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GaAlAs/GaAs MOCVD Growth for Surface Emitting Lasers

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A GaAlAs/GaAs MOCVD has been introduced to grow a flat and smooth surface for the purpose of reducing the threshold current density of a surface emitting (SE) laser as well as the monolithic integration of optical functional devices based on the SE laser. GaAlAs/GaAs DH (double-heterostructure) wafers with a thick active layer (d=3μm) and $Ga_xAl_{1-x}As$/AlAs multilayer Bragg reflector were grown by MOCVD. A low nominal threshold current density as low as 3.6kA/cm$^2\mu$m was obtained in a stripe laser with cleaved facets. Room temperature pulsed operation of an MOCVD grown SE laser was obtained by a preliminary experiment. Also, the reflectivity of 97% was obtained by a Zn-doped 30 layer $Ga_{0.9}Al_{0.1}As$/AlAs Bragg reflector.

1. Introduction

A surface emitting (SE) laser [1],[2],[3] is considered as one of dynamic-single-mode lasers or low noise lasers for optical communication, laser disks and lightwave sensing. The MOCVD (metalorganic chemical vapor deposition) is much attractive for growing the SE laser, where a smooth crystal surface is required. In addition, the MOCVD technique can easily provide thin multilayers, which enables DBR and DFB type SE lasers [4],[5]. So far, the MOCVD for a relatively thin active layer has been mainly reported [6] and the properties of a DH wafer with a thick active layer (>1μm) and growth of DBR are still not clear.

In this paper, GaAlAs/GaAs DH wafers with a thick active layer (d=3μm) were grown by MOCVD and were characterized for the SE laser. Oxide stripe lasers using these wafers exhibited low nominal threshold current density as low as 3.6kA/cm$^2\mu$m. A room temperature pulsed operation of an MOCVD grown SE laser was obtained. In addition, $Ga_{0.9}Al_{0.1}As$/AlAs multilayer Bragg reflector with reflectivity of 97% was obtained.

2. MOCVD Growth of GaAlAs/GaAs Multilayers

1) DH Wafer with Thick Active Layer

A MOCVD system consisting of a vertical cold wall reactor with inductively-heated SiC coated graphite susceptor was designed in house. Five epitaxial layers, i.e., n-GaAs buffer layer (Se-doped, 0.5μm), n-$Ga_{0.71}Al_{0.29}As$ cladding layer (Se-doped, 2μm), p-GaAs active layer (Zn-doped, 3μm), p-$Ga_{0.71}Al_{0.29}As$ cladding layer (Zn-doped, 1μm), p-$Ga_{0.9}Al_{0.1}As$ cap layer (Zn-doped, 0.2mμm) were successively grown on (100) Si-doped GaAs substrate at the temperature of 780°C under atmospheric pressure. Figure 1 shows an SEM photograph of a cleaved and etched cross section of a grown DH wafer. This structure is almost the same as that grown by LPE for the GaAlAs/GaAs SE laser.

2) Semiconductor Multilayer Reflector

For the purpose of realizing DBR SE lasers, a DH wafer with a 3μm thick GaAs active layer sandwiched by a couple of periodic layered Bragg reflectors composed of 30 layers of alternating $Ga_xAl_{1-x}As$ (x=0 and x=0.1) and AlAs with quarter wavelength was grown. For injecting carriers into the active layer, multilayers were doped Zn and Se for p-type and n-type doping, respectively.

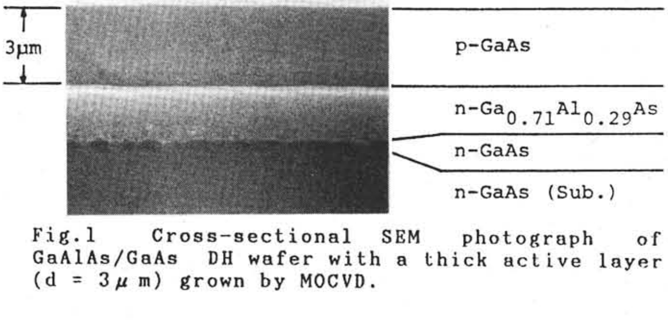

Fig.1 Cross-sectional SEM photograph of GaAlAs/GaAs DH wafer with a thick active layer (d = 3μm) grown by MOCVD.

