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

By

A S Upadhyaya & P K Bandyopadhyay

Instruments Research & Development Establishment

Dehra Dun

Vision in Dark

Vision in dark always in human endeavor for civil and allied operation.

Challenges in night vision devices is never ending and scope for betterment is always promising.

SWIR imaging is quietly earning a growing place in night vision system with state of art detector system.

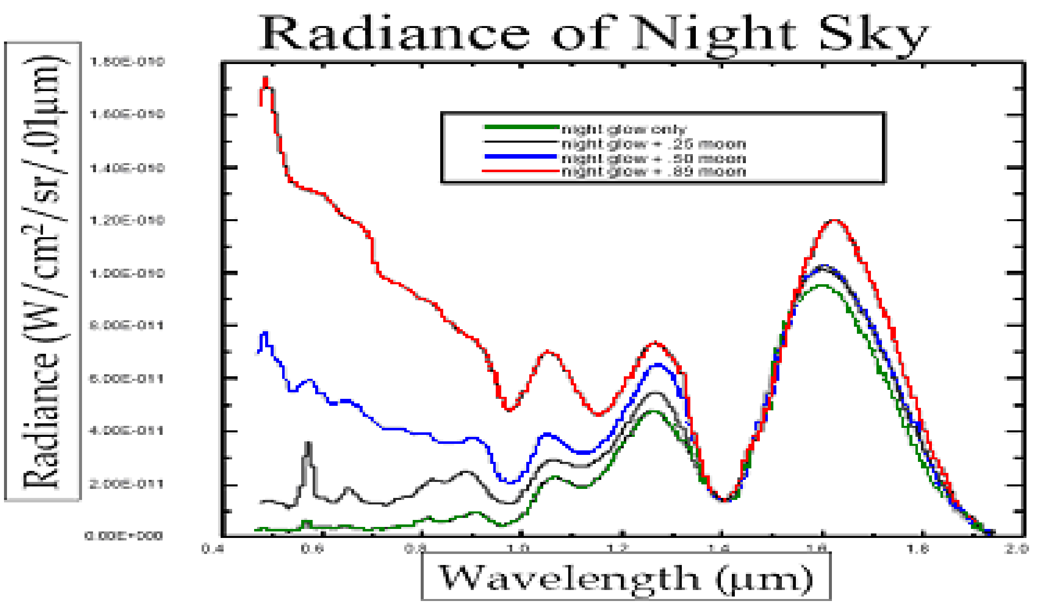
These devices are based on image enhancement techniques.

SWIR Imaging

SWIR ranges from 900 to 2500 nm waveband.

SWIR imaging is used in night vision systems.

The atmospheric phenomenon called night sky radiance emits five to seven times more illumination than starlight.



Ref: L.V.Mirshri, "Atmospheric Optical Environment", R&D Technical Report ECOM-7023, Sept 1972.

