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Wet etching technique for fabrication of GaSb based mid infrared single lateral mode lasers

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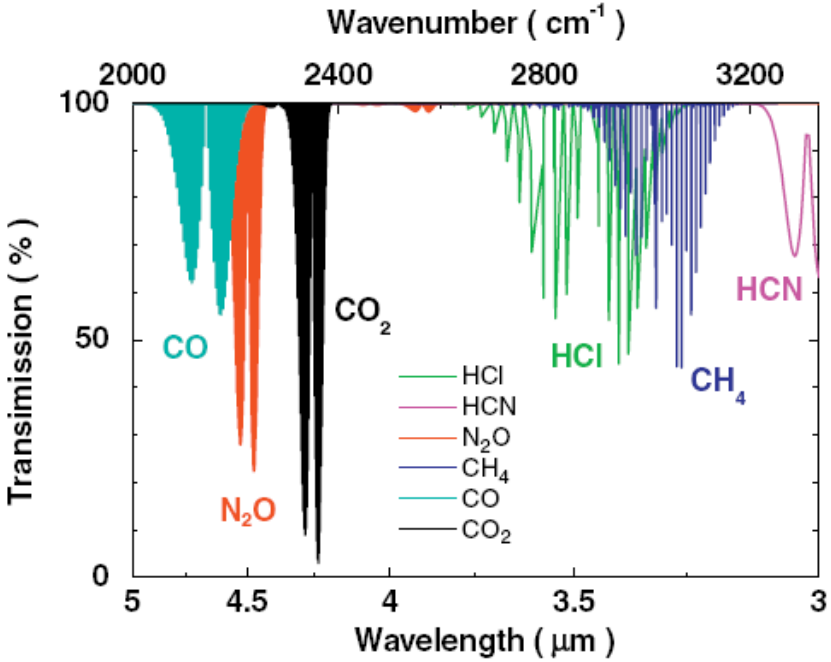
Outline

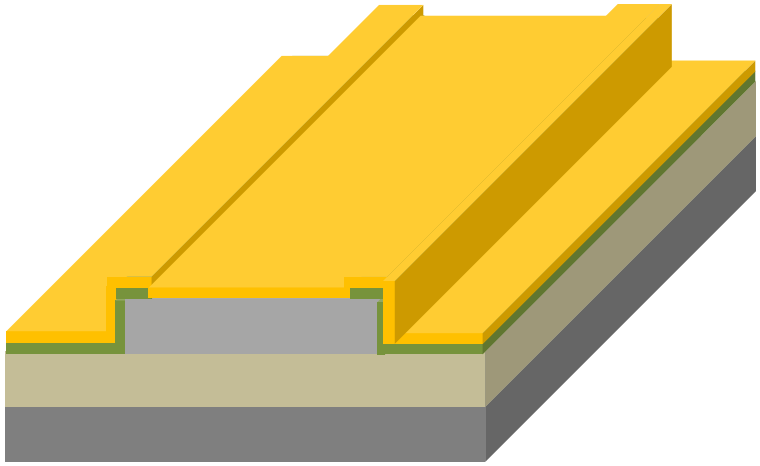
- Motivation
- Technology description
- Device fabrication
- Result and discussion
- Summary

