Plasma Optik Techne System for UV Coatings

Executive Summary

Ultraviolet lasers operating around 200nm are becoming more common. This is due to both the utility of these lasers and the increased manufacturing capability allowing their production. The spectrum of UV light includes wavelengths shorter than violet light at 380nm. The frequency for wavelengths below 380nm results in radiation with a very high ionization potential. Optics to support these applications must survive high laser fluence for extended periods under the ionizing radiation of these UV lasers. Plasma Optik has manufactured ion beam sputtered (IBS) UV coatings for applications in these wavelength ranges and the status of this effort is discussed.

Lasing in the 200nm range is accomplished using harmonics of Nd: YAG or other similar laser materials. Frequency quadrupling (4w) or quintupling (5w) is required to get UV laser light. The generation of laser light in the UV range is less efficient compared to the lower-order harmonic frequencies and therefore cannot achieve the same energy levels. UV laser fluence can easily damage even relatively pristine optics despite the lower power due to the high ionization potential. UV lasers have applications in fields such as laser breakdown spectroscopy, laser etching of shiny metals and glass marking. Plasma Optik has prepared and measured ion beam sputtered high reflector samples in the UV range to validate Techne manufacturing capabilities for these challenging optics.

Very high bandgap materials are required for use in the UV range to avoid optical absorption. The standard materials used years ago might have been evaporated cryolite (Na3AlF6) or magnesium fluoride as the low index material with silicon dioxide or aluminum oxide as the high index material[1]. The terminology here is a little inconsistent, since SiO2 and Al2O3 are used as low index materials for most sputter applications. The extremely large bandgap requirements for use in the UV wavelength range changes the useful material choices and this is part of the challenge of UV coatings for IBS systems. Materials used for UV IBS applications will have to be specially chosen for resistance to UV laser fluence, environmental durability and sputter compatibility.

Plasma Optik has taken proprietary steps to manage some of the historical issues with the use of high bandgap sputter materials in the UV. Problems such as poor transmission around 200nm have been difficult to overcome.

Plasma Optik
7330 Greendale Road
Windsor, CO
80550-8004 USA

1-970-786-6218
info@plasmaoptik.com

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More work toward the highest quality optics should continue but much progress has been made. Transmission levels are very high as absorption causing defects are found and reduced or eliminated.

Generation of a dispersion model for the materials used for this application is the first step toward understanding material performance. Therefore, dispersion data was generated in the UV wavelength range for both alumina and silica materials. With this new dispersion data, a theoretical design was made. The design is for a high reflector at 225nm which can be tuned down to 210nm at 45° AOI and 200nm at 57° AOI. This design is a good example of a general high reflector coating which satisfies many applications utilizing the 5w Nd: YAG lasing window. Transmission and reflection spectrum based on the dispersion model generated shown below.

