UV dichroic coatings on metallic reflectors

2008 J. Phys.: Conf. Ser. 114 012032

(http://iopscience.iop.org/1742-6596/114/1/012032)

UV Dichroic Coatings on Metallic Reflectors

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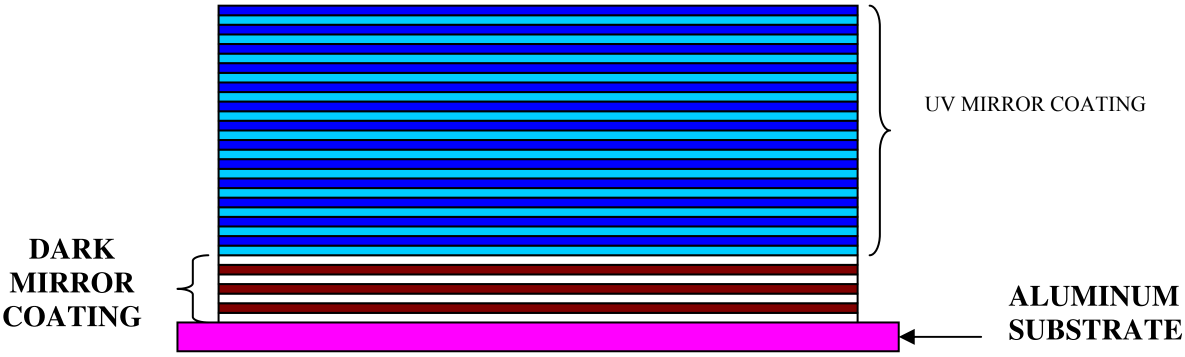
Abstract: The work presented here explains the design and deposition process of dichroic coating on metallic reflectors developed for UV curing systems. Special designs are adopted to achieve the spectral band and optimized to suit to the requirements. A mirror, which reflects the UV radiation (220 – 400 nm) and absorbs visible and infrared radiation (400 – 2000nm), is described in detail.

1. Introduction:

UV curing is hardening of a liquid film of material when exposed to ultraviolet light. The particular substance to be processed may vary widely depending upon its application and final use, but basically is composed of base polymers, non-solvent diluents and photo initiators. The rate or speed of curing will depend on four factors chemical compound, thickness of coating, UV Spectrum emitted by the source and amount of UV intensity per unit surface.The light source used for UV curing emits radiation in UV, Visible and Infrared. Visible light and infrared radiation causes abnormal curing of inks. The light energy, which is reflected, should not contain Visible and Infrared radiation. This is achieved by using a glass reflector, which is coated with an UV dichroic reflective coating. This coating will reflect the UV radiation and transmits Visible and Infrared radiation of the spectrum. We have developed another dichroic coating on metals as a replacement for glass, since processing of glass substrate is difficult. Polished Aluminum reflectors are used to reflect UV radiation. Since Aluminum reflects the UV, Visible and Infrared radiations, a suppression of Visible and Infrared radiation is required. In this paper we present a coating design and deposition method. The present coating reflects above 90% of Ultraviolet radiation from 220-400 nm and reflects less than 20% of visible and infrared radiation from 401-2000 nm.

2. Coating Design

Aluminum is the most widely used reflecting mirror, since it offers a high reflectance throughout the visible, near infrared and near-ultraviolet regions of the spectrum. Aluminum oxidizes in the atmosphere and forms an oxide layer on top of the surface, which is tough and corrosion resistant. But oxidation significantly reduces aluminum reflectance in the ultraviolet and causes slight scattering throughout the spectrum. To overcome the above oxidation and reflectivity in the region of visible and infrared radiation polished aluminum surface is to be protected and enhanced by depositing a coating.



Section 1.01 Fig. 1 UV Dichroic Coating on Aluminum

Coating on polished Aluminum is a combination of two mirrors coatings. The first mirror is a dark mirror, which absorbs Visible and Infrared radiation. The second mirror is a highly reflective coating to enhance the reflectivity in the region of Ultra violet.

