InP−based materials for optoelectronic devices: old issues and new challenges for MOVPE

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InP and related compound semiconductors are key materials for optoelectronic devices in optical fiber communication.

Nowadays MOVPE is the primary growth technique for InP−based materials and InP technology is considered matured to the level where it is possible to produce high volume of high performance, high reliability electronic and photonic devices using full wafer processing.

This assumption is valid for standalone active devices, showing single functionality, very often requiring only a single epitaxy step as in the case of ridge structure laser.

At present advanced optoelectronic devices based on indium phosphide for 1300 nm and 1550 nm windows of silica fiber−based telecommunication applications, mostly require:

1− high speed operation (10 Gb/s)
2− high temperature operation (T>100 oC)
3− high degree of integration

Mass production of such devices involves some difficulties and needs both accurate investigation over a number of technological steps and a better understanding of already known technological issues, in order to be successfully transferred from R&D to manufacturing line.

1− High speed devices

A key point to obtain high speed lasers is the device capacitance reduction. This can be achieved by replacing the conventional p−n current blocking layers with a semi−insulating (SI) iron−doped InP layer. To be effective, InP:Fe blocking layer must be thick, leading to undesirable overgrowth effects near the edges of the masked stripes during the planarization of the tall mesa. In addition, iron suffers from a rapid interdiffusion with zinc from the adjacent layers and a highly undesirable diffusion into the active structure. These are well known problems related to the fabrication of SI−BRS (semi−insulating buried ridge structure) laser, operating at a modulation bandwidth starting from 10 Gb/s, using iron as dopant. From the epi−side, there is still a lot of interest in minimizing iron diffusion : to our knowledge, no valid alternative to iron has been found up to now.

Overgrowth step is very sensitive to mesa shape; therefore processing step and growth step embedding the active stripe must be carefully harmonized, to obtain perfect planarization, thus making the following steps easier.

2− High temperature operation devices

Uncooled lasers are cheaper and more reliable than thermo−electrically cooled ones because of their simplicity in packaging. It is rather difficult to make high performance uncooled lasers in the region 1300 nm − 1550 nm, using conventional GaInAsP/InP material system, because of the poor electron confinement resulting from small conduction band offset (deltaEc = 0.4 deltaEg).

It has been already demonstrated that a AlGaInAs/InP system shows better temperature characteristics because of its large conduction band offset (deltaEc = 0.7 deltaEg).

In principle the combination of Al−material and SI−BRS lateral structure already developed for the GaInAsP system is a basic ingredient to make a laser with good dynamic performances (10 Gb/s) at high operation temperature (T>100 oC).

Unfortunately, aluminium reacts with oxygen very easily, making the laser structure rather sensitive to air and leading to poor performance devices, especially from the reliability standpoint.

The new challenge for MOVPE is called In−Situ Etching (ISE), a relatively new technique capable of etching active stripes into the reaction chamber of a MOVPE system under high purity, inert gas flow.

After stripes etching, InP:Fe overgrowth can be performed, embedding the laser active region and preventing Al−material from air exposure.

Etching procedure as well as some best chlorinated compounds responsible for etching are still under investigation. During this talk, Agilent's approach to this topic will be addressed.

To date, this route seems to be the most promising solution to produce large volume, high speed laser operating at high temperature

3− High degree of integration

The increased functionality demanded from InP optoelectronics can be addressed using both hybrid and monolithic integration technologies. From the cost point of view, hybrid integration is a powerful solution, but as sophistication of InP technology continues to mature, monolithic integration can easily replace the hybrid solution at lower cost.

An example of this is the integration of a DFB (Distributed Feedback) laser with an EAM (Electro−Absorption Modulator). The integrated laser−modulator transmitter offers a number of advantages compared to external modulators; electro−optical performances (very low laser−modulator insertion loss), reduced size, lower power consumption and reduction in packaging effort (and thus in cost).

Basically, there are two ways to produce such an integrated transmitter: either butt−joint or selective area growth (SAG) .

Both solutions require quite sophisticated epitaxial growth techniques and choosing between them to produce an integrated device brings up an important dilemma:

- need of separate optimization of laser and modulator specs −> technological complexity
- trade−off solution of laser and modulator specs −> relative technological simplicity.

The above solutions, as well as the effective lateral blocking structure and Al−materials represent important building blocks for the present and next future device needs.

The talk will expand on these topics with illustrative examples.