SWIR detectors

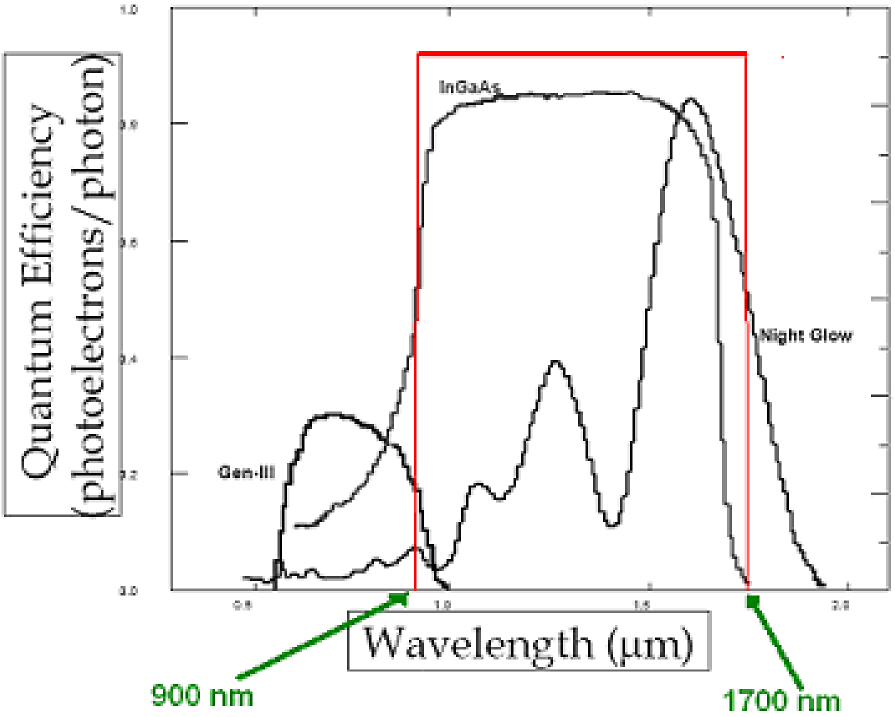
•Various type of detectors are used

•InGaAs is the most popular detector

•It has high quantum efficiency

• InGaAs (1.7mm) detector based SWIR cameras operate at room temperature

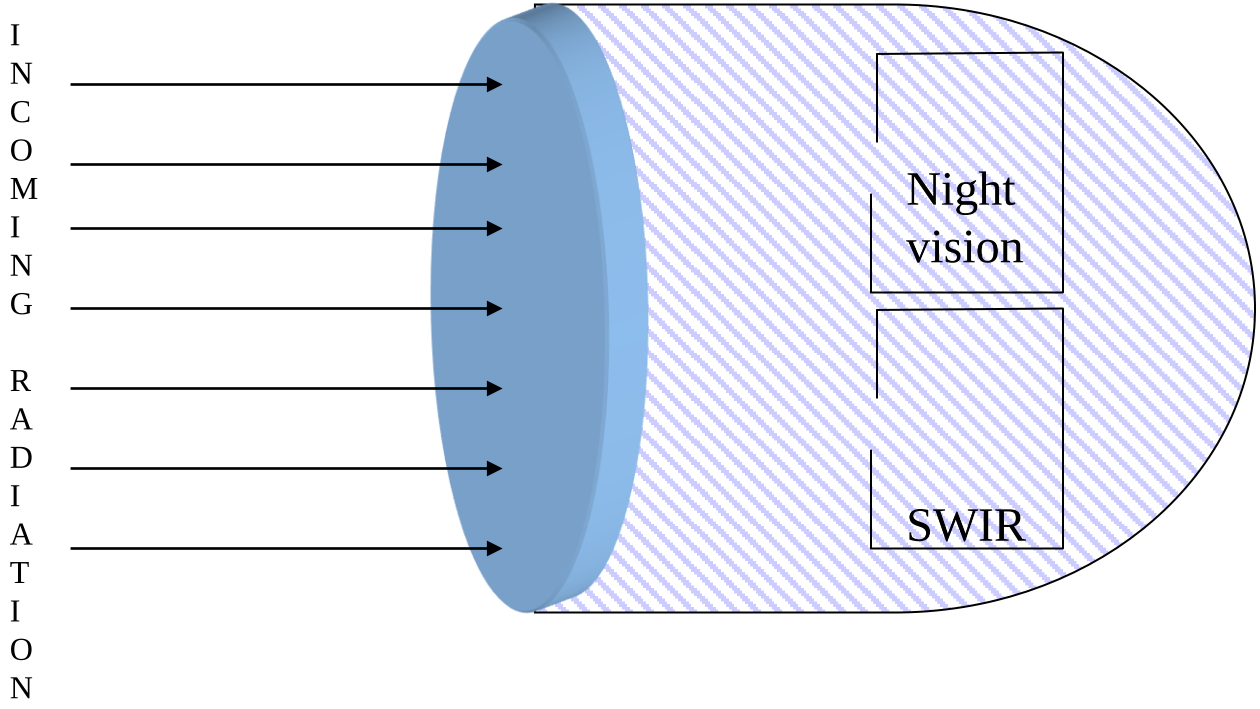
•Compact, versatile and simple to use



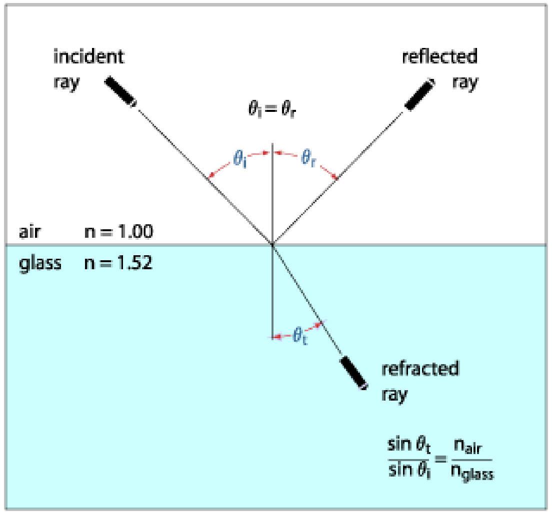
(Ref: Photonic Solution for the design engineer-“PTB Photonics Tech Brief” April 2004)

Integrated Device

A state of art surveillance system uses night vision system and SWIR system.
A common system reduces weight and space covered.
More accurate identification of object.



Antireflection Coating



Intensity $r = (n_g - n_a)/(n_g + n_a)$

Whenever there is some medium change, reflection loss occurs.

This loss is a critical factor as the flux in night is around 10^7 times less as compared to daylight.

For SWIR camera with InGaAs (1.7µm) detector we require highest light gather efficiency of the glass based optics in 900 nm to 1700 nm band.

Quantum efficiency of the detectors used for image intensifier based Night vision devices is maximum between 650 to 850 nm wavelength.

Substrate

ZnS is a widely used window for multispectral region, starting from visible to LWIR.

Presently the region of interest is night vision region (650-850 nm) plus SWIR region (0.9 -1.7μm).

Uncoated transmission of ZnS is **72%**

… So the aim of this work is design and development of broad band antireflection coating for **650 to 1700** nm wavelength region to make the substrate useful for practical applications.

Important parameters of AR coating

Refractive index of Incident medium(n_0),

Refractive index of thin film (n_p)

Thickness (t_q)

Refractive index of the substrate (n_s).

Selection of Coating Materials

Materials Choice:

Stable High Index Materials: TiO_2, Ta_2O_5, ZrO_2, HfO_2

Stable Low Index Materials: MgF_2, SiO_2, Al_2O_3

After studying all these above mentioned materials , we found that the best material combination for this coating is SiO_2/ TiO_2

This SiO_2/ TiO_2 material combination has very good compatibility with each other. They are environmentally stable materials. This combination can also can be evaporated easily using electron beam gun evaporation source.

We selected SiO_2/ TiO_2 for our present work.

Flip Flop Method of Design

Design of the coating is based on **Flip Flop method,** done with the help of ‘Macleod Thin Film Design’ software. Following is steps of this method:

a) Select a total physical thickness of the coating

b) Divide this into very thin layers

c) Assign two initial indices high and low

d) Take starting design with all high or all low index.

e) Evaluate a merit function of starting design.