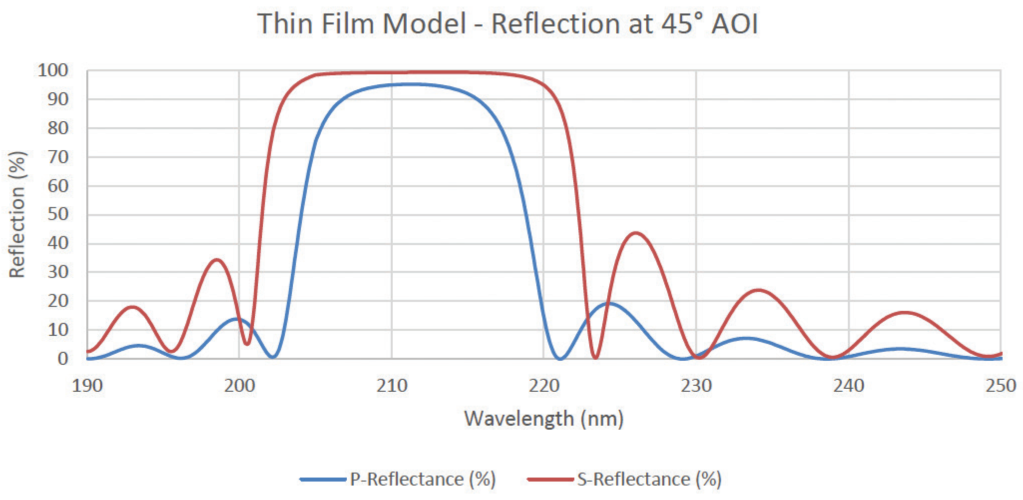

Figure 1. Thin Film Model - Reflection at 45° AOI

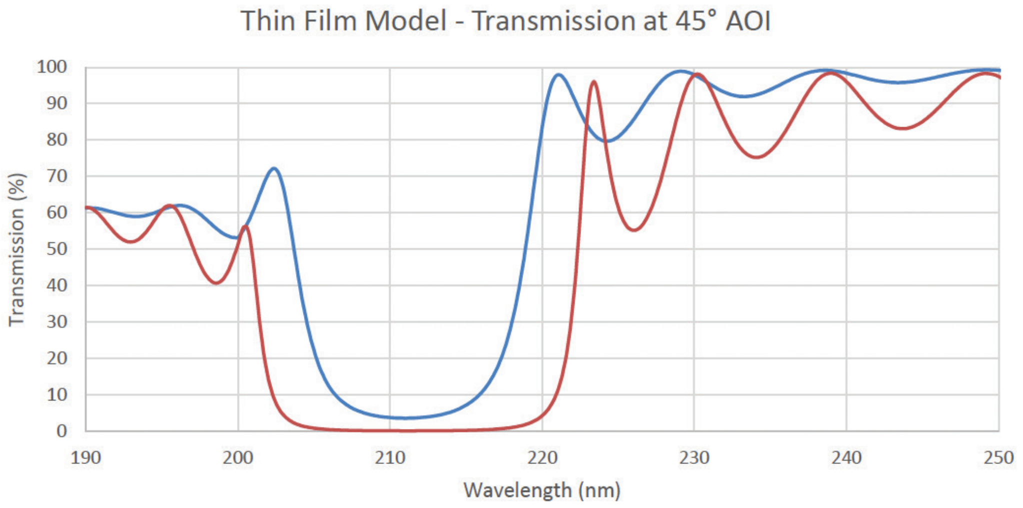

Figure 2. Thin Film Model - Transmission at 45° AOI

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A coating run based on this design was done for dispersion validation. These parts were then measured at normal angle of incidence in transmission utilizing a Cary 5000 spectrophotometer. Reflection measurements were also made with the Cary 5000 using both a standard 7° Angle of Incidence (AOI) reflection accessory from Harick Scientific and a variable angle specular reflectance accessory (VASRA) from Agilent technologies. The VASRA is capable of automated reflection measurements from 20° to 70°.

One problem that arose during this effort is that reflection measurements require having a well characterized reference reflector. Fused silica, silicon and aluminum or gold mirrors are common choices for reference reflector material. However, in the UV range, reflection and transmission values are much more subject to surface conditions of the optic and the limited reflectivity range of these materials can make their use in the UV problematic. Other issues can arise due to the specific grade of material chosen. For example, fused silica and fused quartz have very similar transmission characteristics in the visible to NIR range. However, the microstructural differences between these materials makes a tremendous difference for UV applications.

Since transmission scans at normal incidence do not have these referencing requirements, they are a good place to start. A normal AOI transmission measurement is compared to thin film model below.

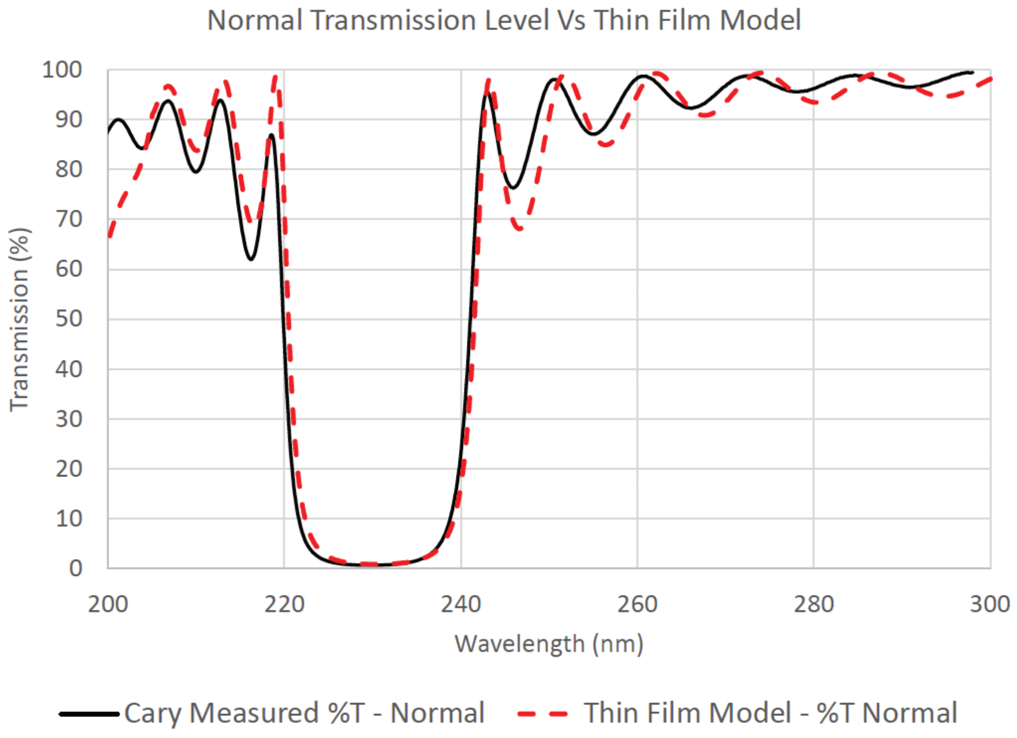

Figure 3. Normal Transmission Level vs Thin Film Model

There is generally good agreement between the thin film model and measured data although values are not as perfectly matched as is typical at longer wavelengths. Part of the problem here may be layer errors due to the optical monitoring occurring from 380-1000nm. An ultraviolet light source and monitoring in the 4w – 5w range would likely produce better results.

