L.11. Development of dielectric coating for semiconductor laser facets

Optical coatings lab, LSED has been actively involved in the development several types of optical coatings for varied applications. In recent years, coating of facets has got considerable interest in high power semiconductor lasers. Principle objective of this work is to develop anti-reflection (AR) and high reflectance (HR) coating on GaAs wafers and to find out the desired deposition parameter for the coating to enhance laser output power. In a semiconductor laser two end facets act like mirrors. An uncoated laser diode facet has a reflectivity ~28%. To obtain the high optical output power from the front facet and also to protect the laser facets from catastrophic optical mirror damage (COMD), front and back facets are coated with the AR and HR coatings respectively.

Usually single layer Al_2O_3 is used as AR coating on GaAs facets. Therefore, optimization of Al_2O_3 is carried out. For this purpose, the films are deposited by 1) E-beam evaporation at different ion current and ion energy at 150C and by 2) RF sputtering in Ar/O_2 mixture with different $O_2/Ar+O_2$ ratio at the room temperature. Optical and electrical properties of films deposited by ion assisted e-beam and RF sputtering under different deposition conditions have been studied. For comparison, a film without ion assisted growth is also grown. Transmission and reflectivity spectra (Fig.L.11.1) of ion assisted e-beam deposited Al_2O_3 films show that films are non-absorbing in Vis-NIR region as required for facet coating. Film deposited without ion gun shows inhomogenity. Film grown with ion energy 97.5 eV and ion current 0.75 A/cm^2 is found to be optimum to obtain homogeneous and good optical quality. The films are hard, durable and adherent to the substrate. Ellipsometry measurements show that refractive index (r.i.) of Al_2O_3 film deposited under optimum ion beam parameters is 1.64.

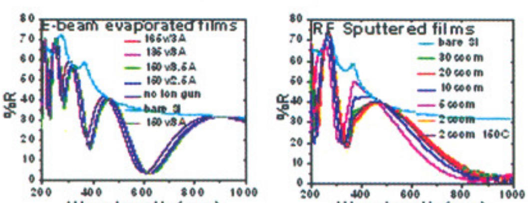

Fig L.11.1.Reflectivity spectra of Al_2O_3 films deposited by E-beam evaporation and RF sputtering.

Good quality, stochiometric Al_2O_3 films have been deposited at room temperature by RF sputtering of Al target at various oxygen partial pressures. Film deposited with 2 sccm O_2 has the highest refractive index (1.66) and very low optical absorption Ellipsometry shows that r.i. systematically increases with decreasing O_2 partial pressure. These r.i. values are close to that of the ideal material.

Films are found to be very smooth, homogeneous, and free from pores. AFM results show that the average and r.m.s. roughness of the film is 2.3 and 2.9 Å respectively. A single quarter wave layer of Al_2O_3 would reduce the reflectivity of GaAs to 1.5%. In order to further reduce reflection loss a multilayer coating with more than one material of non-quarter wave thicknesses is required. TiO_2-Al_2O_3 double layer dielectric coating have been designed and deposited on Si and GaAs wafers. The measured reflectance is close to 0% at reference wavelength 808 nm as shown in Fig.2. For HR coating alternate TiO_2 - SiO_2 thirteen layers are deposited by ion assisted e-beam evaporation. The measured reflectance is 98% at reference wavelength 808 nm as shown in Fig. *L.11.3*.

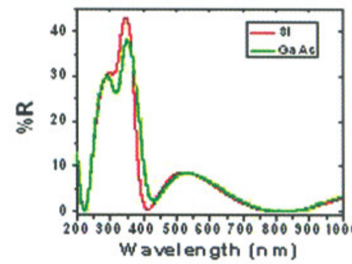

Fig L.11.2.Reflectivity spectra of TiO_2-Al_2O_3 two layers AR coating deposited by E-beam evaporation.

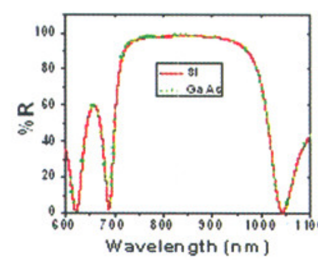

Fig L.11.3. Reflectivity spectra of alternate TiO_2-SiO_2 thirteen layers HR coating deposited by E-beam evaporation.

Besides the optical properties, electrical properties like breakdown voltage and leakage current through these films are important. We find that the all the films deposited by RF sputtering had a lower breakdown voltage and larger leakage current as compared to the e-beam evaporated films. The highest breakdown field was found to be 1.9MV/cm for the e-beam deposited film at 97.5eV, 0.63A/cm^2 of current. The leakage current for this film was ~$5x10^{-8}$ A/cm^2. Further optimizations in the thin film growth process are being carried out to obtain higher breakdown voltages & lower leakage currents.

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