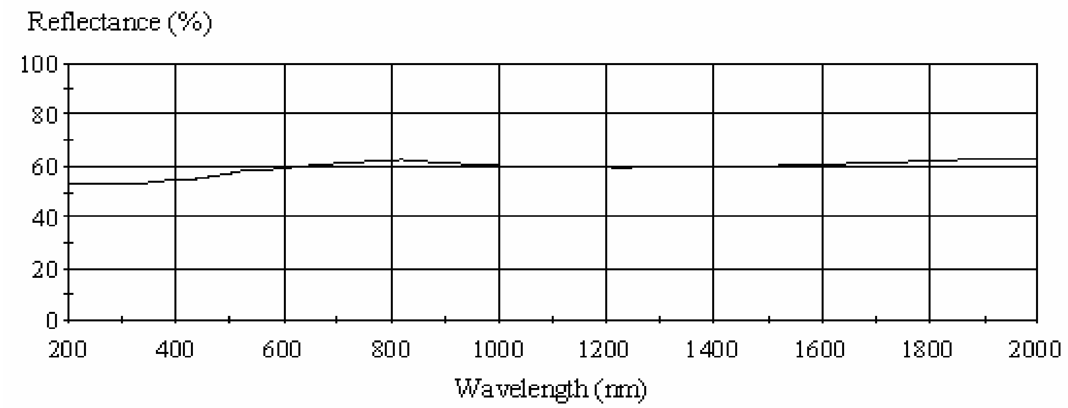


Fig. 2 Quarter wave design of the dark mirror (HL) [4]

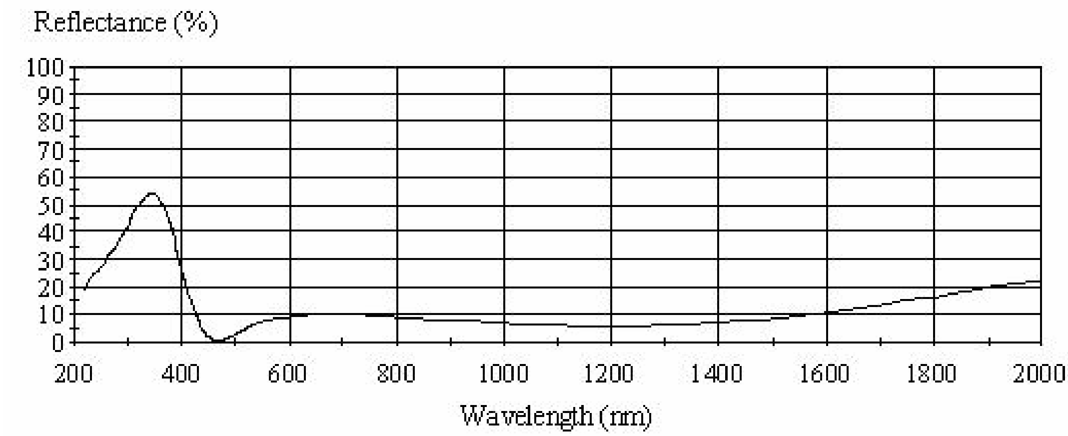


Fig.3 Reflectance of the dark mirror coating after optimizing with non quarter wave thicknesses on aluminum substrate.

Dark mirror was designed with the combination of metallic and oxide layers, which can absorb the Visible and Infrared region of the spectrum. Titanium (**Ti**) (i.e. High index and highly absorbing material) is the material used along with Silicon dioxide (**SiO2**) (i.e. Low index and Low absorption material) to achieve high absorption with dark mirror. The initial design with quarter wave layers of silicon dioxide and Titanium Could absorb in the region of Visible but there was a good amount of reflection in the region of Infrared as shown in fig.**2**. When the design was optimized to a non-quarter wave layer there was a significant absorption in the cutoff region below 20% as shown in fig.**3**.

