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Small Batch High Throughput Plasma Activated Magnetron Sputtering System

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1. Summary

Magnetron sputtering has a number of advantages over conventional physical vapour deposition techniques such as electron beam and thermal evaporation. For example, the kinetic energy of the sputtered atoms is typically 10 times higher than that of evaporated species, this results in much harder and much more adherent coatings. The energy of the process also removes the need for substrate heating during deposition which is of specific benefit when coating plastic substrates or other temperature sensitive substrate materials. This means that deposition is carried out at room temperature allowing different materials such as glass and plastic to be coated even in the same batch. Compact magnetron sources are also capable of high deposition rates which result in fast process cycle times.

The metal-oxide materials used in multilayer optical coatings are good electrical insulators and while it is possible to sputter insulators using radio-frequency power, the deposition rates are too low to be economical. To overcome this problem, following early work by Schiller et al [1], Scobey et al [2] and Howson [3], techniques have been developed in which a few monolayers of metal are deposited using dc sputtering in one zone of a vacuum chamber and the metal is then oxidised in another zone as the substrates rotate. This technique is illustrated schematically in Figure 1.

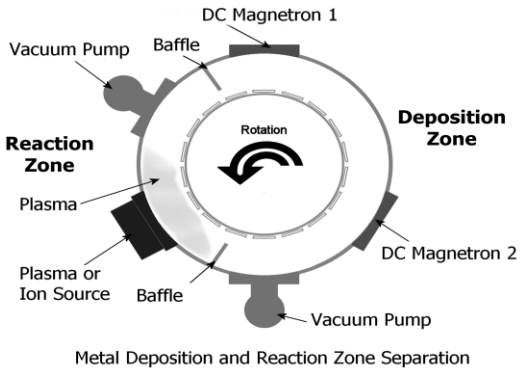

Figure 1

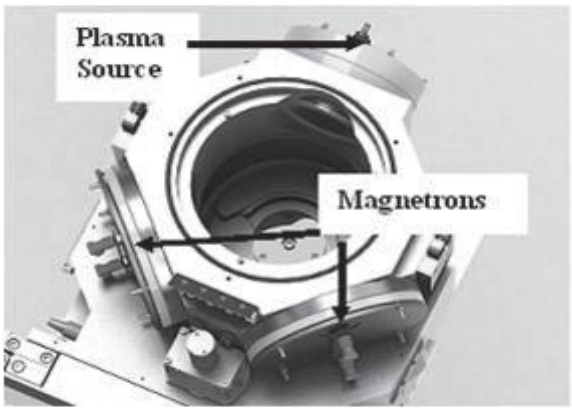

Figure 2

The method uses zone separation, ensuring process stability of the metallic surface being maintained in the deposition zone. The metal-oxide deposition rate is determined by the efficiency of the metal oxidation on the substrate surface. Partial or incomplete oxidation results in optical absorption in the film. In these systems, a plasma source is required to activate the oxidation process. A small scale chamber configured for the process as described in this paper is shown in Figure 2 – pumping is single turbo pump above plasma source port.

In this paper we describe a small scale high throughput sputter machine with loadlock delivery of substrates into the deposition chamber - system name is “PlasmaCoat. This ensures main deposition chamber is always maintained under vacuum. The machine configurations, is two magnetrons with metal targets with a separate plasma source as shown in Figures 1 and 2.

The PlasmaCoat uses reactive magnetron sputtering process to produce dense optical coatings with outstanding durability. Coatings can be applied to mineral, glass as well as to a variety of plastics including hardcoated CR39 and polycarbonate. The machine is usually supplied for deposition of multilayers incorporating two materials. Silicon dioxide is the low index material and zirconium oxide is supplied as the high index material. However other materials such as niobia, titania, hafnia and tantala are available. These materials are ideal for precision optics and photonics applications.