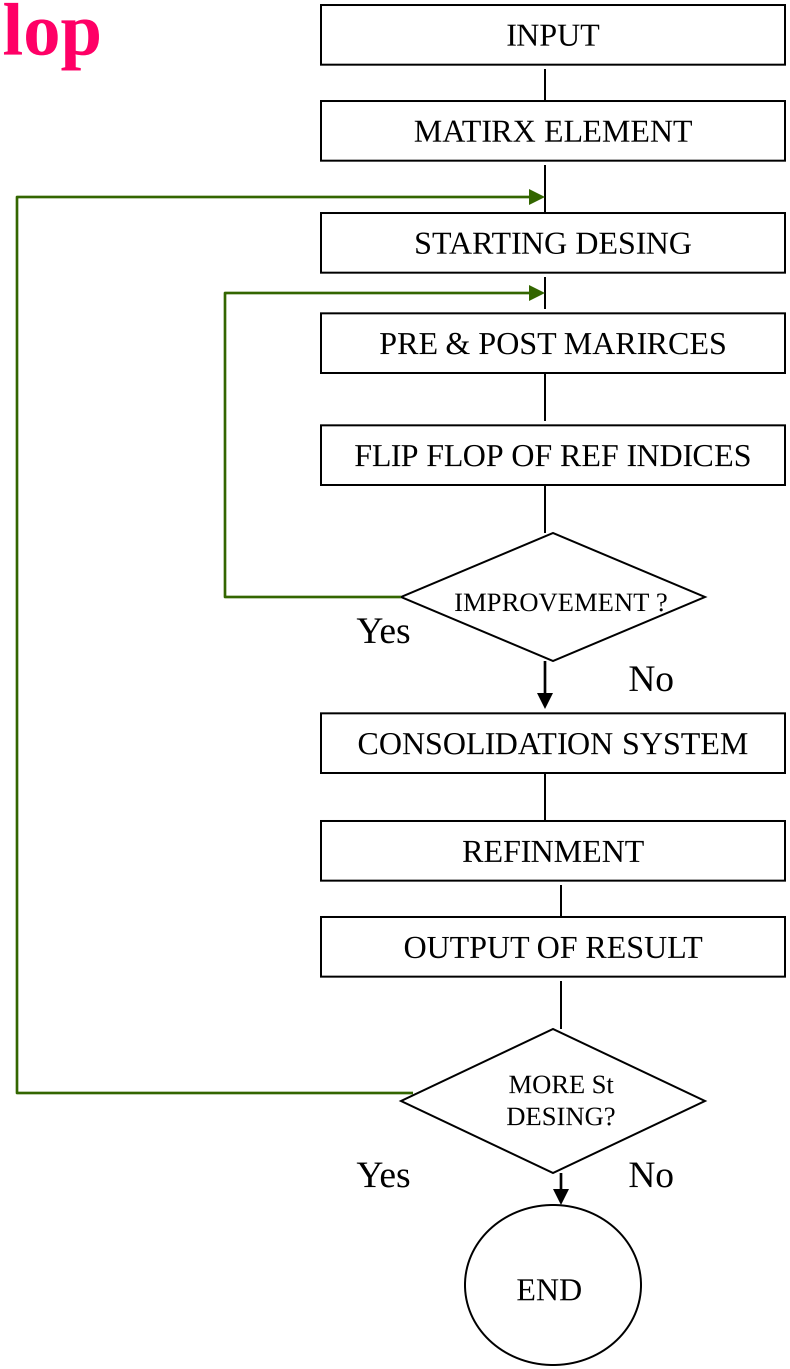
f) Change the state of each layer, one at a time

g) Reevaluate the merit function

h) If the performance is better in flipped state, retain the change otherwise restore it.

i) Repeat it for all the layers.