Applications of Mid IR Lasers



A. Krier et al, phys. stat. sol. (a) 205, No. 1, 129–143 (2008)

Absorption spectra of various gases within Mid IR (2 ~ 5 μm) range



<Schematic of the narrow ridge laser>

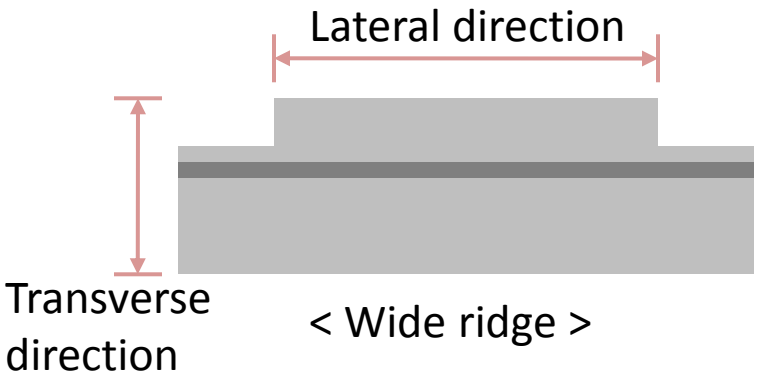
<Applications>

- Gas detection

- Free space communication

- Medical diagnostics

Wide ridge vs. Narrow ridge lasers



< Wide ridge >

< Narrow ridge >

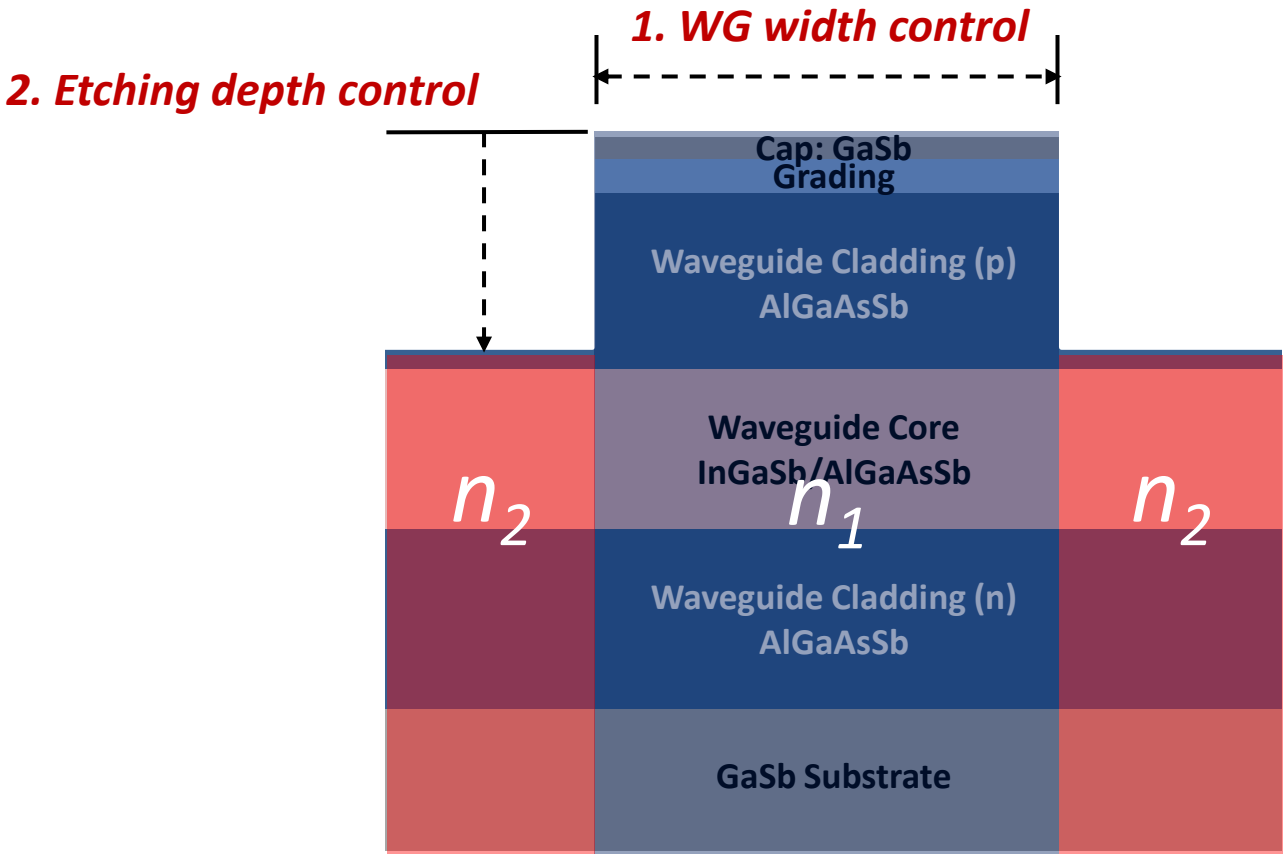
Characteristics

-Wide mesa width ~ 100 μm
-High power
-Lateral multimode operation
-Relatively easy fabrication

