

# Oxidation of AlInAs for Current Blocking in a Photonic Crystal Laser

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*To make a direct electrically pumped photonic crystal membrane laser is a challenging task. One of the problems is how to avoid short circuiting between the p- and n-doped parts of the laser diode, when the membrane thickness is limited to 200-300nm. In COBRA, we want to use the oxide of AlInAs to realize the current blocking function. In this way, together with a submicron selective area re-growth technique, we expect to make electrically injected Photonic crystal lasers with higher pumping efficiency and small threshold currents, as well as low power consumption. In this paper results are presented on the development of oxidation of AlInAs. The results show that it is practically feasible to use oxide of AlInAs for current blocking in a photonic crystal laser in a InP-based membrane system.*

## 1 Introduction

Wet oxidation of Al containing materials has brought clear improvements in Vertical Cavity Surface Emitting Laser (VCSEL) performance<sup>1</sup>. Use of this native oxide as a dielectric aperture for optical and current confinement has enabled ultra-low threshold currents and high-output power VCSELs<sup>2</sup>. Building on a submicron selective area re-growth technique<sup>3</sup>, we want to use the oxide of AlInAs for current blocking in an InP-based membrane photonic crystal laser (Fig. 1). Due to the high resistance in the oxide, carriers are forced through the active region in the cavity. Thus the pumping efficiency is increased. Therefore the threshold current and power consumption will be reduced.

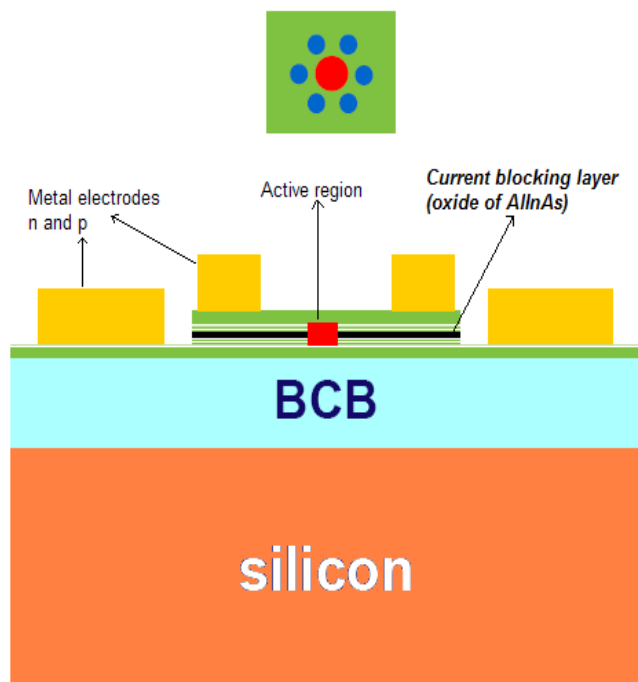


Fig. 1. Schematic view of one photonic crystal laser

## 2 Design and Fabrication

### 2.1 Experimental set-up

The oxidation experiment was carried out in a horizontal quartz tube in a furnace. This furnace is fed by nitrogen gas passed through a water bubbler maintained at 95 °C.

### 2.2 Layer stack of the test wafer

Fig. 2 shows the layer stack of the test wafer. On top is a 60nm InP cap layer. Both 225nm p-InGaAs and p-InGaAsP are for the p side-metal contact. Beneath them are the 35nm InP layer and most importantly 100nm of AlInAs layer for oxidation. The substrate is n-type InP and n side metal contact is deposited on the back side.