Flow chart of Flip Flop



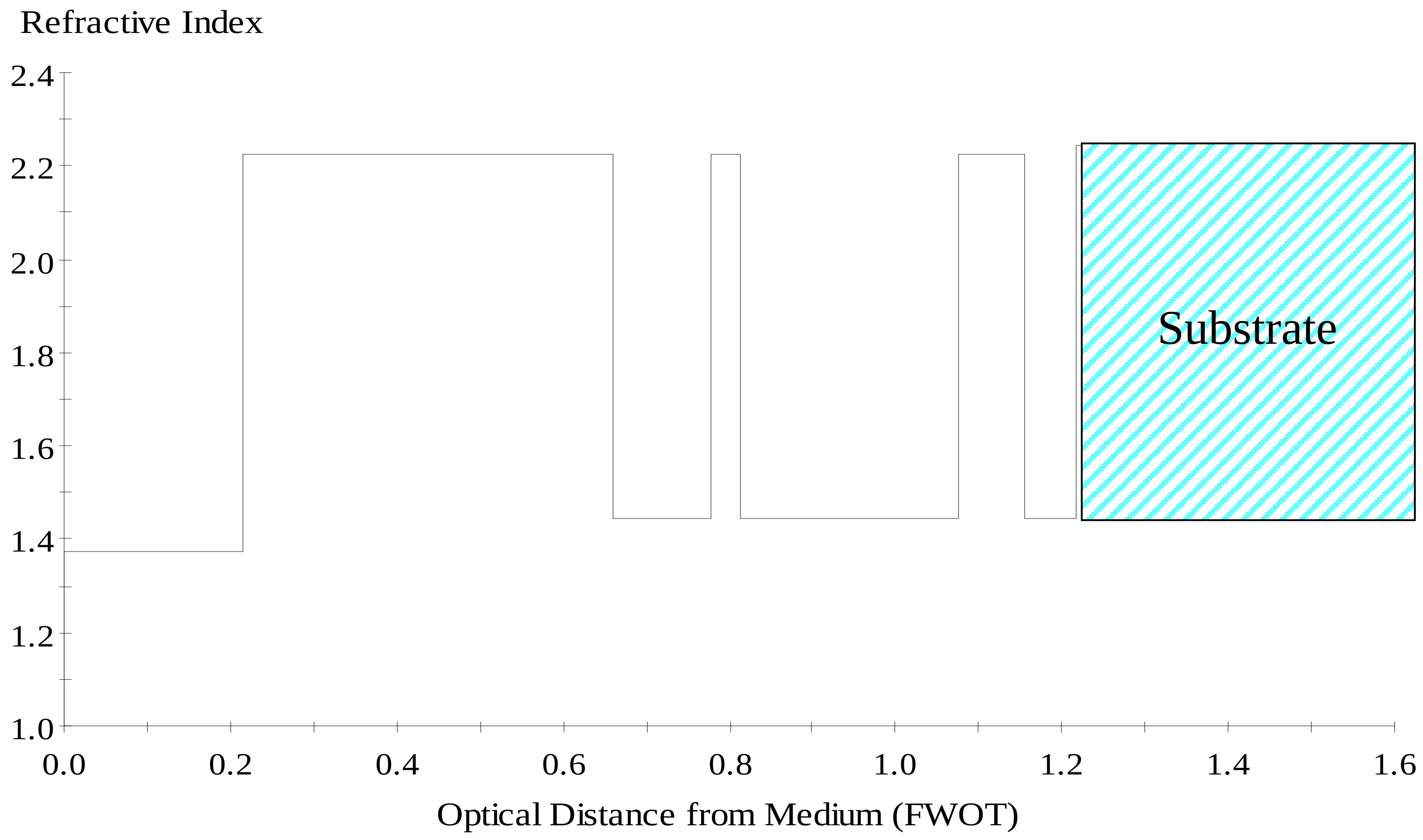
Coating Design Parameters

Substrate:	Zinc Sulphide
Refractive index:	2.2
Uncoated Transmission:	72%
Design Approach:	Flip Flop
Starting Thickness:	1.5 λ
Wavelength:	1300 nm
Thickness division:	λ /100

We have tried this design with all high and all low starting design. The lowest merit function design was kept. The top layer of SiO_2 was replaced with lowest available material MgF_2 And final design is refined with simplex method.

Theoretical Design

Seven layer stack of SiO_2/TiO_2



Experimental Detail

Substrate: ZnS φ 25 mm; t = 3 mm

Cleaning:

* 10 minutes in soap solution
* 10 minutes in deionized water
* 20 minutes in isopropyl alcohol
* One hour vapour degreasing in isopropyl alcohol
* 5 minutes glow discharge cleaning before coating(in-situ)

ULTRASONIC CLEANING

COATING UNIT: **HHV BC 600 having oil diffusion pump backed by rotary pump with electron beam evaporator and liquid nitrogen cooling facility.**

MONITORING:

