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Invited

MBE as a Mass Production Technology for AlGaAs Lasers

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We are the first to succeed in mass production of a AlGaAs visible semiconductor laser diode on a commercial basis using MBE. In this conference,five points,as follows i ~ v ,are discussed.
i Poor reproducibility of MBE system and its solution.
ii Explanation of SAM (Self-Aligned structure by MBE) laser .
iii The advantage of SAM laser compared with other laser types.
iv Examples of SAM laser diodes mass produced by MBE technology.
v Progress of MBE technology within ROHM on a commercial basis.

MBE offers planar,uniform and high quality over large wafer areas, as compared with conventional LPE. The first current injection AlGaAs DH laser was prepared by Cho and Casey (1) in 1974. In 1979, Tsang (2) first obtained AlGaAs DH lasers by MBE with threshold currents at least as low as those prepared by LPE. In 1980,Tsang demonstrated MQW and GRIN-SCH lasers(3)(4) by MBE. For the industrial production of lasers using MBE, however, two main problems needed to be overcome: poor reproducibility and lack of stripe structure fit for MBE. These are included in the discussion points i ~ v ,below.

i Poor reproducibility of MBE system and its solution.

We modified conventional MBE Riber 32P.The modified points were ① one-touch substrate mounting; ② large volume cells (2400h) ; ③ precise substrate temperature control (±5℃) ;④ increased shutter reliability. Fig.1 shows the room temperature photoluminescence intensity of DH samples as a function of time. After the MBE system is reloaded, the system is baked (72h,200℃) and sources are purified. About two days of growth are enough to obtain high quality DH wafers. Usually, if the PL intensity is higher than the dashed line level, high quality AlGaAs DH lasers can be fabricated reproducibly over more than 100 days, operating day and night under computer control (5).

ii Explanation of SAM laser.

The devices were grown on a (100) oriented Si doped GaAs substrate (2 inch wafer) .

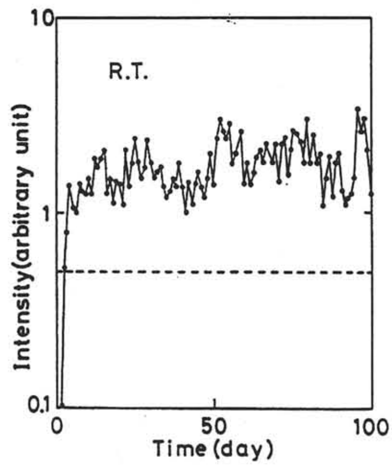


Fig 1. Room temperature photoluminescence intensity of DH samples. If the intensity is higher than the dashed line level,high qualty AlGaAs DH lasers can be fabricated reproducibly.

Growth rates were 1.2 μm/h for GaAs and 3.0 μm/h for AlGaAs (x=0.6) . An active layer was grown at 690℃. Schematic illustrations of the process and structure of the SAM laser are shown in fig2.In the first growth of the two step technique, six layers were grown:①n-AlGaAs (x=0.6,Si:5x10^{17}cm^{-3}) ,1.3 μm;②undoped AlGaAs (x=0.15) active layer, 0.07 μm; ③p-AlGaAs (x=0.6,Be:5x10^{17}cm^{-3}) , 0.35 μm;④ n-GaAs (Si:5x10^{18}cm^{-3}) ,0.24 μm; ⑤n-AlGaAs (x=0.15,Si:5x10^{18}cm^{-3}) ,0.07 μm; ⑥ undoped-GaAs, 0.04 μm. After the first growth step, the wafer was taken out from the MBE system, and stripes were opened along <110> direction with a conventional photolithographic technique.

The width of the stripes used in this work was $4\,\mu m$. The channels were etched into the wafer using a H_2SO_4:H_2O_2:H_2O mixture. A thin GaAs layer about 1000 Å was left on the p-AlGaAs layer for passivation as shown fig.2 .The wafer was then inserted into the MBE system for the second MBE growth step. Prior to regrowth,the thin GaAs passivation layer on the p-AlGaAs cladding layer and the n-AlGaAs current confinement layer was thermally desorbed under As_4 pressure. The thermal desorption rate of GaAs at 740℃ under As_4 pressure was about $2\,\mu m/h$ while that of AlGaAs ($x \geq 0.15$) under the same condition was negligible. The wafer was heated for 15 min at 740℃ under As_4 pressure. After the thin GaAs layers were selectively desorbed,two layers were grown: ① p-AlGaAs (X=0.6,Be:$2x10^{18}cm^{-3}$) , $1.3\,\mu m$; ② p^+-GaAs (Be:$2x10^{19}cm^{-3}$) ,$1.5\,\mu m$. Fig.3 shows a cross-sectional SEM photograph of the SAMstructure laser. In this two-step molecular beam epitaxy method,the thickness of each layer was controlled within the accuracy of MBE.Metal contacts of Ti-Au and alloyed Au-Ge were then formed on the wafer . There was no additional current confinement such as oxide stripes on the surfaces. Devices with a $250\,\mu m$ long cavity were fabricated as usual by cleaving, sawing and coating (6).