Also, note that the attenuation of fringes on the short side of the spectrum shows the absorption edge of the model occurs around 205nm but the measurement of the actual reflector indicates continued dielectric behavior. In this case our coating outperforms the model. Good agreement between the bandwidth of the reflection zones indicates the difference between high and low index materials is correct in the model[2]. Overall, a good first step toward generation of a very accurate dispersion model.

Reflection measurements were also made at 7°, 20° and 45° AOI. The reference used for 20° and 45° was an aluminum single layer reflector made by Plasma Optik from an aluminum target with 99.999% purity. Although this was a high-quality reflector, there is not good agreement between theoretical aluminum reflection levels and the measurements made. There is better agreement when a fused silica sample was used for reference at 7° and these results are shown.

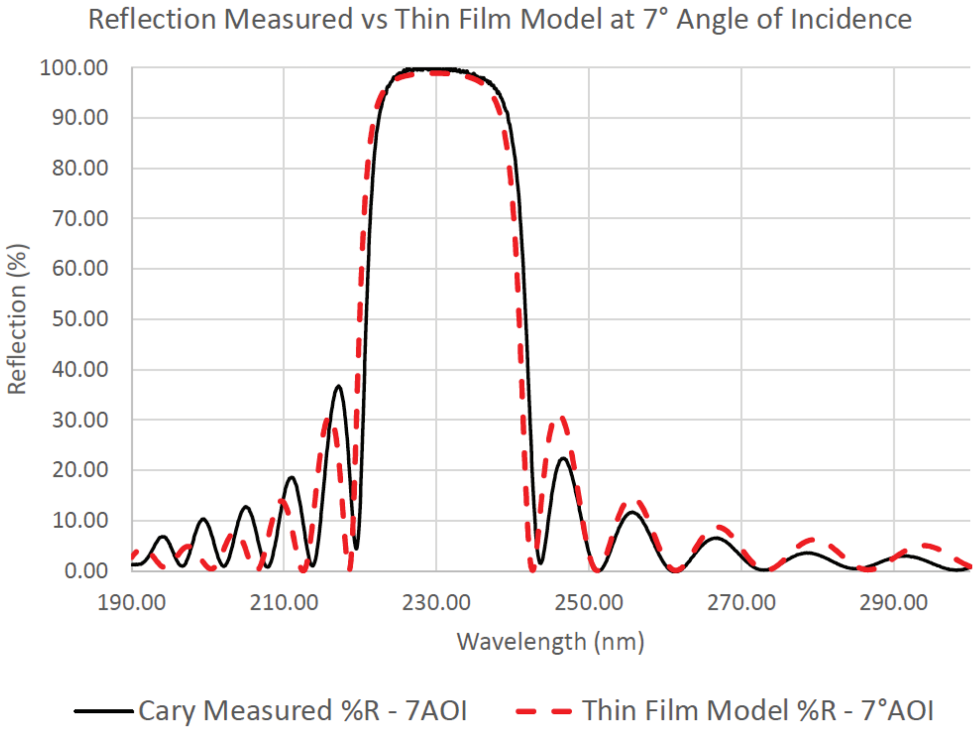

Figure 4. Reflection Measured vs Thin Film Model at 7° Angle of Incidence

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Again, the model and measured data do not match perfectly, with layer errors the likely suspect. Additional work toward optimization of individual material dispersion data may also help to bring these values into better agreement.

Work remains to be done here but the data so far gives Plasma Optik confidence that the Techne system can manufacture a reflector suitable for use in the 4w to 5w Nd: YAG lasing window. Both transmission and reflection data are closely matched with dispersion data generated from thin film model. Additional work will need to be done to quantify the laser fluence level which can be supported with these optics. With the very competitive results generated with the Techne system in both laser damage and absorption testing at 532 and 1064nm, our expectations are that there should be similarly excellent results with optics for the 4w and 5w wavelength range. Ion beam sputtered coatings for UV applications are a manufacturing challenge, but progress is being made toward making a robust option for high performance optics from the ultraviolet to near infrared wavelength ranges.

References

1. Macleod, Angus. Thin Film Optical Filters. CRC Press; 4th edition, 2010. ISBN: 978-1420073027

2. Willey, Ronald. Field Guide to Optical Thin Films. SPIE Publications, 2006. ISBN: 978-0819462183

Plasma Optik manufactures bandpass filters, notch filters, edge filters, polarizing beam splitters, non-polarizing beam splitters, mirrors and anti-reflective coatings. Our optical monitoring capability combined with ion beam sputtering technology allows us to manufacture precision optical coatings from the ultra-violet to near infrared wavelength ranges. Plasma Optik is always happy to talk about high laser damage threshold optics with low absorption.

Please feel free to contact Plasma Optik with any questions about your application.