An electrically driven membrane microdisk laser for the integration of photonic and electronic ICs.

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Abstract— **We report on electrically pumped lasing in a microdisk cavity in an InP-based membrane bonded on top of a silicon wafer. The top metal contact is placed in the center of the disk, whereas the bottom contacting is done by means of a thin lateral contacting layer. In order to avoid large optical absorption in p-type contact layers, a tunnel junction was used in combination with two n-type contacts. Lasing was observed in pulsed regime with a current threshold of about 1.5mA, for microdisks with a diameter of 8μm.**

I. INTRODUCTION

For future generation electronic circuits, a severe bottleneck is expected on the global interconnect level. With decreasing device dimensions, it is increasingly difficult to keep propagation delays and power consumption acceptable. Therefore there is a need for radically different interconnect approaches and one of the most promising solutions is the use of an optical interconnect layer. A possible approach for a compact optical link is the use of a Silicon-on-Insulator (SOI) passive waveguide layer [1] in combination with III-V semiconductor microlasers and microdetectors, which are defined in a III-V membrane bonded on top of the SOI-stack. A good candidate for the microlaser is the membrane microdisk laser: optically pumped lasing in this type of devices was already reported [2], however, electrical injection remained a major difficulty. In this paper, we report on the design, fabrication and measurement results of electrically injected membrane microdisk lasers.

II. DESIGN ASPECTS

Optically pumped lasing was reported [2] for completely etched microdisks in an InP membrane with an optical thickness of about half the lasing wavelength, bonded onto a Si wafer with an 800nm-thick intermediate SiO_2 layer. In order to make these microdisks compatible with electrical injection, a pn-junction needs to be added around the active layers as well as two metal contacts, while preserving the quality of the laser resonator. In our design, the top metal contact is placed at the centre of the disk, where the optical intensity of the laser mode is very low, thus causing no extra absorption loss. The bottom contact is placed on a very thin semiconductor layer that extends laterally at the bottom of the microdisk (see figure 2). This bottom contact layer can cause optical leakage if it is too thick. However, a 3D FDTD analysis revealed that these structures can support whispering gallery modes with quality factors over 10000 for a 50nm-thick bottom contact layer, a disk diameter of 4μm and a total disk thickness of 0.5 or 1.0μm. The total disk thickness was increased to reduce optical absorption due

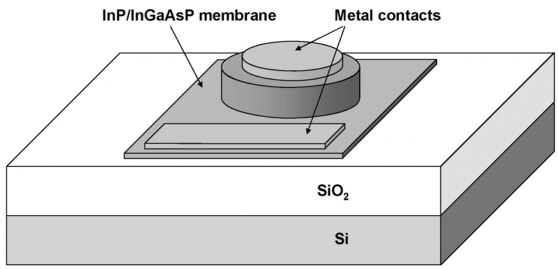

Figure 1. General layout of the membrane microdisk laser

to doped semiconductor layers. An ohmic p-type contact to InP typically requires thick, highly doped, low band gap contact layers which are highly absorptive. In order to avoid these highly p-type doped contact layers, we chose to use a tunnel junction in combination with another n-type contact. This tunnel junction consists of a reverse-biased Q1.2 p++/n++-junction with layer thicknesses of only 20nm and doping levels above $10^{19}cm^{-3}$. This type of tunnel junctions can have low absorption losses in combination with a low resistivity [3].

III. FABRICATION AND MEASUREMENT RESULTS

The laser heterostructure including three quantum wells and the tunnel junction was grown by molecular beam epitaxy (MBE) on a 2 inch InP wafer. This wafer was bonded onto a Si wafer by molecular bonding (for more details, see [2]). After substrate removal, the microdisks were defined by optical lithography and were etched into the 800nm-thick bonded membrane by reactive ion etching (RIE) using a Ti hard mask. The RIE etch was incomplete, leaving a thin bottom contact membrane of about 65nm. These structures were covered with a benzocyclobutene (BCB) film, which was etched backed before applying the top and bottom metal contact. A Ti/Au bottom contact was deposited as well as a low-loss Au-based top contact. The contacts were fast-alloyed at 400°C (figure 2).

Electroluminescence as well as IV-measurements were performed on these microdisks. The series resistance of the microdisk was very high, about 350 Ohm, due to a non-optimized tunnel junction design. Due to this high resistance in combination with the poor heat sinking ability of this membrane device, lasing could only be observed in pulsed regime (6ns-pulses, 3MHz repetition rate, 20°C). For a disk with a diameter of 8µm, the threshold was about 1.5mA ($3kA/cm^2$) and the lasing wavelength was 1520nm (see figure 3).

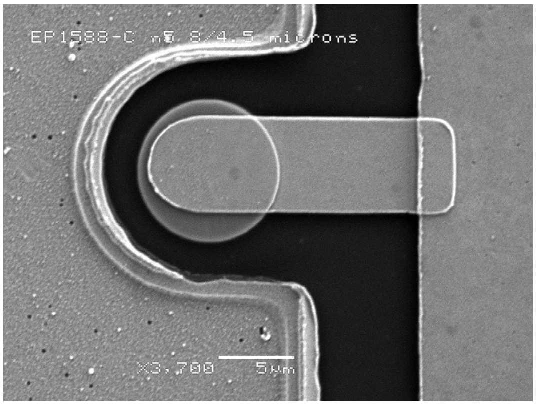

Figure 2 SEM picture of a membrane microdisk laser

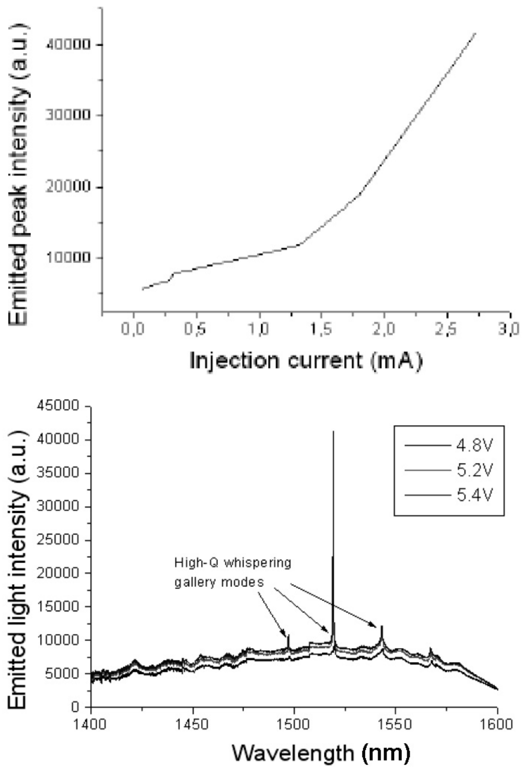

Figure 3 PI-curve and emission spectrum of a membrane microdisk laser (diameter=8µm)

IV. REFERENCES

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