

## Buried heterostructures for deep UV lithography

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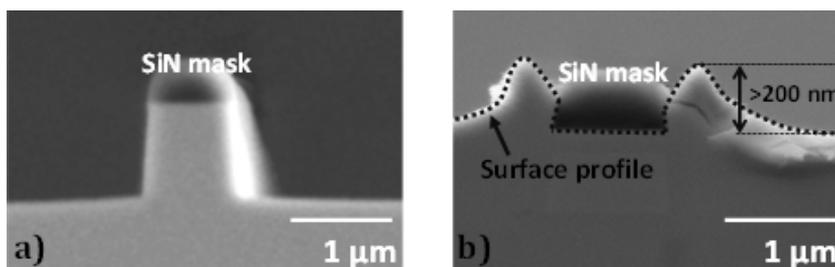
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Buried Heterostructure (BH) lasers and amplifiers are known to have good thermal performance and efficient current injection [1-2]. However they have not so far been integrated with ridge waveguide devices, preventing complex circuit integration. The inclusion of BH waveguide in photonic circuits requires their integration with deep and shallow waveguides and this has been challenging to achieve because the active and passive waveguides are defined in different mask layers. The waveguides may be connected using either precision tapers [3] and or precision mask alignment at the 100 nm scale.

Among all the lithography techniques, which enables wafer scale production, deep UV (DUV) scanner lithography allows for high resolution and high precision alignment (100 nm). Therefore, in this work we propose the use of DUV scanner for the integration of BH and passive structures on the same circuit, and develop the processing steps required to minimize wafer flatness within the accepted field of focus.

In a DUV scanner, the pattern is projected on the substrate through a lens system, which reduces (four times) the pattern present on the mask. The used wavelength is short (195 nm) so the depth of focus is low and it requires a total thickness variation (TTV) of 1  $\mu\text{m}$  and a local focal point variation (LFPV) of 200 nm: therefore, it is necessary that the exposed wafer present a flat surface during the exposure to ensure the wanted resolution all over the wafer. In a BH laser or amplifier the mesa is first defined by etching and later on is buried by the InP regrowth. The hard mask is removed after the InP regrowth and the passive integration can be carried on by DUV lithography. Then the COBRA generic integration process can be implemented to complete circuit fabrication [4].

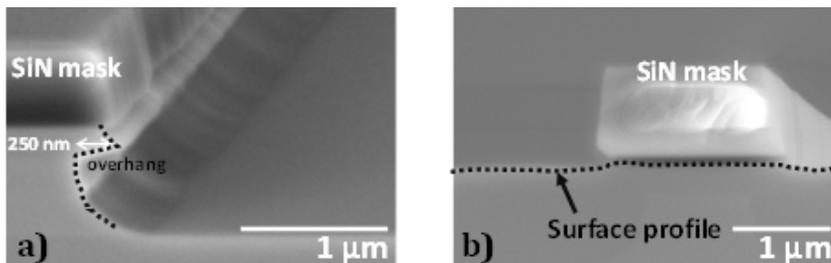
Figure 1 shows a SEM picture of the cross section of a BH before (1-a) and after (1-b) regrowth.



**Fig. 3. SEM cross section of the mesa after dry etching and after InP regrowth (b); the overgrown material at the edge of the stripe doesn't allow for the use of DUV.**

The mesa were oriented in the  $[0\bar{1}1]$  direction and were defined by ICP with a  $\text{CH}_4/\text{H}_2$  chemistry and SiN as hard mask. The successive InP regrowth was performed by MOVPE. The resulting topography shows an anomalous growth in the vicinity of the mask. These overgrowth defects have thickness of 500 nm meaning that the surface profile does not meet the DUV requirements mentioned above. As demonstrated in [5-6], to improve the wafer flatness for planar BH, one solution is to create, by wet etching, an overhang under the hard mask. The purpose is to prevent the InP under the overhang to grow upward.

Figure 2-a shows a SEM picture of the cross section of a mesa defined by wet etching: the created overhang (dotted line) is about 250 nm. In the sample, the mesa was created using diluted hydrochloric acid (25 %) for 1 min to etch the InP layer and citric acid to etch the quaternary active layer. The measured overhang is around 250 nm for the optimized process flow. After the definition of the mesa, the InP regrowth was performed (see Fig 2-b) by MOVPE with the same parameters as before. It is clear that, thanks to the overhang, the resulting surface profile is almost flat. Therefore, after removing the SiN mask, it is possible to use DUV.



**Fig. 4. SEM cross section of the mesa after wet with creation of the overhang (b) mesa after the regrowth: the surface profile is now compatible with DUV scanner.**

In this work we have demonstrated a first step towards the integration of BH lasers and amplifiers with passive components. The critical steps involved in the fabrication of BH components have been shown to be compatible with the use of DUV lithography. The use of DUV lithography will enable to align with high accuracy active and passive components.

#### References

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