selective dry etch process to prevent leakage of the optical field (Fig. 1b).

For characterization, 7 ns pump pulses from a 532 nm Nd:YAG nanosecond pulsed laser are delivered to the sample in a uniform rectangular area covering a single cavity. After being scattered by the second order grating located at one end of the DBR laser, the laser emissions is collected by a 50x, 0.65 numerical aperture (NA) objective and measured through a ¼ m monochromator. The single mode spectrum in Fig. 1c and the S-shaped light-light curve convincingly show the devices exhibit indeed laser operation. Efficiencies of more than 5% and high reproducibility of these results over multiple devices and multiple wafers has been demonstrated.

The top-down integration process, high yield and high controllability together with the in-plane laser configuration, thin buffer layer and selective area process make this device highly promising as a source for future photonic ICs.

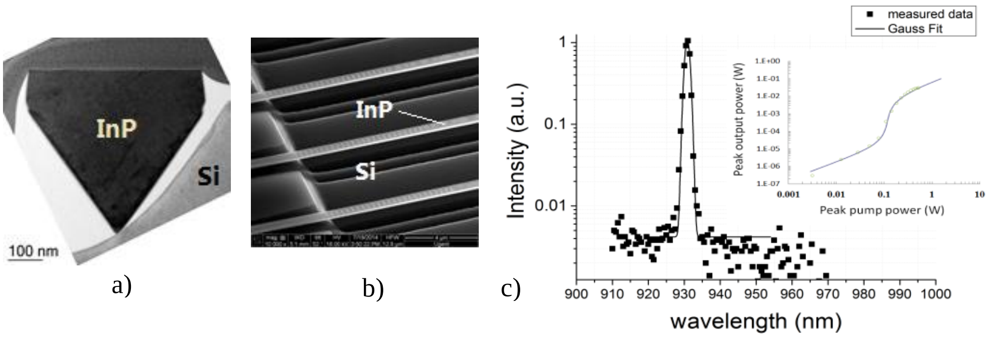

Fig. 1 a) TEM image of the cross section of the InP waveguide, the dark part is on the bottom is the defect area. b) SEM picture of the second order Bragg grating on the suspended InP waveguide. c) Measured spectrum and L-L curve(inset). The centre wavelength of the laser is 931.3nm and the FWHM is 1.7nm, the threshold is around 77 mW.

References

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