Planarization of overgrown tunnel junctions for InP-based VCSEL by MOVPE

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InP-based long-wavelength vertical-cavity surface-emitting lasers (VCSEL) have emerged to cost-effective light sources for telecom applications, which is mainly due to the benefits of on-wafer testing capability, simple array integration and high fiber coupling efficiency. In our approach, the InP-based VCSEL consists of an MBE grown basic structure, which includes an AlGaInAs/AlInAs top DBR, the AlGaInAs-based active region and tunnel junction. To create a current aperture, mesa structures with a height of around 15 nm and 5 µm in diameter are fabricated using a dry etching process. After a cleaning procedure the patterned sample is then overgrown with silicon doped InP and a thin GaInAs:Si contact layer, which provides a good thermal and electrical conductivity to the gold heatsink as shown in Fig. 1. (The wafer was flipped and the substrate removed.)

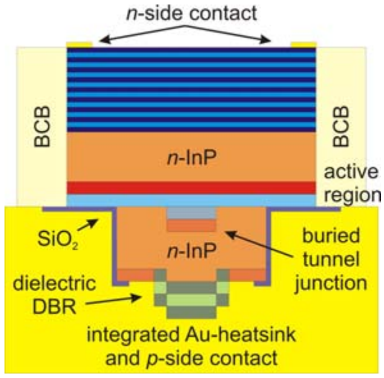

Figure 1: Overview of the InP-based VCSEL structure.

A certain drawback of this concept is the strong index guiding of the optical wave caused by the step-like profile of the refraction index in the dielectric bottom mirror. This structure has its origin in the surface profile after capping the BTJ with InP. Due to the higher accessible growth temperatures compared to MBE and therefore higher migration lengths of the atoms at the surface, the MOVPE offers the opportunity to plane the step profile during the overgrowth, which reduces the strong index guiding. From this reduction, the laser device gains higher sidemode suppression, which enhances the single mode operation leading in the end to a higher output power.

The InP overgrowth has been carried out with an AIX 200/4 MOVPE system at temperatures of 500 and 600°C, respectively, at a pressure of 150 mbar (H_2 ambient). As precursors TMGa, TMIn, PH_3, AsH_3 and SiH_4 have been used. The thickness was controlled in-situ by using a Laytec EpiTT reflection measurement setup. The morphology was characterized with Nomarski microscope images, whereas the surface profile of the overgrown structures was measured by atomic force microscopy. Finally, the electrical properties of the overgrown tunnel junctions were studied.

As shown in Fig. 2 an almost complete planarization of the etched structures after the deposition of 1.2 µm of InP could be achieved at a growth temperature of 600°C. The measured tunnel junction blocking ratio of around 500 indicates also a superior electrical quality, since MBE-overgrown tunnel junctions usually have a blocking ratio of around 100. This technique is therefore a very promising tool for the fabrication of high performance InP-based VCSEL.

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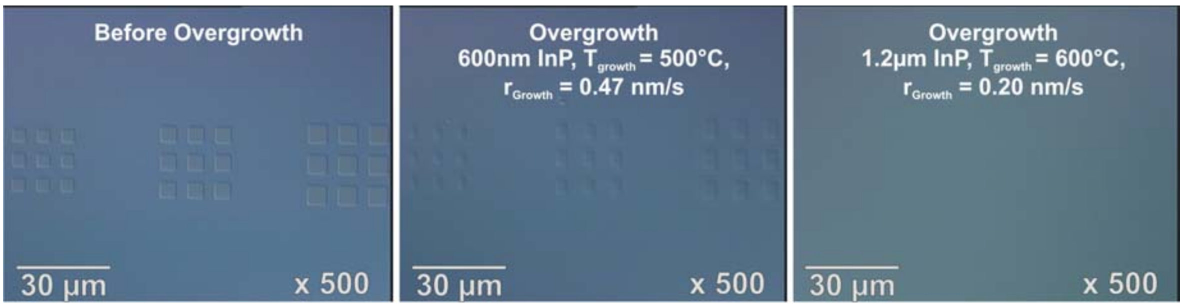

Figure 2: The microscope images illustrate the planarization of the etched structures at 600°C, whereas at 500°C only an elongation in (01$\bar{1}$) direction could be observed.

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