Characteristics

-Narrow mesa width < 10 μm
-Low threshold
-Lateral single mode operation
-Relatively difficult fabrication
-Necessary step for the longitudinal single mode operation

Crucial points to fabricate the narrow ridge



< Typical GaSb based mid IR laser QW laser structure>

Lateral single mode requires the precise refractive index step (n_1-n_2) control together with the mesa width.0

Fabrication of narrow ridge

<Dry etching>

Advantages
- Precise control of etching depth
- High degree of Directivity
- High degree of non-selective etching

Disadvantages
- High cost
- Low throughput

<Wet etching>

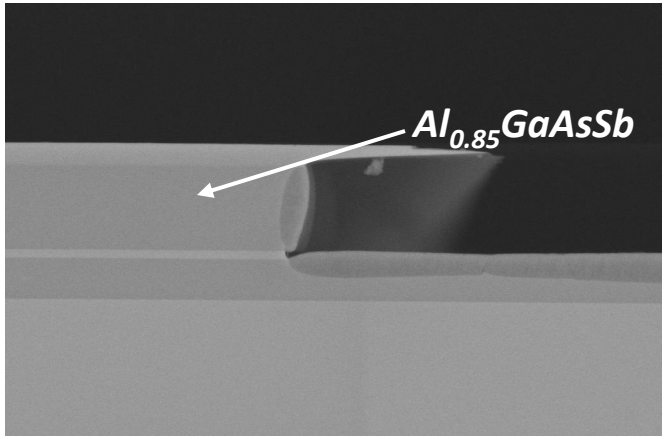
Advantages
- Cost effective
- High throughput
- Relatively easy implementation
- High degree of material selectivity

Disadvantages
- Low degree of directivity
- High degree of material selectivity

Could be preferred to industrial process.

Implementation challenges using wet etching

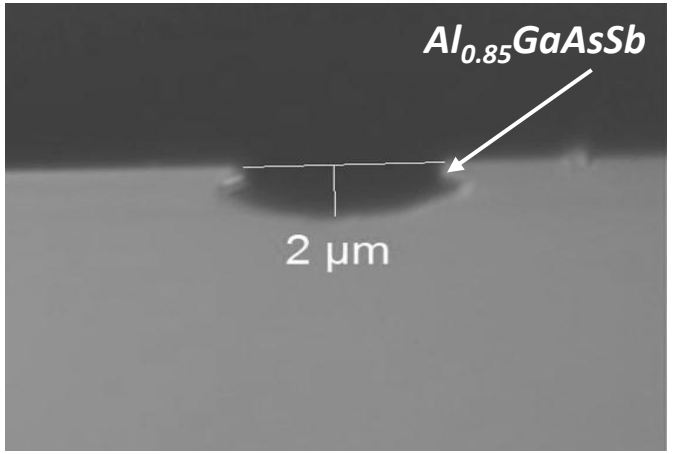
Material selectivity



< Etching test with HCl based solution>

→Fast etching rate for Al-rich material

Isotropic etching profile



< Etching test with Tartrate based solution>

→Fast etching rate for non Al-rich material

Two major points of this technique

Complementary Etching

- Role:
  To compensate etching selectivity between the GaSb and AlGaAsSb layer.

- Procedure:
  1. Etching GaSb with Tartrate solution
  2. Etching AlGaAsSb with HCl solution