3. **Characterization for Surface Emitting Laser**

1) Nominal Threshold Current Density

It is very important to clarify the nominal threshold current density J_{th}/d against cavity loss for designing SE laser, because the mirror loss of the SE laser is relatively larger than conventional lasers. For this purpose, DH wafers grown by MOCVD were evaluated by measuring the nominal threshold current density by making $17\mu m$ oxide stripe lasers under pulsed condition at room temperature. The nominal current density was calculated by dividing the threshold current by the product of the cavity length, active layer thickness and lasing spot width measured by near-field patterns. By changing cavity length in the range of 45 - $600\mu m$, the threshold current density was measured against the mirror loss, as shown in Fig.2. With a best fitting procedure, the nominal threshold current density J_{th}/d [$kA/cm^2 \mu m$] can be expressed by the mirror loss α_m [cm^{-1}] as follows;

$$J_{th}/d = A(\alpha_m + \alpha_i)^2 \quad (1)$$

with $A = 2\times10^{-5} kA/\mu m$ and $\alpha_i = 400cm^{-1}$. The minimum threshold current density was $3.6kA/cm^2 \mu m$, which is about 20% lower than that grown by LPE. According to eq.(1), the increase of the reflectivity more than 95.5% can provide the threshold current density of an SE laser as low as $20kA/cm^2$.

2) Reflectivity of Multilayer Bragg Reflector

The reflectivity of the multilayer Bragg reflector composed of 30 $Ga_{0.9}Al_{0.1}As/AlAs$ layers was measured from the crystal surface side. The maximum reflectivity of 97% was obtained at $0.87\mu m$ of wavelength.

4. **MOCVD Grown SE Laser**

A GaAlAs/GaAs SE laser was fabricated from an MOCVD grown wafer. The fabrication process and structure were detailed in refs.[2] and [3]. Figures 3 (a) and (b) show a light-output/current characteristics and lasing spectrum of an MOCVD grown SE laser, respectively. The threshold current was 700mA under pulsed condition at room temperature. This is only a primary demonstration, where the mesa-structure for the current confinement was not adopted which gave somewhat high threshold current.

5. **Conclusion**

Low threshold GaAlAs/GaAs DH wafers with thick active layer ($=3\mu m$) grown by MOCVD were obtained for surface emitting (SE) laser. Room temperature pulsed operation of an MOCVD grown SE laser was obtained. Also, a $Ga_{0.9}Al_{0.1}As$/AlAs multilayer reflector for a DBR SE laser exhibits the reflectivity as high as 97%. Extensive improvement could reduce the threshold current of an SE laser.

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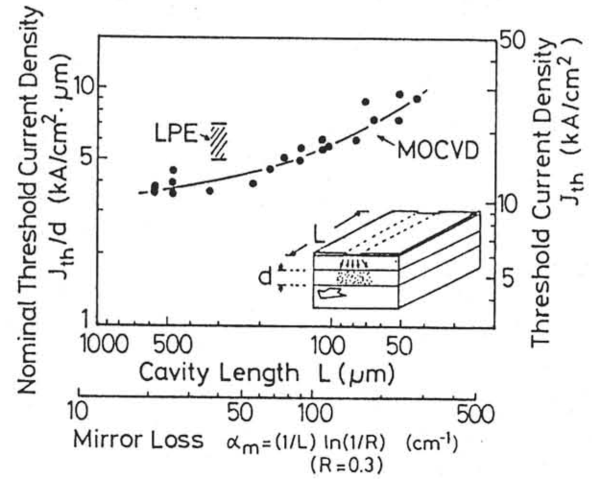

Fig.2 Nominal threshold current density J_{th}/d of oxide stripe lasers with $3\mu m$ thick active layer grown by MOCVD against cavity length.

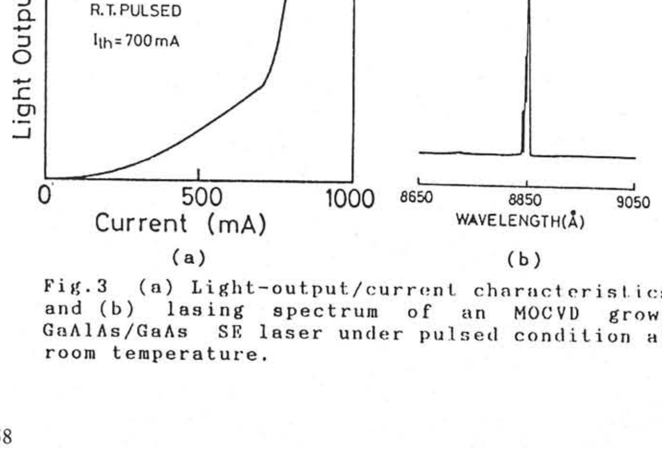

Fig.3 (a) Light-output/current characteristics and (b) lasing spectrum of an MOCVD grown GaAlAs/GaAs SE laser under pulsed condition at room temperature.