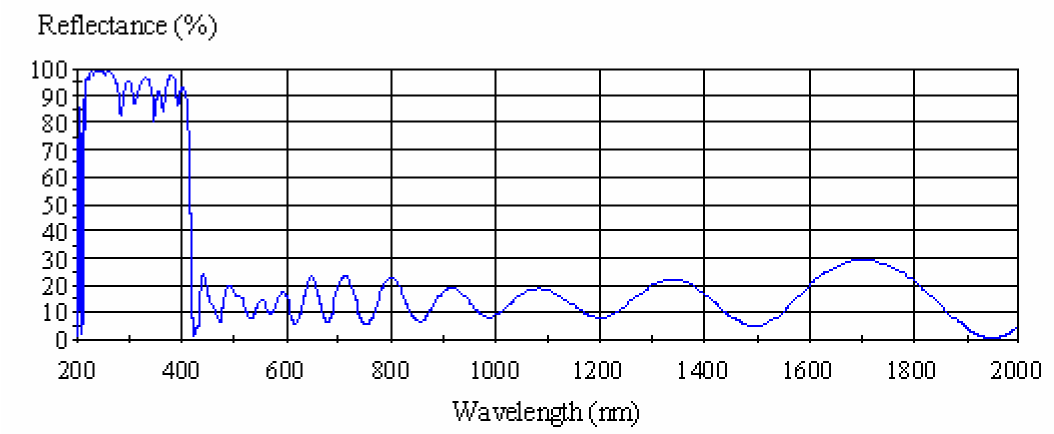


Fig.4 Designed performance of the UV reflective coating on Aluminum substrates

The design of the UV reflective coating is a combination of high and low refractive index oxide materials, i.e Silicon Dioxide (**SiO2)** and Hafnium Dioxide (**HfO2**), which has less absorption in Ultra Violet region. This reflectance is achieved by overlapping three mirrors, which reflects in **UVC** (<280 nm), **UVB** (280 – 320 nm) and **UVA** (320 – 400 nm). The initial design was a basic mirror design with **L** (**HL**)^{q} quarter wave thickness layers. Since to achieve the band with required i.e. 220-400 nm total three mirrors stacks were overlapped. SiO2 and HfO2 were used as the materials for designing the ultraviolet reflecting mirror. The performance achieved was not good and there were more leakages in the UV reflective region. So the design was optimized with non-quarter wave layer thickness to achieve the required performance. The combined reflectance vs wavelength spectrum is shown in fig.4.

3. Preparation of the Coatings

These coatings are done using a BC600 (fig.5 and fig.6) box coater made by Hind High Vacuum Co. Pvt. Ltd. This system is automated and equipped with a 3 KW electron beam gun with 4 crucibles, digital thickness monitor, temperature controller, mass flow controller and rotary drive. A practical study was made to find the appropriate operating parameters to achieve the optical parameters of the materials, which were used at the time of design. Substrates were prepared so carefully to achieve a good adhesion. The system tooling factor was calculated for coating materials and they were incorporated in the design which gives the non quarter layer thicknesses. Oxygen was introduced to compensate the degassing of SiO2 and HfO2 during the deposition. Coatings were done at a high vacuum of 5 x 10 $^{-5}$ mbar and at a temperature of 200 deg C. Coating materials were premelted to achieve uniform rate of evaporation and to avoid spatting.