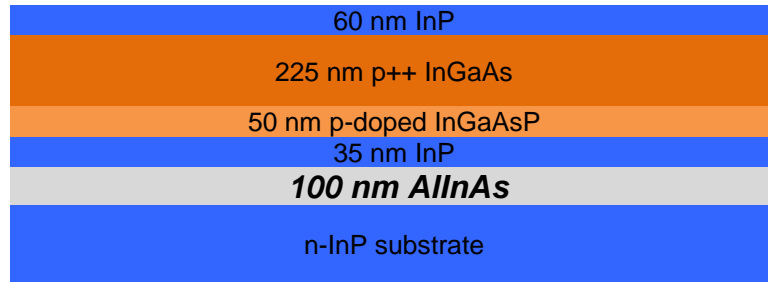


Fig. 2. Layer stack of the test wafer made by PHILIPS

### 2.3 Process exploration

Various kinds of oxidation tests have been done in order to find the right process window. After rounds of process exploration and optimization, good quality of oxidization of the AlInAs is obtained as shown in Fig.3. This oxidation test is done at 450 °C for about 2hrs. The oxidation depth is around 600nm which is enough for future applications in photonic crystal lasers. The depth of oxide formation as a function of oxidation time follows to a square-root function<sup>1</sup>. In this test the oxidation rate is relatively low (0.06µm/min<sup>1/2</sup>) because of the relatively low oxidation temperature.

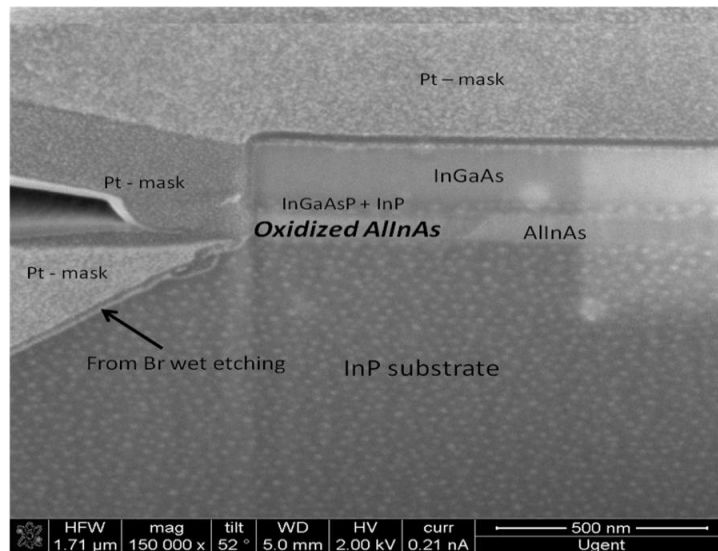


Fig. 3. SEM picture of AlInAs oxide from Focused Ion Beam etching

## 3 Electrical measurement:

### 3.1 Idea and design

One of the key features of the InP-based membrane platform is its ultra-small thickness (200-300nm)<sup>5</sup>. Therefore the thickness of the oxide layer should be limited to 100nm. Whether this small thickness of oxide can give high enough resistance is what needs to

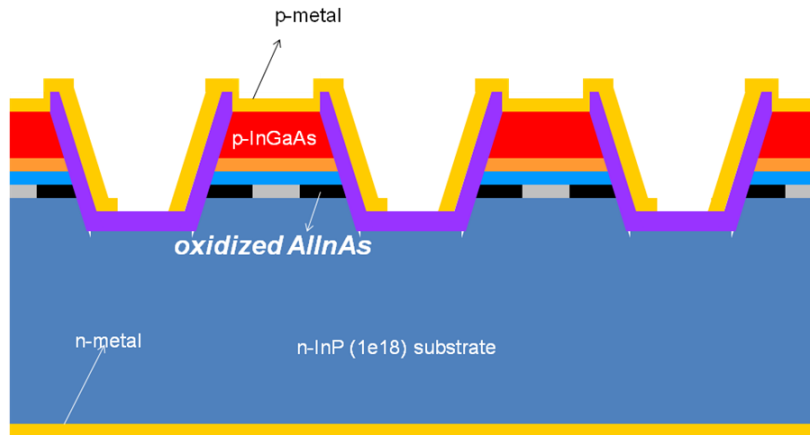


Fig.4. Schematic view of the device for electrical measurement

be determined. Fig.4 shows the schematic view of the p-i-n diode used to measure the resistance of the AlInAs oxide. Stripes of different widths (from 2 $\mu$ m to 10 $\mu$ m) have been formed

### 3.2-Process optimization

Three optical lithography steps are used. The first step is to defines the stripes. After that, Bromine wet etching is used to form the mesa. The oxidation is done afterwards at 500 °C for 1 hour. This relatively high oxidation temperature is used to obtain a oxidation rate of 0.4 $\mu$ m/min<sup>1/2</sup>. This is beneficial to have stripes with a completely oxidized layer. The quality observed on cleaved samples is similar as the oxidation test done at 450 °C. The second lithography step is used to open the top contact for the final metallization. A final optical lithography step is performed to isolate each device from each other as can be seen in Fig.4. Finally, metal contact (Pt, Ti and Au) are deposited on both sides and the whole process is finished with an annealing for the metal contact.

