Effect of facet coatings on laser diode characteristics

P V Bhorea*, A P Shahb, M R Gokhaleb, S Ghoshb, A Bhattacharyab & B M Arorab

aWatumull Institute of Electronic Engineering and Computer Technology, Worli, Mumbai 400 018, India
bSolid State Electronics Group, Tata Institute of Fundamental Research, Mumbai 400 005, India

Received 7 January 2004; accepted 9 June 2004

The cleaved facets of semiconductor diode lasers act like mirror. Mirror coatings are applied to change the reflectivity and passivate the surfaces. Design of antireflection coating is optimized for single layer of Al₂O₃ and high reflection coating is optimized for stacks of Al₂O₃ and Si Bragg reflector. Electron beam evaporation has been used to deposit uniform Al₂O₃/Si film under high vacuum with pressure 10⁻⁶ mbar and temperature 150-160°C. The optimization of experimental parameters for the dummy GaAs substrate has been discussed. Using these parameters laser facets were coated and changes in the L-I characteristics have been measured and investigated step by step. The output light power versus current characteristics of coated laser diode is compared with that of uncoated one for its characterization under pulsed conditions and have shown that the facet reflectivity has played a major role in determining threshold current density of semiconductor laser.

IPC Code: Int. Cl.7 H01S 5/028

The cleaved lasers emit equal light from both the directions having reflectivity each 30%. For all practical applications, we want maximum light out from one end only. So antireflection coating generally of a single layer of Al₂O₃ at the front facet and high reflection coating having reflectivity greater than 90% at the rear facet consisting of alternate stacks of high (Si) and low (Al₂O₃) refractive index material are deposited on facets of semiconductor laser diode. Thickness of each layer is adjusted as \( \frac{\lambda_0}{4n} \) (\( \lambda_0 \) is the lasing wavelength and \( n \) is the refractive index of the material to be coated).

The coatings increase the device resistance to facet damage and ensures a long-term resistance to the mirrors at the facets of cleaved wafer. The experimental work to optimize the coatings parameters incorporated the design of suitable thickness of the dielectric material to be deposited, evaporation of thin film in high vacuum, measurements and calculation of reflectivity of coated GaAs wafers with reference to uncoated GaAs chip, optimization of coating parameters such as refractive index and thickness of the dielectric material along with the other vacuum coating parameters such as temperature and pressure and deposition of AR and HR coatings on facets of laser diode.

Experimental Procedure

550 \( \mu \)m and 750 \( \mu \)m broad area³ laser devices of 100 \( \mu \)m wide stripe lasing @ \( \sim \)900 nm were used for the experiments. The devices were checked for its \( I-V \) characteristics before and after the coatings. One such device which shows the \( I-V \) characteristics measurements is shown in Fig. 1.

Measurement was done using 5 \( \mu \)s current pulse, 1% duty cycle. High pulse power resulted in gross damage in the form of spherical mounds visible at mirror surface where optical flux density was greatest. The damage reduced noticeably as pulse length was reduced from 10 \( \mu \)s down to 1 \( \mu \)s and duty cycle changed from 10% to 1%. Removal of affected devices from the bar continued to show same \( I-V \) characteristics as before otherwise that damage proved all other devices leaky. Typical resistance of 2 to 5 ohms was observed from the characteristics.

*For correspondence (email: preetabhore@rediffmail.com)
Fig. 2—Light power versus current characteristics under coating conditions specified (a) no coating on facet A, (b) no coating on facet B, (c) AR coating on facet A, (d) no coating on facet B, (e) no coating on facet A, (f) HR coating on facet B, (g) AR coating on facet A and (h) HR coating on facet B
Measurements\textsuperscript{4} of \textit{L-I} used conventional pulse driver driven to laser fixed on metal plate supported by thermoelectric cooler. The effect of AR coating on front facet A and HR coating on rear facet on power outputs as a function of current for each facet in 8 steps are shown in Fig. 2.

**Results and Discussion**

Antireflection coating of thickness 1200Å was applied on front facet. Laser threshold as obtained from the knee in \textit{L-I} curve or extrapolation of \textit{L-I} curve to zero light\textsuperscript{5} is observed before and after coatings were applied (Figs 2a and 2b) and output power as a function of driven current (mA)\textsuperscript{6} was plotted for front and back facets separately. As indicated from \textit{L-I} characteristics there was increase of threshold and increased power from front facet which was AR coated (Fig. 2c) compared to lower power from the other end (uncoated) (Fig. 2d) threshold being higher in both ends.

Only HR coating on back mirror reduced the threshold to a noticeable extent and output power reduced for the coated facet but increased for the uncoated facet. (Figs 2e and 2f). Later AR coating on front facet AR and HR coating on back facet (B) resulted in increased threshold and very low output from HR end (Figs 2 g and 2h respectively.)

**Conclusions**

The use of antireflection coating and high reflection coating on laser diode facet provide the necessary passivation and change the reflectivity so that power emission is predominantly from one end.

The results have shown that with experimental optimization\textsuperscript{7} of dielectric coating parameters like refractive index of the material and thickness of deposition are necessary to match with the simulated AR/HR curves\textsuperscript{8}. To improve the device performance the pulse length has been made shorter. \textit{L-I} measurements of coated laser diode compared with that of uncoated one for its characterization under pulsed conditions have shown that the facet reflectivity has played a major role in determining threshold current density of semiconductor laser.

**References**