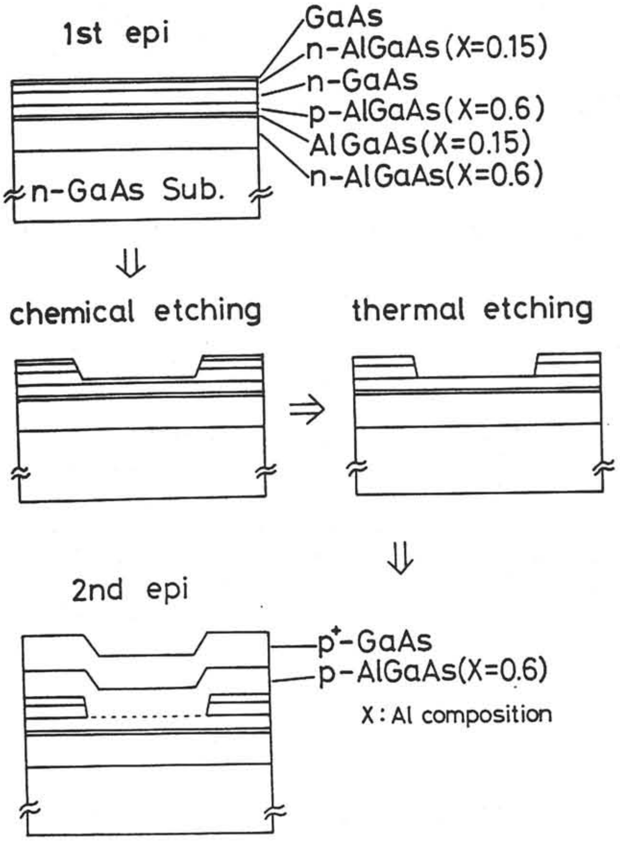


Fig.2 Schematic illustrations of the process of the self-aligned laser fabricated by MBE.

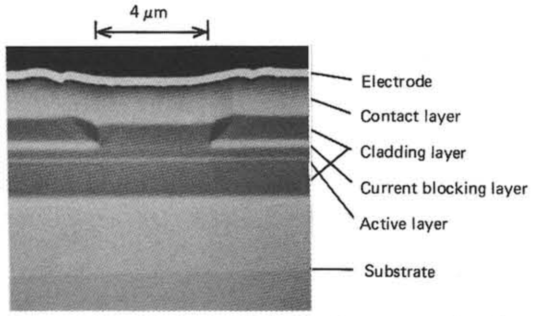


Fig.3 Cross-sectional SEM photograph of of SAM structure laser.

iii The advantage of SAM laser compared with other laser.

Due to excellent control of the film quality by MBE and distinct SAM structure, the variability of the beam divergences parallel and perpendicular to the junction plane are one-third that of conventional LPE lasers;Fig.4.

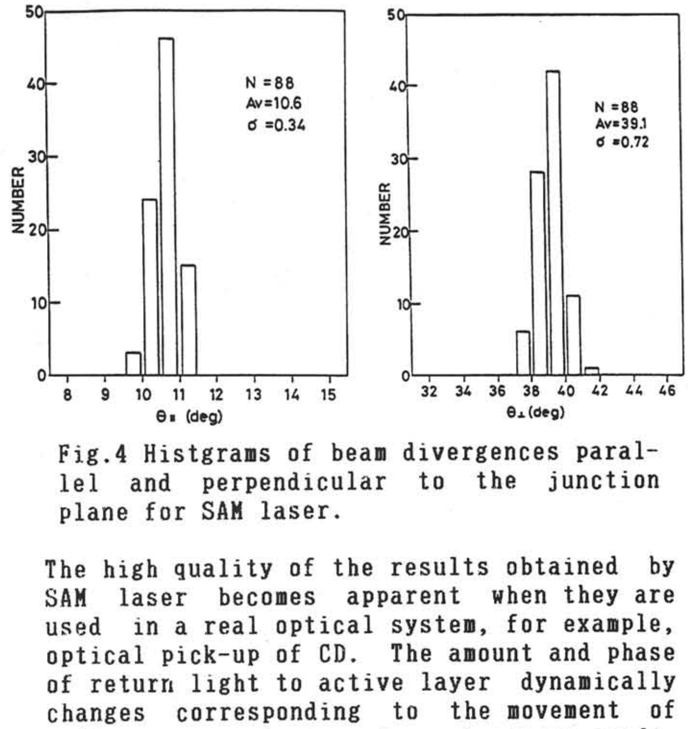


Fig.4 Histgrams of beam divergences parallel and perpendicular to the junction plane for SAM laser.