Etch Stopper

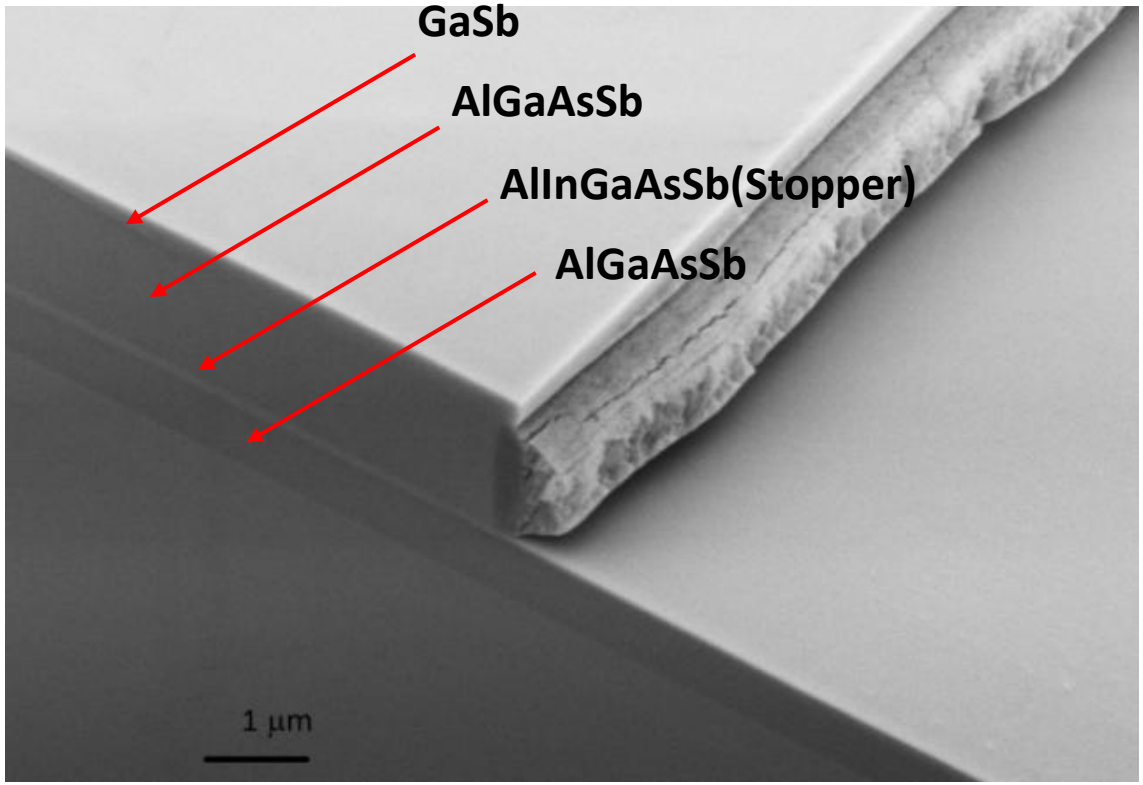
- Role:
  To control precise etching depth

- Requirement:
  1. Slow etching rate with HCl
  2. Need to minimize carrier transport problem

