Phase retarder in chemical oxygen-iodine laser at 45° incidence

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A phase retarder used in chemical oxygen-iodine laser (COIL) system has been fabricated by ion beam sputtering (IBS). When the incident angle is 45° the reflectivity is about 99.9% from 1290 to 1340 nm and about 83.8% at 632.8 nm, and the phase retardance between the parallel and perpendicular polarization components is −92.8° at 1315 nm. In order to get the influence of temperature on the phase retarder, six samples have been annealed from 523 to 648 K at interval of 25 K in air respectively, and the results show good temperature performance. With increasing temperature, phase retardance becomes smaller, and the variation is within 4° at 1315 nm. At the same time, the variation maintains within ±10° for the incidence from 44° to 49°.

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A reflection thin-film phase retarder is a specular reflector that introduces relative phase retardance between the p (parallel) and s (perpendicular) polarization components of the oblique incident light on the reflector. The phase retarders which are superior to the expensive crystalline quarter-wave plate in wide wavelength range (from ultraviolet (UV) to far infrared (FIR)) and less sensitivity in incidence have been widely used in larger aperture and high power laser systems[1−8].

In the chemical oxygen-iodine laser (COIL) resonator, quarter-wave retarder with high reflection is needed for polarization control. However, the traditional multi-layer cannot satisfy the increasing power of the laser. This paper describes a new dielectric multi-layer phase retarder. The phase retarder has above 99.9% reflection at 1315 nm with −90° phase retardance for 45° incident line polarization light. Meanwhile, for the demand of adjusting light, it also has about 83.8% reflection at 632.8 nm. The performances of reflectivity and phase retardance with wavelength of the phase retarder are described, as well as the incident angle and the performance at different annealing temperatures.

Using Ta_2O_5 as the high index material and SiO_2 as low index material, an optimum technique has been used to design the retarder with minus (90°±10° or 270°±10°) phase retardance between the p- and s-polarization components over a broad wavelength range from 1290 to 1340 nm, meanwhile maintaining above 99.9% reflectivity for both components and above 80% at 632.8 nm. Figures 1 and 2 show the designed plots of transmission T and phase retardance Δ at 45° incident angle, respectively. From these figures, it can be seen that the reflectivity reaches about 99.9% from 1290 to 1340 nm and about 84.2% at 632.8 nm, and the retardance is about −88.8° (271.2°) at 1315 nm for 45° incidence.

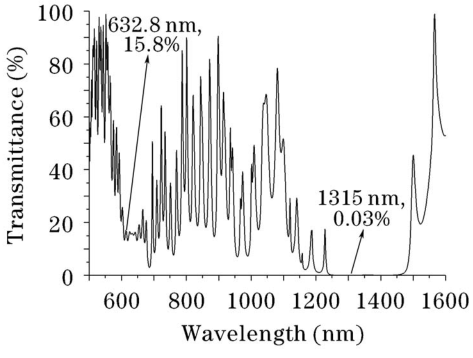

Fig. 1. Designed plot of transmission T versus wavelength λ for 45° incidence.

Ta_2O_5 and SiO_2 films were sputtered periodically on BK7 glass substrate (Φ30×3 (mm)) by ion beam, and the physical thickness was controlled by time-power method, which was based on the fact that there was a sufficiently constant rate of deposition of physical thickness. The substrate was baked to about 100 °C before coating.

In order to maintain the uniformity, six samples were selected from the same circle of the substrate holder. When the high power system works, the temperature will increase inevitably which would influence the performance of the retarder. Therefore, in order to find out the influence of temperature on the performance of phase retarder, the samples were annealed at six different temperatures from 523 to 648 K at interval of 25 K for 3 hours in air respectively. The transmittance and the phase retardance of samples before and after annealing were measured by the Lambda 900 spectrophotometer

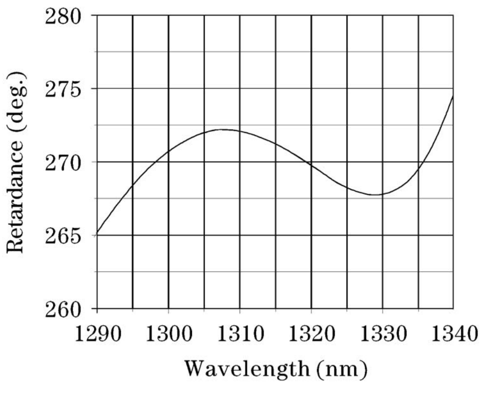

Fig. 2. Designed plot of phase retardance Δ versus wavelength λ for 45° incidence.