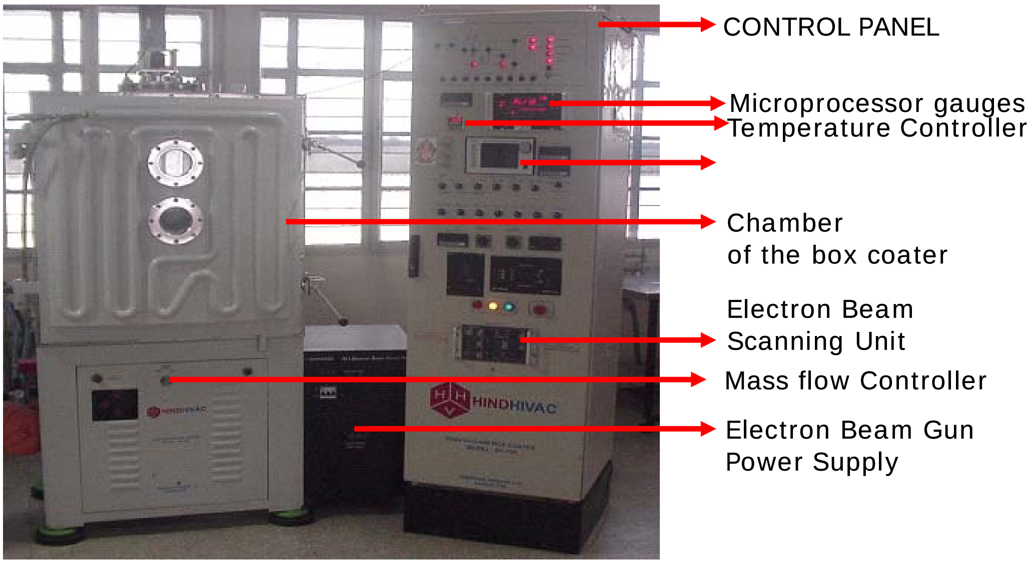


Fig. 5 BC600 Box coater made by Hind High Vacuum Co. Pvt. Ltd.

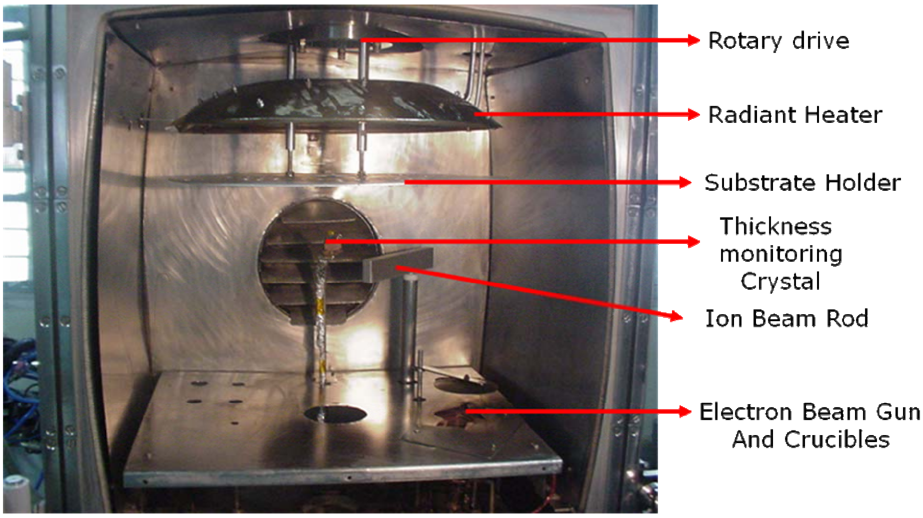


Fig. 6 Inside view of the BC600 chamber

First the dark mirror layers were deposited. Since the titanium layers in the dark mirror were so thin, lower rates of deposition were maintained to achieve uniformity. Then the UV mirror layers were deposited. Before removing the substrates they were allowed to soak for twenty minutes. The trial coupons of aluminum and aluminum coated glass were characterized using a shimadzu spectrophotometer (190 - 2000 nm).The spectrum of the coating was shown in the **fig.7** and **fig.8.**

Trial coupons were subjected to various tests like adhesion, corrosion and temperature tests. A good adhesion was achieved and there was no sign of peel off after subjecting to a temperature of 250 deg C for 4 hours.