Proper material selection

AlInGaAsSb

Preliminary wet etching result



<Etching test with the etch stopper>

Processing detail: Etchant preparation

<Tartrate based solution>

Tartrate : DI Water : H_2O_2 : H_3PO_4
=5 g : 90 ml : 30 ml : 30 ml

Under stirring for 2 days

<HCl based solution>

HCl : DI Water : H_2O_2
= 50 ml : 50 ml : 1 ml

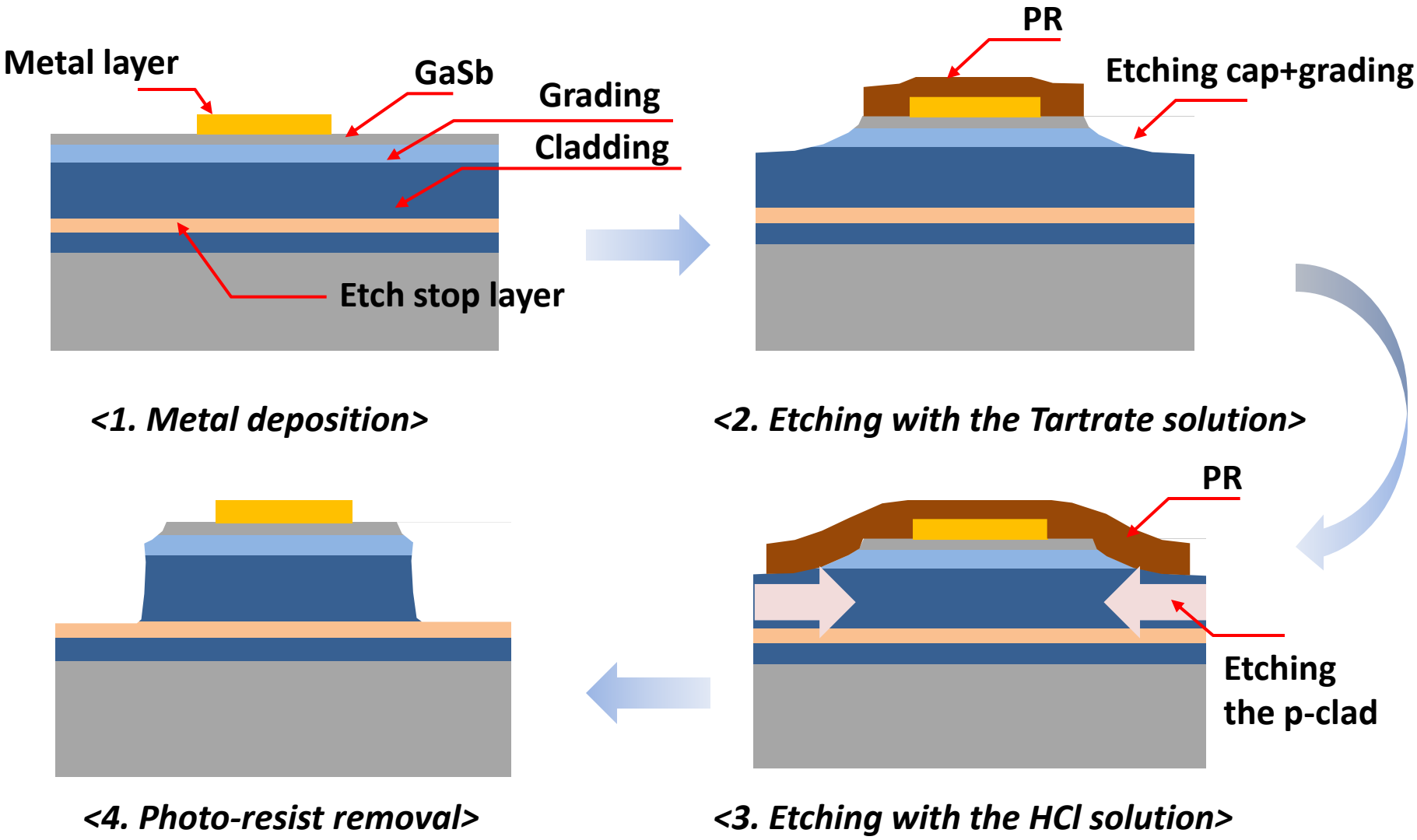
H_2O_2 was added just before used.

<Etching rate of etch etchant>

Material	***GaSb***	***AlGaAsSb***	***AlInGaAsSb***
Role	***Cap***	***Cladding***	***Etch stopper***
Etching rate of Tartrate (nm/sec)	***16.6***	***5***	***-***
Etching rate of HCl (nm/sec)	***3.2***	***30***	***1.1***

Highly selective!