(PERKIN Elmer) and the variable angle spectroscopic ellipsometers (VASE) (American WOOLAM). The results are illustrated in Figs. 3—5.

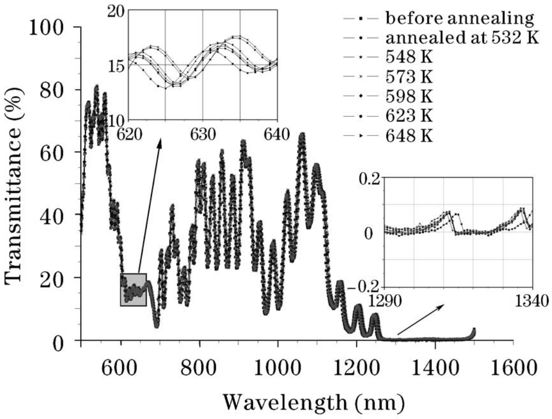

Fig. 3. Transmittance of samples before and after annealing versus wavelength.

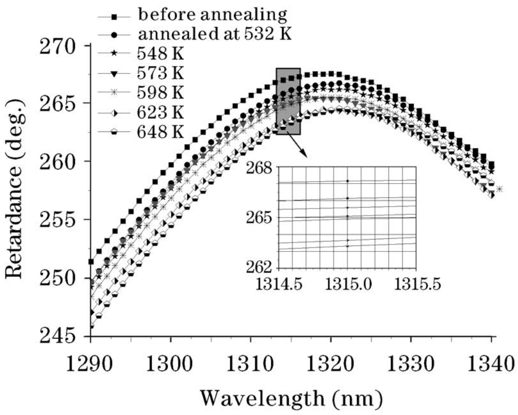

Fig. 4. Phase retardance Δ of samples before and after annealing versus wavelength.

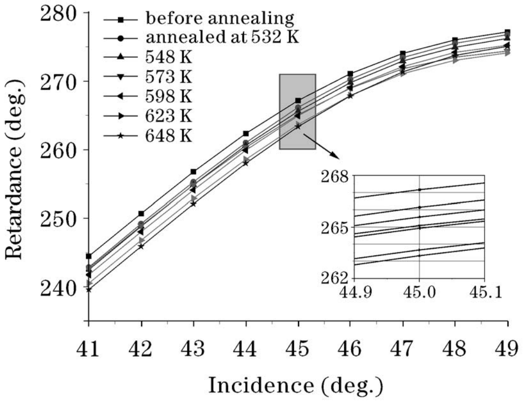

Fig. 5. Phase retardance of samples for incident angles ranging from 41° to 49° at wavelength of 1315 nm.

Figure 3 shows that the reflection is about 99.94% from 1290 to 1340 nm and about 83.8% at 632.8 nm for 45° incidence before annealing, and it has very little change after annealing, which indicates that the high temperature has little influence on the reflection. The phase retardance of −92.8° (267.2°) at 1315 nm before annealing is obtained from Fig. 4. The deviation between the experiment and design can be explained that, the phase retardance is highly sensitive to the top few layers. In the process of ion beam sputtering (IBS), when changing the target material, the ion source has to stop and restart, thus the power of ion source will become lower for a moment, which makes the refraction of film lower. Meanwhile, the top layers would absorb the hydrosphere and dust, which also generated the translation layers[9]. From Fig. 4, it can also be concluded that with increasing the annealing temperature the phase retardance becomes smaller and the variation in phase retardance is within 4°.

The plot of wide range of incidence at different annealing temperatures versus the phase retardance can be seen in Fig. 5, which shows that with the temperature increasing to 648 K, the variation requirement of within ±10° could be met for wide range of incidence from 44° to 49°.

In conclusion, −92.8° phase retarder has been prepared, and the reflection is about 99.9% at 1315 nm and about 83.8% at 632.8 nm for 45° incidence before annealing. From the annealing results it is concluded that the high temperature has little influence on the reflection. With the temperature increasing, the phase retardance becomes smaller, and the variation is within 4° at 1315 nm for 45° incidence. It also has a wide range of incidence from 44° to 49° to meet the requirement of the retardence variation within ±10°. The obtained experimental performance shows that this phase retarder can be well used in the high power laser system.

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