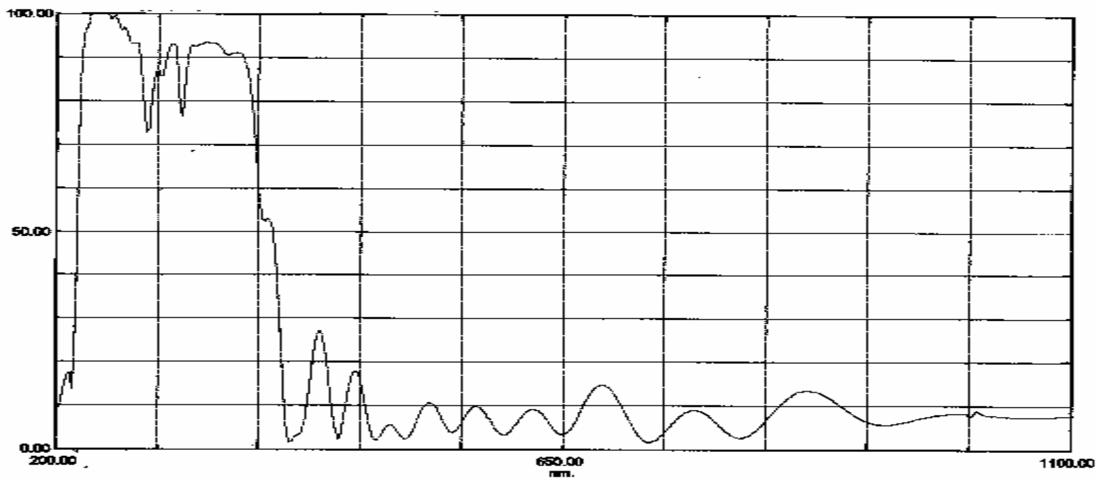


Fig. 7. Reflectance spectrum measured on Al trail coupon

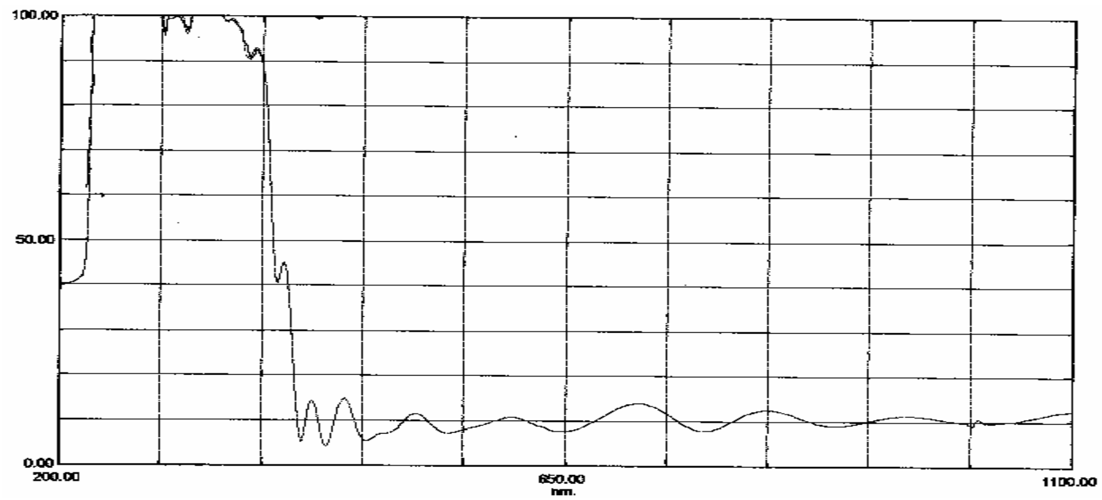


Fig. 8. Reflectance spectrum measured on Aluminum coated Glass trial coupon

The coatings were subjected to adhesion, thermal, corrosion and humidity tests according to the MIL standards for the durability.

4. Results

- A good reflectivity in the region of UV i.e. 220 – 400 nm were achieved.
- The amount of absorption in the region of visible and infrared i.e. 401 – 2000 nm was below 15% and 25%.
- A good adhesion was achieved when subjected MIL Standard test for adhesion.
- The coating did not loose its characteristics though it was subjected to a heat of 250 deg C for four hours.

5. Conclusion

The coatings were designed and prepared successfully. The coatings were also thoroughly tested for various MIL standards. The coating could withstand for 250 deg C for a longer duration but there was an increase in visible and infrared region when it is subjected to 300 deg C. Still we are working to achieve the durability at 300 deg C for longer durations. We expect that by increasing the packing density of the materials the durability at 300 deg C can be achieved.

6. References

[1] Philip W. Baumeister, Optical Coating Technology, SPIE Press,
[2] Thin Film Design Software, Essential Macleod,