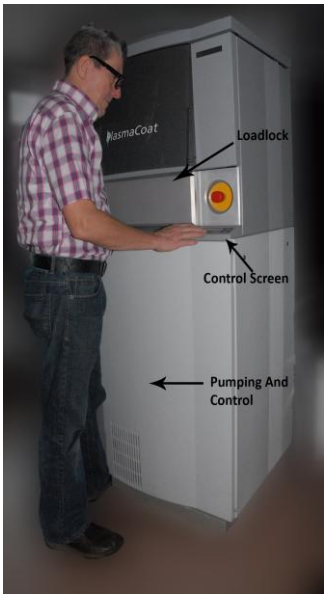

Figure 3

Figure 4

Figure 5

The magnetron sputtering system for small batch high throughput production is shown in Figure 3. The machine is compact and highly automated. It is simple to operate with staff needing only a few hours training. The machine is controlled via a simple keypad display. Once the substrates are loaded, subsequent operation is completely automatic. It employs a vacuum load lock to maximize coating throughput with minimal maintenance. Substrates are mounted on a vertical rotor which has up to six positions for substrates. Figures 4 and 5 below show standard configuration substrate carousel and substrate carousel mounted within loadlock with door open.

Once loadlock is pumped out the rotor lifts the substrate carousel into the deposition chamber (deposition chamber configuration shown in Figure 2). A gate valve separates loadlock and deposition chamber ensuring deposition chamber is always maintained under vacuum. The system is ready to deposit in less than 10 minutes after pumpdown is initiated.

Single layer results for a thick (336nm) zirconia layer are shown in Figure 6 and 7. Measurements shown in Figures 6 and 7 are made with an Aquila nkd 800 variable angle spectrophotometer. n and k are derived from fit to transmission and reflection measurements shown in Figure 6. The k value is $< 10^{-6}$ for both zirconia and silica.

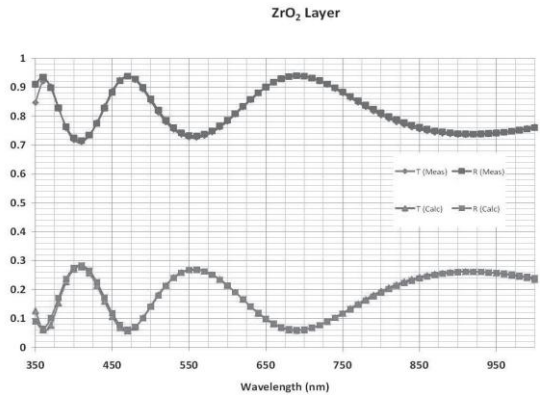

Figure 6

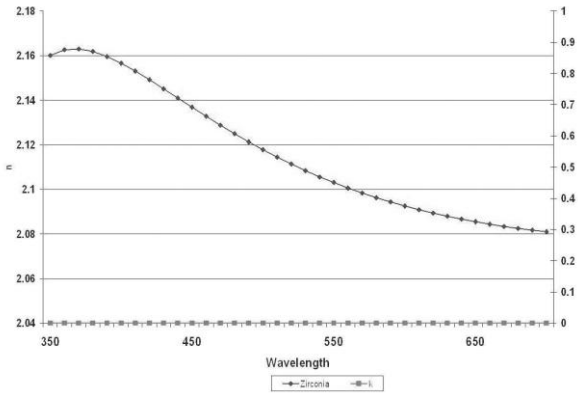

Figure 7

AR coating is a two layer ZrO2 26.5 nm | SiO2 114.3 nm design, glass coated both sides (Figure 8). Design wavelength 460 nm.