Processing detail: Etching Procedure



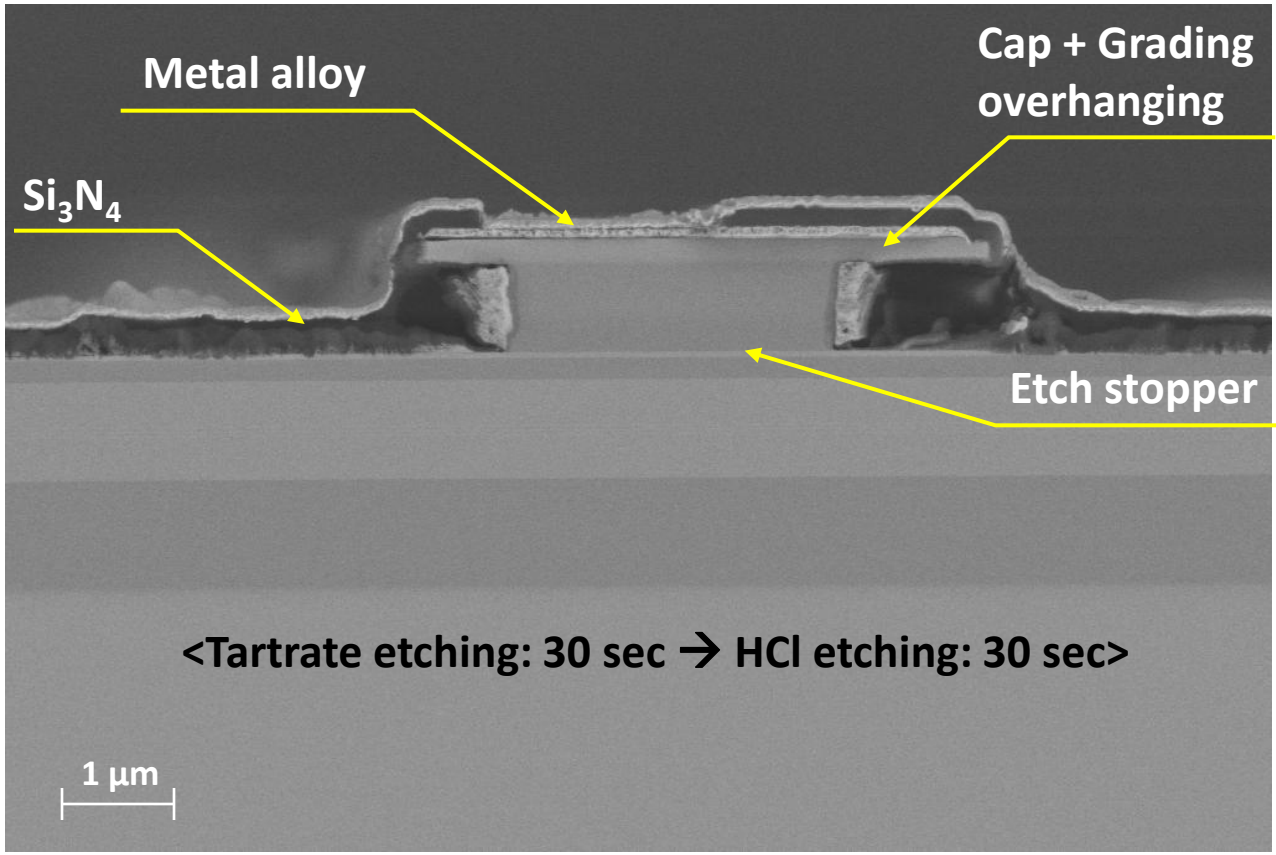
<1. Metal deposition>

<2. Etching with the Tartrate solution>

<3. Etching with the HCl solution>

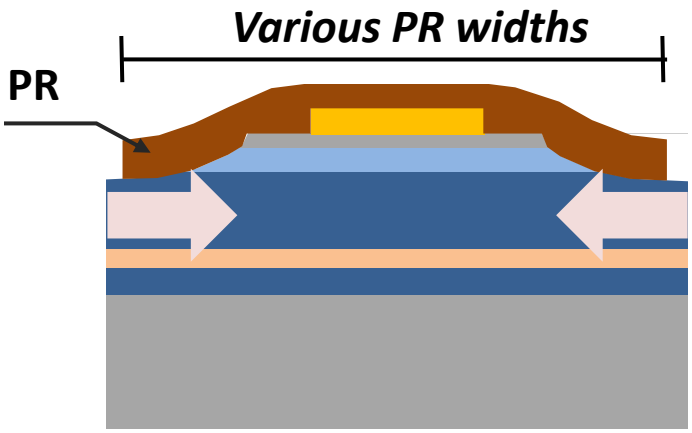
<4. Photo-resist removal>

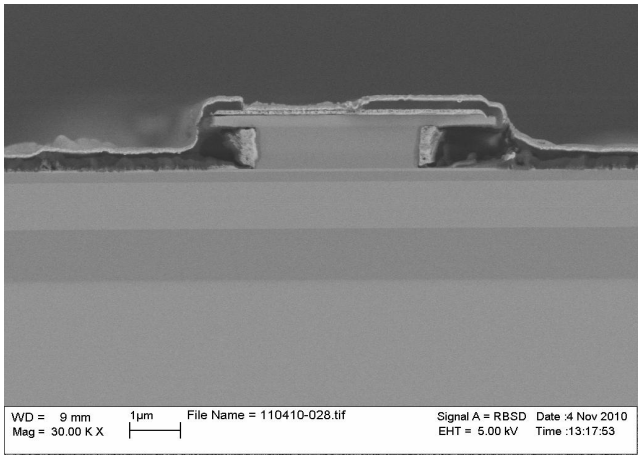
Vertical wall narrow ridge with wet etching



