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Development of active-passive regrowth for butt-coupled lasers in membrane photonic integrated circuits

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Introduction: Photonic integration on membranes can be used to combine electronic and optical functionality. An InP membrane on Si (IMOS) [1] is an advantageous solution, since it can include lasers, detectors and waveguide devices. In order to scale down the footprint of active devices such as photonic crystal nanolasers (Fig. 1a.), active passive regrowth is necessary. This paper reports on the design of the active layer stack and development of an active-passive regrowth process for integrated active devices which are butt-coupled to membrane waveguides. A first realized structure with this technique is shown in Fig. 1b.

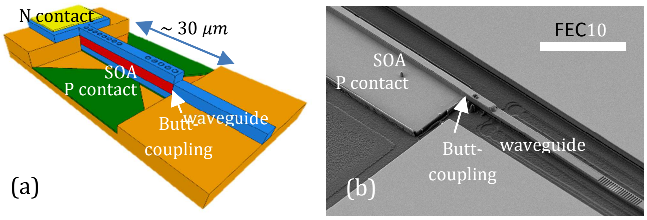

Fig. 1. (a) Schematic of a laser butt-coupled to a waveguide; (b) SEM image of a realized structure.

Active layer stack design: Electrical and optical confinement is provided by a double heterostructure with bulk InGaAs or InGaAsP as the active layer and doped InP as a barrier layer. We use bulk material in order to provide higher gain in small devices when cavity losses are large and high injection currents are necessary (Fig. 2a.). We carefully choose doping levels and thicknesses in order to make a tradeoff between technology and SOA performance. On the one hand, we need to isolate optically the active region and reduce cladding doping levels in order to reduce the internal loss of the SOA. On the other hand, we cannot afford a total thickness higher than 1 μm to perform high quality dry etching using a thin hard mask. Moreover, a thin layerstack and high doping of the cladding will minimize the series resistance of the device. Apart from that we need to include several sacrificial and etch stop layers (green in Fig.3a) in order to make successful regrowth possible. Optimized layer stack parameters are presented in Fig. 3a. Fig. 3b. shows the optical mode distribution in a designed layer stack. Fig. 3c. depicts loss and mode confinement dependence on SOA width for a chosen layerstack. In order to avoid multimode behavior we have to stay below 1 μm SOA width where we expect high loss and a low confinement factor. Thus, choosing an optimal layerstack is very important for a butt-coupled membrane integrated platform.

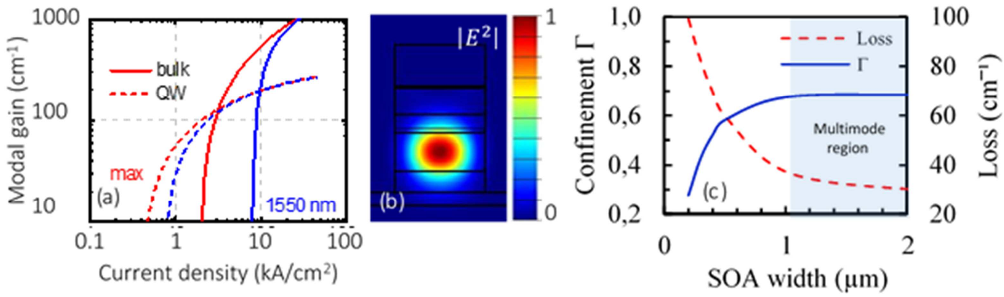

Fig. 2. (a) Modal gain dependence on current density for bulk and quantum well active material; (b) mode distribution in SOA; (c) loss and mode confinement dependence on SOA width.

Active-passive regrowth: Using MOCVD we first growth the active layer stack on top of a (100)-InP wafer. Then, we pattern active areas with 30 µm width and various length with optical lithography and apply a combination of dry and wet etching to remove etch stop layer and obtain atomic flat surface which will reduce loss in passive parts of the circuit. Finally, we regrow a 300 nm thick InP infill layer for the passive regions of the chip. On the active regions a 200 nm thick Si_xN_y mask prevents further growth. We characterize the regrowth with cross-sectional SEM images as shown in Fig. 3. As a result of the wet etching process the $(0\bar{1}\bar{1})$ and $(01\bar{1})$ facets are shaped differently, typically characterized as dove tail and V-grove facets [2]. In the cross-sectional SEM we observed a gap (Fig. 3c) for the V-grove facet. This facet of the InGaAs compound does not allow InP to nucleate on its surface, thus creating the gap, which prevents light coupling. The dove tail facet, on the other hand, provides a homogeneous interface suitable for active-passive coupling, as shown in Fig. 3b.

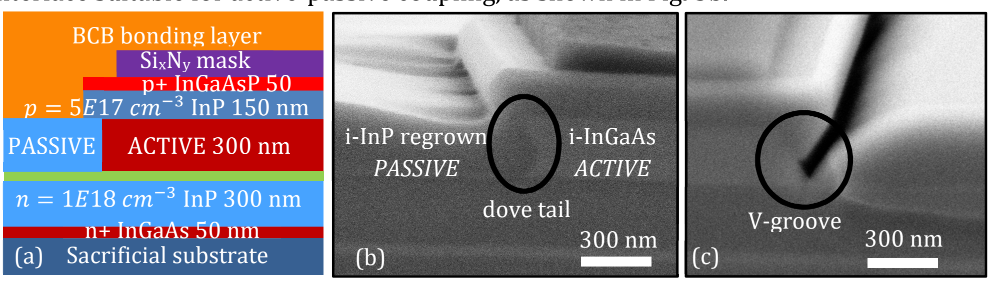

Fig. 3. (a) Designed layer stack for butt-coupled IMOS platform; (b) SEM image of $(0\bar{1}\bar{1})$ facet (dove tail); (c) $(01\bar{1})$ facet (V-groove).

Conclusion: In this work we have presented the successful active-passive regrowth for fabrication of small footprint membrane photonic integrated devices. Active passive regrowth allows us to fabricate lasers with a footprint below 30 µm². Fabrication of the butt-coupled lasers is currently ongoing. During the conference we will show more results of the fabricated devices.

References

[1] J. van der Tol, et al, "Photonic integration in indium-phosphide membranes on silicon (IMOS)," *IET Optoelectron.*, vol. 5, p. 89880M, 2014.

[2] S. Adachi, "Chemical Etching Characteristics of (001)InP," *J. Electrochem. Soc.*, vol. 128, no. 6, p. 1342, 1981.

[3] L. A. Coldren and S. W. Corzine, "*Diode lasers and photonic circuits*". 2012.