L.8: Development of Anti-Reflection Coating for Ti-Sapphire Laser Rod

Anti-reflection (AR) coatings have been widely used for increasing transmission, specially, in high power laser systems. High power lasers are extensively used in material processing, frequency conversion and other applications. One such laser is Ti-Sapphire. Principle objective of this work is to develop AR coating on Ti-sapphire laser rod for both pump and lasing wavelengths.

Laser induced damage in optical materials remains a limiting factor in the development of high power laser systems. Pulse width of high power lasers play a very important role in deciding the damage threshold. HfO_2 is one of the most important high index materials for the production of optical multilayer coatings. It is known for its high laser induced damage threshold (LIDT). It has been shown through different studies that hafnia coatings with very high LIDT can be obtained in the nano-second, pico-second and femto-second regimes.

Therefore, optimization of HfO_2 is carried out. For this purpose, films are deposited by ion-assisted e-beam evaporation at different ion beam parameters and deposition rate at 150 °C. Optical and structural properties of films deposited under different deposition conditions have been studied.

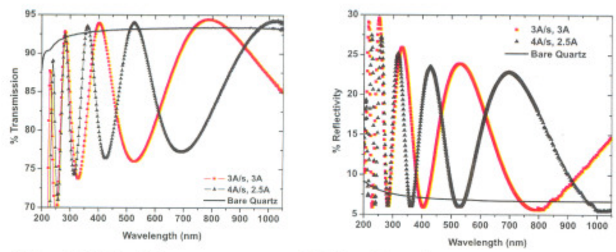

Fig. L.8.1.a)Transmission & b)reflectivity spectra of HfO_2 films grown by ion-assisted e-beam evaporation.

Transmission (Fig.L.8.1a) and reflectivity spectra (Fig.1b) of deposited HfO_2 films show that films are non-absorbing in UV-Vis-NIR region down to 230 nm. Both the films show small amount of refractive index (R.I.) in-homogeneity along the thickness of the film. This could be mainly due to inadequate ion beam parameters. To study this R.I. in-homogeneity, ellipsometry measurements were carried out in the range 290 to 890 nm. The optical model that describes the best fit is shown in Figure 2(a). Film in-homogeneity is described by a three layer structure with refractive index increasing along the growth direction. Using these values, transmission spectra is calculated and compared to the experimental transmission spectra as shown in Figure L.8.2(b). These two spectra match fairly well.

Design & Growth of AR coating for Ti-Sapphire: Achieving very high transmission both at 532 nm and 800 nm requires non-quarter-wave layers. We have restricted to a limited no. of layers with thickness that can be deposited repeatedly with minimum run-to-run variation. We have optimized a four layer structure SUB/0.25H/0.35L/2.1H/1L/AIR, where H and L represents one quarter-wave HfO_2 and SiO_2 layers respectively. This layer structure yields a residual reflection loss nearly 0.002% per surface at 532 and 0.01% at 800 nm.

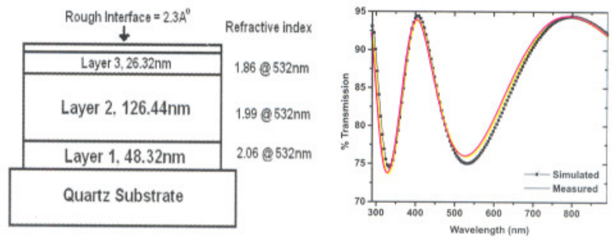

Fig.L.8.2.a) Optical model describing R.I. inhomogeneity, and b) simulated & measured tranmission spectra.

The designed four layer structure (SUB/0.25H/0.35L/2.1H/1L/AIR) is made on a dummy sapphire substrate. Figure L.8.3a shows the transmission of bare sapphire, deposited 4 layer structure and calculated transmission spectra of the same structure. It can be seen that experimental and calculated spectra match fairly well. Small deviations that exist is due to the thickness difference between design and deposition values. It can be seen that there is gain in transmission of more than 6% at both pump and lasing wavelengths. Finally, the 4 layer structure was deposited on both the sides of a Ti-Sapphire rod (20 mm dia., 20 mm long). Reflectivity spectra of both the end faces of the coated rod were recorded and are shown in Figure 3b. Residual loss of ~ 1.0% is measured at 532 and ~ 0.9% at 800 nm. These residual losses are higher compared to our design results. This could be due to fact that the optical constants of the laser rod are not exactly known (not revealed by the manufacturer) and are considered to be same as that of sapphire for all our calculations.

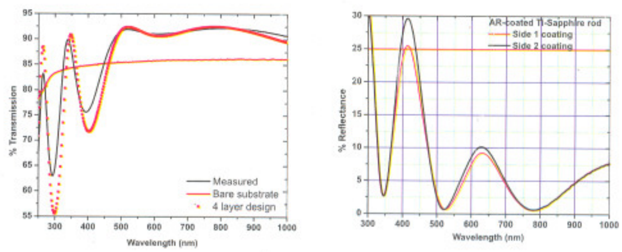

Fig.L.8.3.a)Transmission of bare sapphire, deposited 4 layer structure & calculated transmission spectra, & b) reflectivity spectra of end faces of the coated rod.

This AR coated rod is used as a four pass amplifier in a Ti-sapphire laser (650 mJ, 0.2 nsec, 10 Hz). No coating damage is observed even at maximum laser power level.

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