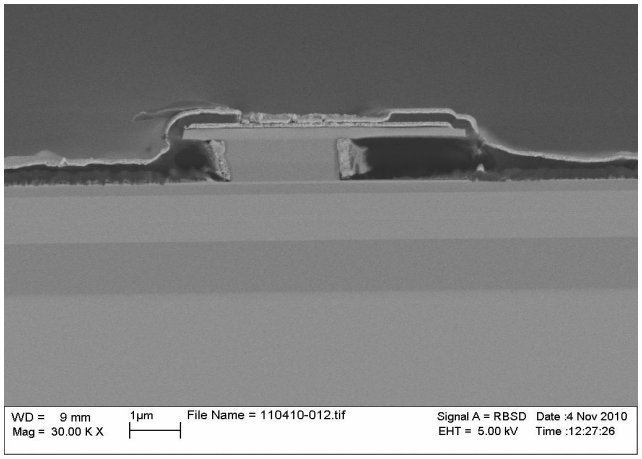
< SEM image of the complete laser device>

Mesa width control

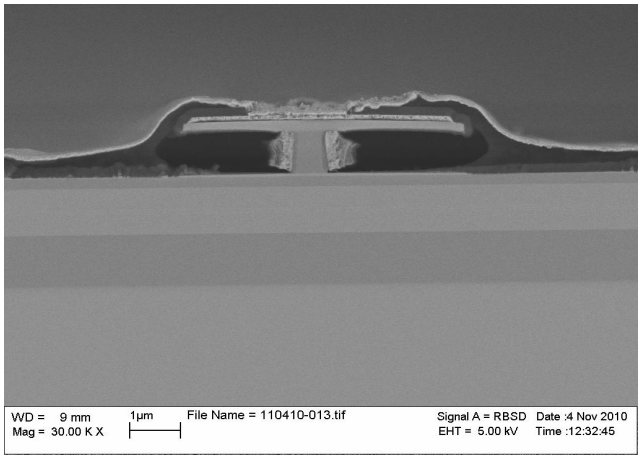




<4.2 um (12 µm) >

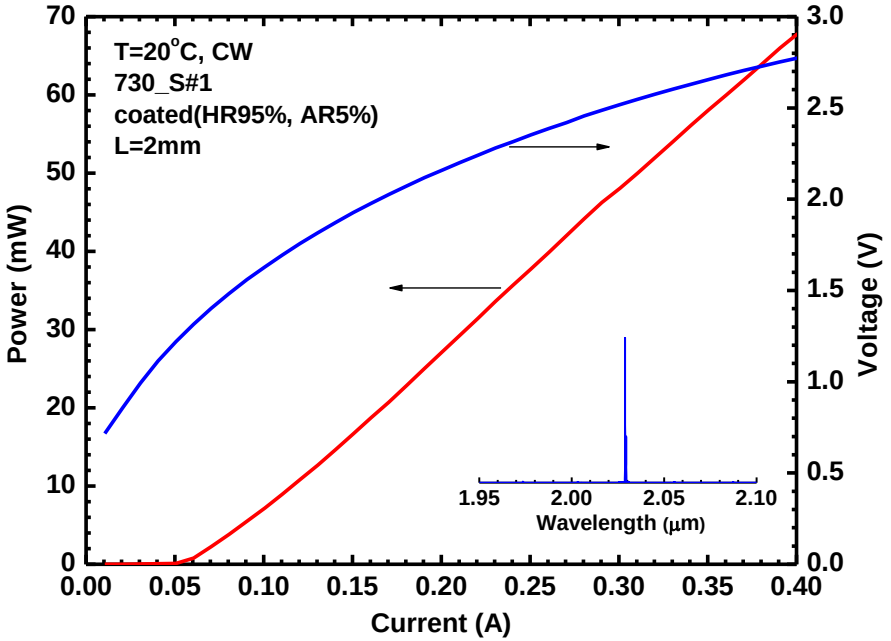


<2.4 µm (10 µm) >

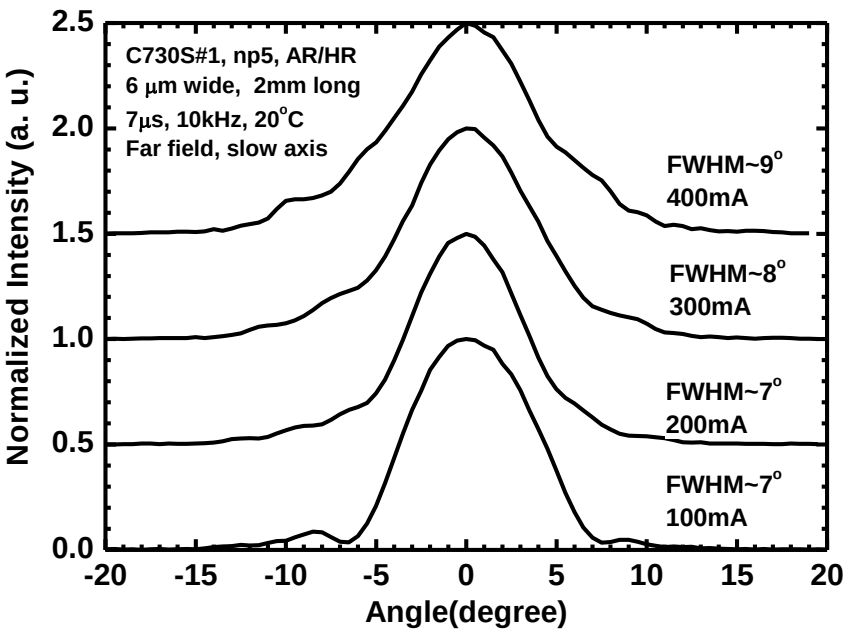


<0.5 µm (8 µm) >

Laser performance



RT cw power: ~70mW



Far field at slow axis: ~8° (FWHM)

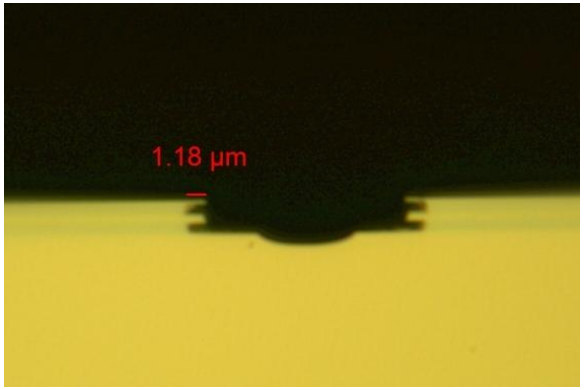
Summary and Future work

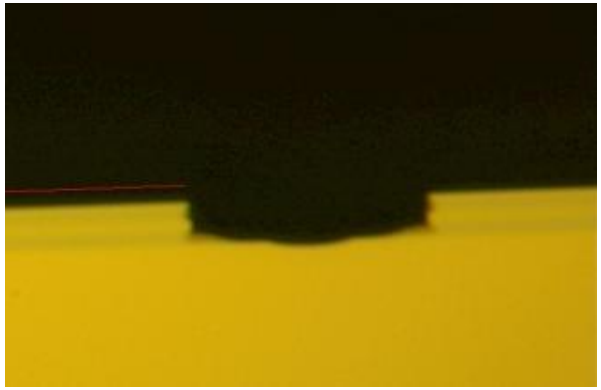
<Summary>

- *The lateral single mode laser has been fabricated by cost effective wet etching technique.*
- *Complementary etching with the etch stopper demonstrated effective mesa width and etching depth control.*
- *This technique can be used for sidewall smoothing, standing free 2D wire, etc. consisting of Al-rich and InGaAsSb sequential layers.*

< Future work>

- *Optimization of the etching process for precise etching control.*





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