The high quality of the results obtained by SAM laser becomes apparent when they are used in a real optical system, for example, optical pick-up of CD. The amount and phase of return light to active layer dynamically changes corresponding to the movement of active servomechanism. In such severe conditions,the mode hopping noise problem becomes dominant. To avoid this noise problem, it is essential to control lasing spectral to multi mode, keeping astigmatism less than $10\,\mu m$ on average. The limitation of astigmatism is required to keep the jitter value low enough to assure the playability of CD player. The variability of the beam divergences parallel and perpendicular to the junction plane is closely related to that of lasing spectral and astigmatism. Hence the SAM laser offers considerable practical advantage over the conventional LPE laser.This is the main reason that ROHM has rapidly increased its share in the huge CD laser market.

iv Examples of SAM laser diodes mass produced by MBE technology.

We are mass producing many types of laser diodes which have the most suitable characteristics to individual markets (CD,CD in car,battery-driven CD,video disc,leser beam printer,MO disc, optical link,medical,etc.) Now, two examples of SAM laser diodes are presented which are distinct from other laser diodes prepared by LPE or MOCVD.Fig.5 shows a histogram of operation currents at 3mw and lasing spectrum. Low operation current has been realized by optimizing the carrier concentration of the first p-AlGaAs cladding layer to minimize the lateral current spreading and carrier out-diffusion from the stripe. The laser operates in a multi longitudinal mode at 3mw. This means that mode changes are performed smoothly by the return light and that low noise is maintained.A Large amount of these laser diodes are used in battery-driven CD player market.

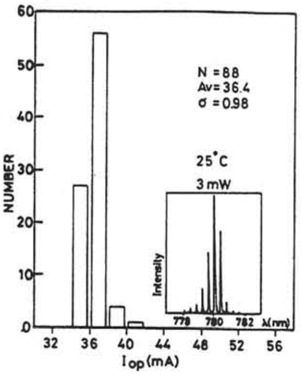


Fig.5 Histogram of operation current and lasing spectctrum at 3mw optical output.

Fig.6 shows the self-pulsation wave form observed by sampling optical-synchroscope. The operating current of this laser is 50 mA at 80℃ and its lasing wavelength is 790nm at room temperature. The excellent control of MBE and structural flexibility of SAM laser realize the mass production of self-pulsated and low operation current lasers for optical links.

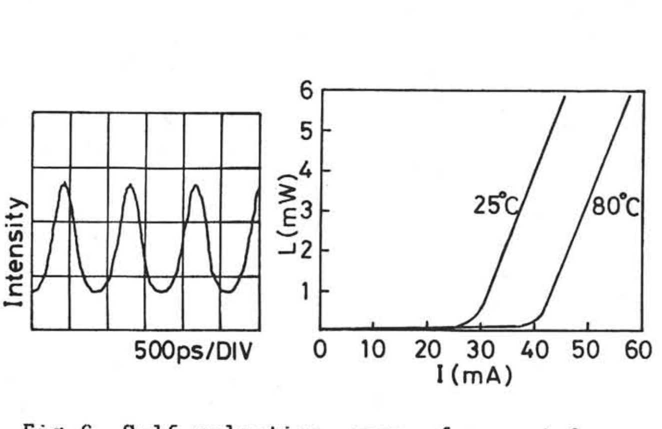
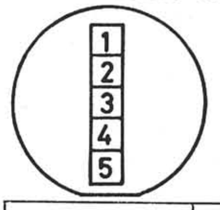


Fig.6 Self-pulsation wave form at 3mw optical output and If-Il characteristics.

v Progress of MBE technology within ROHM on a commercial basis.

The mass production technology developed for laser diodes is also applicable for GaAs high-speed and microwave devices, As mentioned above, in Fig.1 the dashed line indicates enough photoluminescence level to fabricate high quality AlGaAs DH lasers.The dashed line also indicates the growth condition to fabricate high quality high-speed devices. Fig.7 shows the distribution of mobility and the product of mobility by carrier concentration, using van der Pau method with the 8mmx8mm samples.The samples were metallized directly on to the surface of AlGaAs (x=0.22) barrier layer. The same MBE machines and operators are also providing epitaxial growth services to meet in-house demand for other types of GaAs wafers with simply a change of floppy disc. Another division of ROHM is using these for mass production of microwave devices for the satellite broadcasting market.



modulation-doped structure
channel layer $In_{.2}Ga_{.8}As$
barrier layer $Al_{.22}Ga_{.78}As$
(100) oriented semi-insulated GaAs 2" substrate

	1	2	3	4	5	$\bar{x}$
μ $cm^2/V \cdot Sec$	5297	5334	5786	5869	5809	5619
$\mu \times N$ $\times 10^{16}/V \cdot Sec$	1.04	1.10	1.18	1.14	1.04	1.10

Fig.7 shows the distribution of mobility and the product with carrior concentration.

CONCLUSION.

In 1983 ROHM commenced the development of laser diodes by MBE, culminating in the invention of the SAM laser in1985. Concentrated development effort has made it possible to increase the reproducibility of the MBEsystem above the level required for mass production.Due to the excellent performance achieved by this process, the SAM laser has grown to dominate the AlGaAs laser diode market.The technology has also been adapted for the mass production of digital and microwave GaAs devices within ROHM. Hence ROHM MBE technology can be considered to have reached an advanced state of industrial viability for the production of both optical and high-speed devices.

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