High efficiency infrared broadband AR coatings for thermal imaging applications

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Introduction

Thermal imaging night vision systems that works in FIR(8-12 µm) region, images the scenes based on the surface temperature by detecting the infrared radiation that emanates from the objects and surrounding environment. Thermal imaging has applications in defense, industrial security, transportation, cancer detection, body scans, and hot-spot detection.

Germanium is the widely used material in 8-12µm band. Its high refractive index (~4 @ 10µm) makes Ge ideal for low power imaging systems because of minimum surface curvature. Another advantage is that the chromatic aberration produced by germanium lenes is small, thus eliminating the need for correction. Unfortunately, the radiation reflection losses from the surface of the Germanium are very high thereby reducing the overall efficiency of the system. Due to unintended reflections from lens surfaces in a thermal imaging system, the detector sees sources at temperatures other than the background ambient with the reflections of the detector itself, produces ghost images (Narcissus effect). To enhance the signal to noise ratio and to reduce the ghost images, antireflection coatings (AR) are applied on to the germanium lenses.

In this paper, the design approach and investigation results of High efficiency broadband (8-12 µm) antireflection coatings on germanium substrate are presented.

Design approach

Essential Macleod thin film design software was used for the design optimization. Germanium and YF3 are used as high and low index materials respectively and ZnS used as medium index material. The Selection of coating materials was done based on their refractive index, IR transparency and its stability. The simplex optimization technique was used to achieve the lowest value of the merit function for the set reflection targets.

Experimental setup

The multilayer stack was fabricated by using electron beam gun evaporation system in HHV BC-600 vacuum coating unit. This system is automated and equipped with four pocket 3KW E-beam gun power supply, Digital Thickness Monitor, Mass flow controller, lamp heaters with temperature controllers and rotary drive. Base vacuum of the chamber maintained 5*10^-6mbar. Before the deposition, substrates were pre-cleaned with ion bombardment with chamber pressure 5*10^-3 mbar.

A practical study was made for each material to optimize the process parameters to achieve design optical constants. Germanium, Yf3 and ZnS films were evaporated using E-beam source. Deposition rate of germanium, Yf3 and ZnS were maintained 5,4 and 10 A/sec respectively. During the deposition chamber temperature was maintained 120C. System tooling factor was calculated for coating materials and they are incorporated in the design and which gives the non quarter layer thickness. Pre-melting of the coating materials were done to achieve uniform deposition rate and to avoid spatting. Germanium test coupon with thickness 1mm was used as substrate. Multilayer stack was applied to both sides of germanium test coupon. Transmission and reflection measurements were conducted on coated germanium test coupons with FTIR spectrophotometer (Shimadzu IR-Affinity)

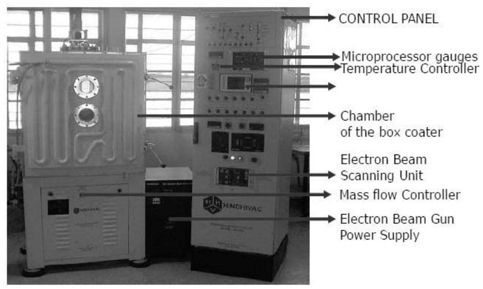

Fig.1 HHV BC-600 vacuum coating unit

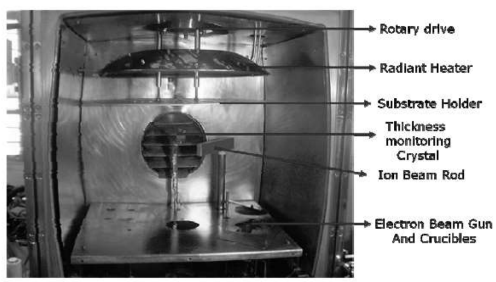

Fig.2 Chamber configuration

Results and discussion

A broad band antireflection coating in the 8-12µm with the low reflection values has been developed. The transmission characteristics of the coating are shown in figure 3. We have achieved an average transmission >97% in 8-12µm region on 1mm thick germanium substrate. The achieved reflection is <0.3% per surface as shown in the figure 4.

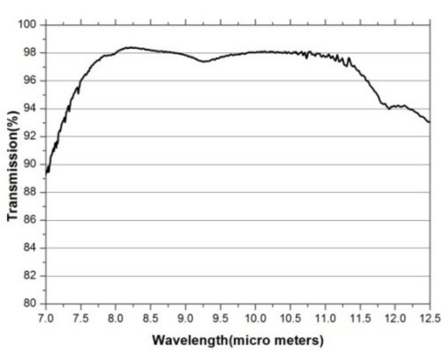

Fig.3 Transmission spectra of wide band AR coating on Germanium

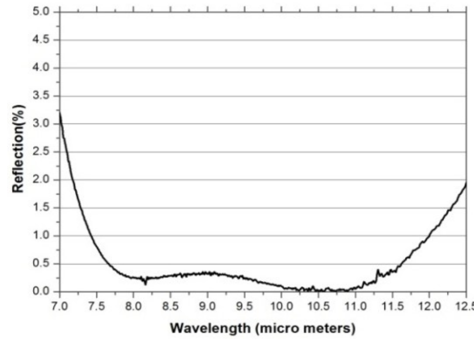

Fig.4 Reflection spectra of wide band AR coating on Germanium

We prepared 4 different samples both sides coated in different coating runs and subjected them for MIL-C-48497A. The results are shown in table-1. It is seen that coating is reproducible and also environmentally stable.

Table 1: Durability test results

Test	specifications	Result
Humidity	24h, 98-100%RH: Temp 49±1^{0}C	Pass
Abrasion	50 rubs by cheese cloth	Pass
Adhesion	Pull by scotch tape	Pass

Conclusion

IR Multilayer stack was successfully deposited on germanium substrate. High Transmission and very low reflection was achieved over 8 to 12 micron region. Test coupons were successfully passed the specifications of MIL-C-48497A tests.

References

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