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Broad Band Antireflection Coating on Zinc Sulphide Window for Shortwave infrared cum Night Vision System

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Abstract. In state of art technology, integrated devices are widely used or their potential advantages. Common system reduces weight as well as total space covered by its various parts. In the state of art surveillance system integrated SWIR and night vision system used for more accurate identification of object. In this system a common optical window is used, which passes the radiation of both the regions, further both the spectral regions are separated in two channels. ZnS is a good choice for a common window, as it transmit both the region of interest, night vision (650 – 850 nm) as well as SWIR (0.9 – 1.7 μm). In this work a broad band anti reflection coating is developed on ZnS window to enhance the transmission. This seven layer coating is designed using flip flop design method. After getting the final design, some minor refinement is done, using simplex method. SiO_2 and TiO_2 coating material combination is used for this work. The coating is fabricated by physical vapour deposition process and the materials were evaporated by electron beam gun. Average transmission of both side coated substrate from 660 to 1700 nm is 95%. This coating also acts as contrast enhancement filter for night vision devices, as it reflect the region of 590 – 660 nm. Several trials have been conducted to check the coating repeatability, and it is observed that transmission variation in different trials is not very much and it is under the tolerance limit. The coating also passes environmental test for stability.

1.Introduction

Vision in dark is not only important but it is necessary toll for modern civil and allied operations. Night vision devices based on image enhancement and thermal imagers are already available for this purpose. Shortwave infrared (SWIR) imaging is quietly earning a growing place in night vision system, although thermal imaging has been well established for night vision. It is poised to make night vision capabilities even better than they are today. Even in moon less night, the short wave region of EM spectrum contains five to seven times more energy than any other spectral wavelength from star light and glow of the night sky [1]. SWIR camera is smaller and lighter then all thermal cameras, and cost far less than many of them. SWIR detectors can see through glass and also can see things intrinsically which thermal detectors cannot. Thermal imagers are good at spotting temperature differentials; but they have drawbacks that it does not work well at dawn or dusk, which are known as the crossover points. But SWIR do not have this problem which is a complement to this technology. As per surveillance experts SWIR works well round the clock and especially well at those crossover points. SWIR also produces images similar to a black and white visible camera, requiring almost no training to interpret. With SWIR, the pedestrian or middle size vehicle can get information of a distant vehicle, even on a moonless night where as interpretation of thermal images, by contrast, requires intensive training and, even then, does not permit definitive identifications.

To detect SWIR wave, different types of detector generally used depending on the different sub-band between 0.9μm to 3 μm range. They are NVG Gen III, Silicon CCD, and different InGaAs based detector. InGaAs based detectors have different types, depending on higher wavelength cut. InGaAs (1.7μm) detector based SWIR cameras operate at 27^0 C, mechanical shutter or cooling is not required, it never need field Non Uniformity Corrections (NUCs) and also have high quantum efficiency [2]. As a result, InGaAs (1.7μm) SWIR cameras are as compact, versatile and simple to use as a commercial digital video camcorder. They provide analog video to standard TV or any commercial frame grabber card.

For SWIR camera with InGaAs (1.7μm) detector we require highest light gather efficiency of the glass based optics in 900nm to 1700nm band. Zinc sulphide's transmission spectrum from 0.4 lm to 11 lm is free from major absorption, with the material easily available in large quantity and high purity to suit for most electro optical applications. Investigation on general optical properties of zinc sulphide has been extensively carried out over the years by different authors [3,4]. Very good surface hardness, robustness and ease of fabrication makes zinc sulphide a strong candidate for optical elements in SWIR (0.9–2.5 μm). Refractive index of zinc sulphide is 2.2, so it transmits only 73% incident radiation in uncoated condition. So antireflection coating is a critical requirement for zinc sulphide substrate, to make it useful for any optical system.

For military applications, it has been seen that the reflectivity of green paint is more than that of green vegetation from 550 to 660 nm region. After 660 nm to the remaining portion of spectrum, green paint reflectivity becomes less than that of green vegetation. So a night vision device with a contrast reversal at 660 nm make easy to detect the green military target. So a state of art system for night surveillance can integrate night vision system as well as SWIR imaging system. The present paper describes design and development of antireflection coating on zinc sulphide substrates, which is effective from 650 nm to 1700 nm. This coating also works as contrast reversal filter for night vision system.

2. Coating Design

Design of the coating is done using flip flop method [4, 6]. In this method the overall thickness is to be chosen. We have fixed the overall thickness at 1.5 λ. It has been shown that the overall thickness between λ and 2 λ give the good result [7]. We have selected λ 1300 nm. Then low and high index materials are selected. We have selected SiO_2 and TiO_2 as two materials [8]. The total thickness is divided in very thin layers and fix the starting index of each layer either low or high index. Each thin layer index is interchanged and the better design is kept. This all is done with the help of the Macleod thin film design software. The final design is refined using simplex method [9]. We get the design with 7 layers, and the top SiO_2 layer is replaced by MgF_2. Index profile of the design is shown in figure 1.