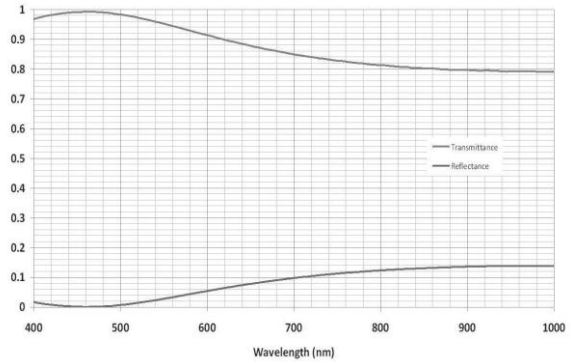

Figure 8

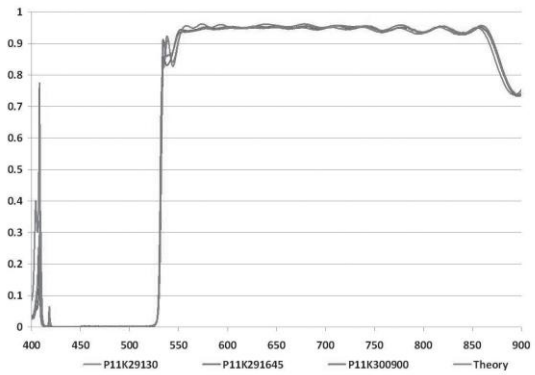

Figure 9

Spectral transmission for three separate deposition runs of a 63 layer ZrO2 /SiO2 edge filter are shown in Figure 9. Comparison with theory also provided.

Thickness control for multilayer optical coatings shown in figures 8 and 9 achieved using power / time control. Demonstrated reproducibility <±1 nm (<± 0.2%).

Figures 10 and 11 show spectral transmittance/ reflectance and refractive index respectively for a thick (physical thickness 2.11 microns) Al_2O_3 layer. Material deposited from an aluminium target and oxygen plasma activation. k-value is < 10-5 over the visible/ near infra-red region.

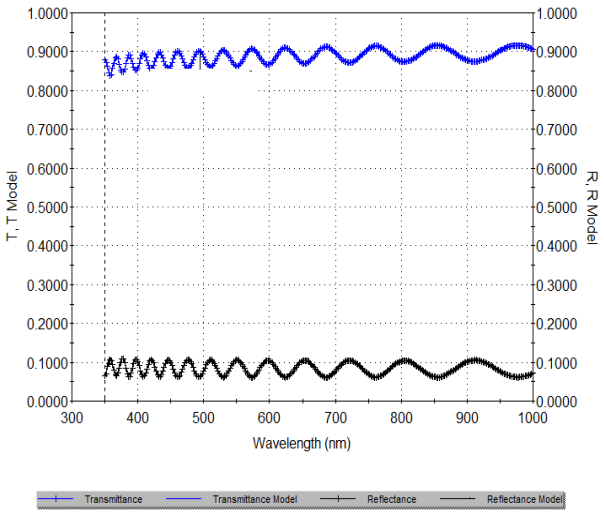

Figure 10

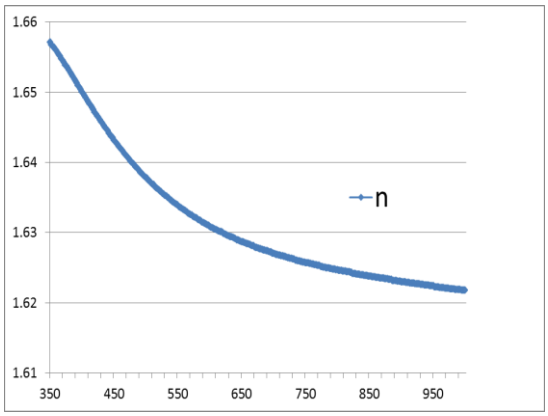

Figure 11

References

1. S. Schiller, U. Heisig, K. Goedicke, J Vac Sci Technol **12** 858 (1975)
2. M. A. Scobey, R. I. Seddon, J. W. Seeser, R. R. Austin, P. M. LeFebvre and B. Manley (1989) US Patent 4,851,095
3. R.P.Howson, *Pure & Appl. Chern.,* Vol. *66,* No. 6, pp. 1311-1318, 1994.

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