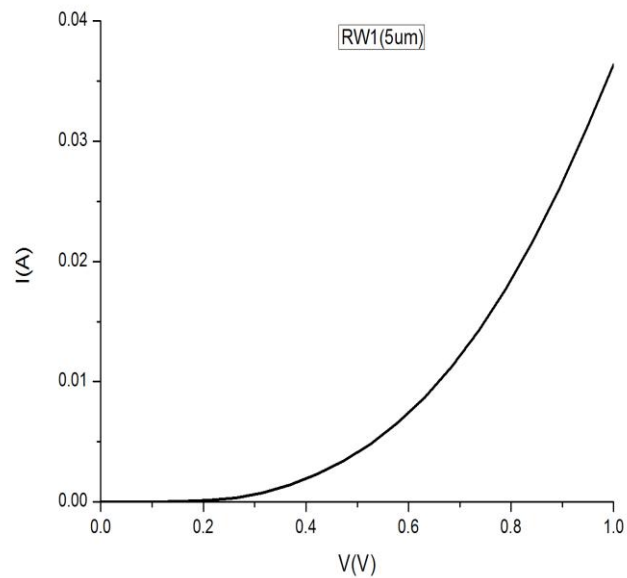


Fig. 5. I-V measurement of the un-oxidized sample.

### 3.3 Resistance measurement

Fig.5 shows the I-V (current-voltage) curve for the un-oxidized sample. The “turn-on” effect of the p-n junction is clearly visible, it is around 0.7 V. Above turn-on voltage, the resistance is around 25Ω.

Fig. 6 shows the I-V curve of the sample (3.2μm in width, 8mm in length) whose AlInAs layer (100nm in thickness) is completely oxidized. The resistance of AlInAs oxide is at least 100kΩ until 3V which means that wet oxidation of AlInAs brought an increase of the electrical resistance for more than 3 orders. This is sufficiently high for use in photonic crystal laser in InP-based membrane.

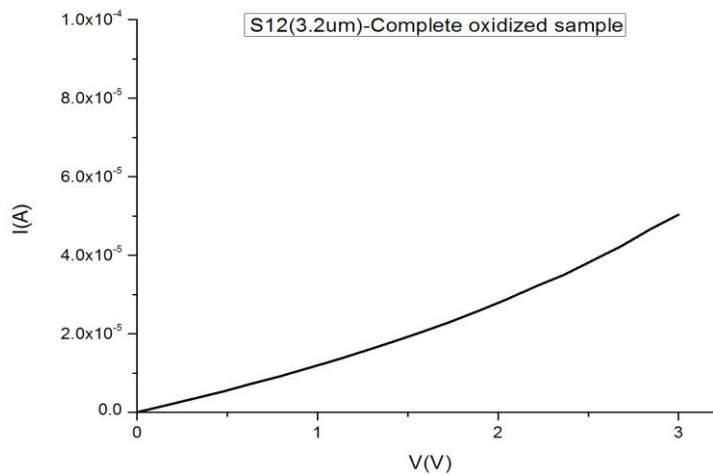


Fig. 6. I-V measurement of a complete oxidized sample.

## 4 Conclusion

The result shows that it is feasible to use AlInAs oxide in an InP membrane based photonic crystal laser for the current blocking function. This technique, combined with submicron selective area re-growth, will enable us to make direct electrically pumped InP membrane based lasers with low threshold currents and low power consumption, as well as high output power.

## Acknowledgements

The authors thank EU Project HISTORIC for its financial support.

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