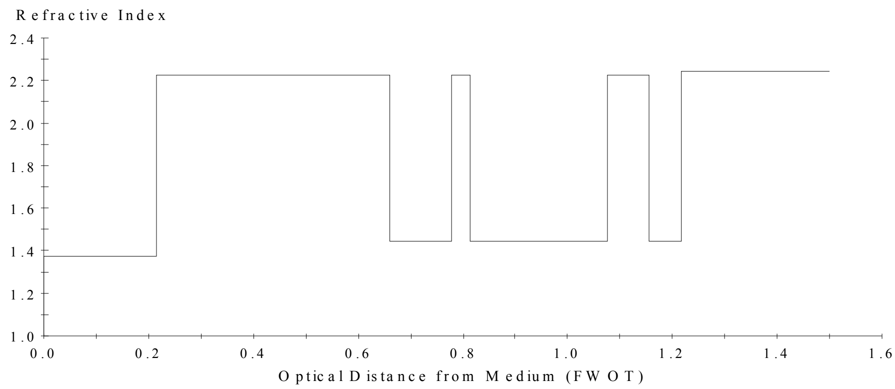

Fig. 1. Index profile of the coating design

3. Experimental

This was fabricated using electron beam gun evaporation technique on Hind High Vacuum coating unit BC 600 on Zincsulphide Substrate. Before deposition, substrate was cleaned ultrasonically in three stages: i) soap solution for ten minutes, ii) de ionized water for ten minutes, iii) isopropyl alcohol for 15 minutes. The substrates were then subjected to vapor degreasing in isopropyl alcohol for half an hour before mounting in vacuum chamber. Substrate was finally cleaned by high tension glow discharge for about fifteen minutes just before coating. Initially chamber was evacuated upto a pressure of $2x10^{-6}$ mbar then TiO_2 and SiO_2 were evaporated in oxygen atmosphere at a pressure of $6x10^{-4}$ mbar and last layer MgF_2 at $2x10^{-6}$ mbar with out oxygen percale pressure. The oxygen atmosphere requires for TiO_2 and SiO_2 for mentioning low absorption in the film. The substrate was heated to 300^0 C (with tolerance $\pm 5^0$C) by radiant heater before coating and the temperature was maintained during deposition. Substrates were rotated on flat plate holders, to ensure layer thickness uniformity.

All the deposition parameters i.e. glow discharge time, heating powers for coating materials, rate of deposition, thickness of various layers, layer sequence etc were controlled by microprocessor interfaced with the coating unit. Thickness and rate of deposition were monitored with quartz crystal monitor. Rate of deposition of TiO_2 was kept at 0.2nm/s for SiO_2 0.3nm/s and rate of deposition of MgF_2 was kept at 1.5 nm/s. The transmission of the coated substrate was measured with the help of Perkin Elmer UV – Vis – NIR double beam spectrophotometer model 'Lambda 950'. The transmission curve is shown in figure 2.

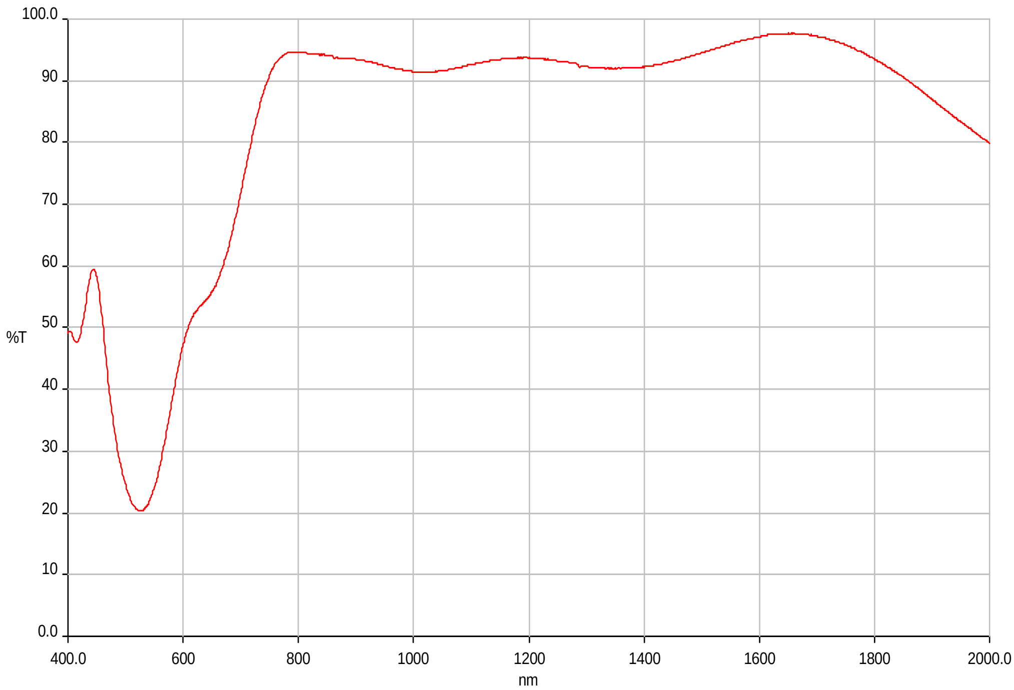

Fig. 2. Transmission variation of both side coated sample

4. Result

The practical transmission variation with wavelength is shown in figure2. The experimental transmission curve is measured in Perkin-Elmer lambda 950 spectrophotometer. Practically is 95% average transmission achieved for both side coated sample (sample thickness is around 3 mm). The average reflection from 590 to 660 nm is 50 %. This coating shows excellent stability and passes the entire MIL standard test as per MIL-F-48497.

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