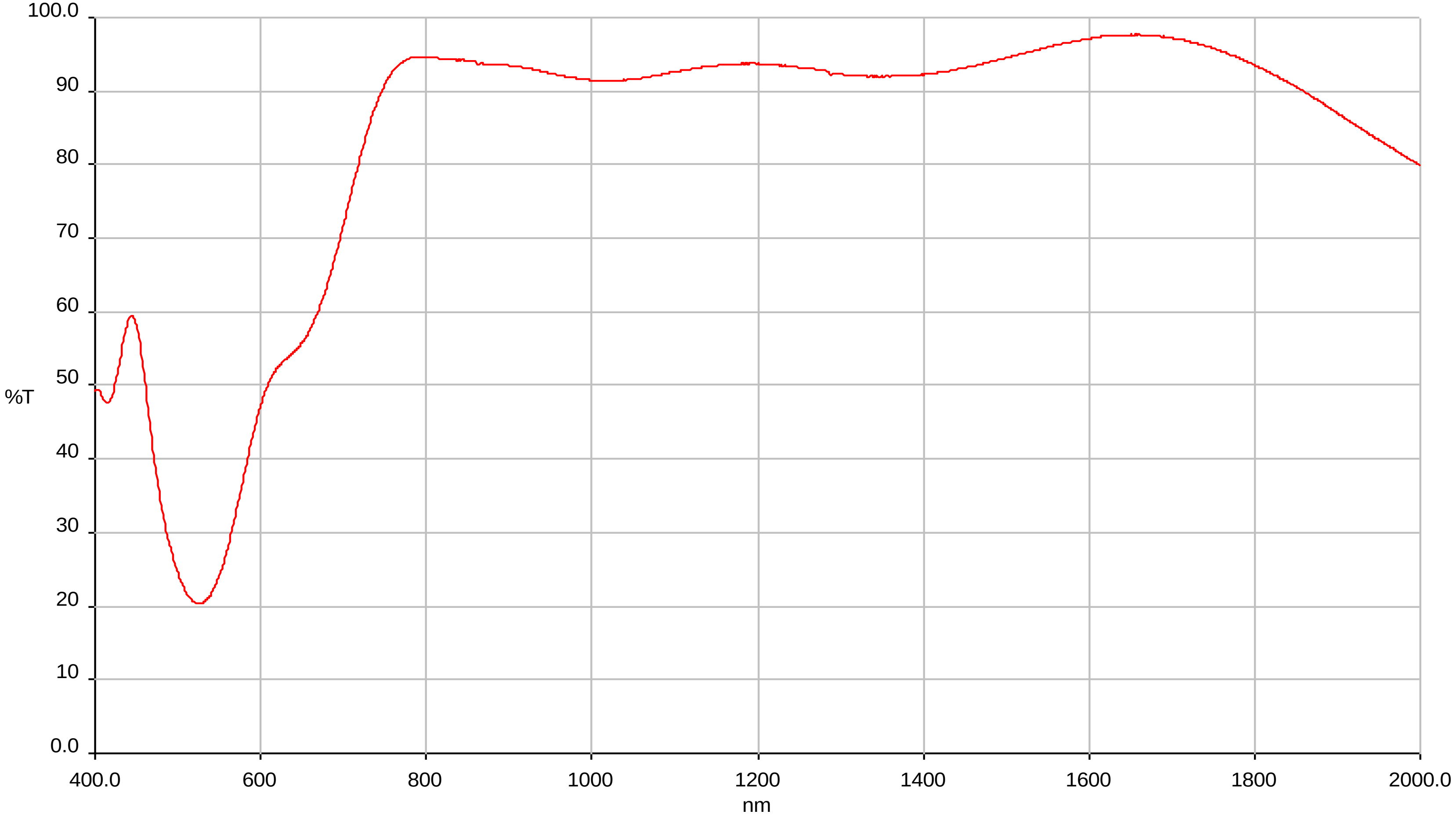
Thickness monitoring

by quartz crystal

PROCESS PARAMETERS

MATERIAL	SiO_2	TiO_2	MgF_2
EVAPORATION PROCESS	EBG	EBG	Thermal
SUBSTRATE TEMP. IN ^0C	300	300	300
RATE OF DEPOSITION (nm/sec)	0.3	0.2	1.5
CHAMBER PRESSURE WITH O_2 (mbar)	$6 X 10^{-4}$	$6 X 10^{-4}$	$2 X 10^{-6}$ (No Oxygen)
PRE DEP. BAKING TIME (hrs)	$2 LN_2$	$2 LN_2$	$2 LN_2$
POST DEP. BAKING TIME (hrs)	1	1	1

Transmission Curve



7 LAYER ANTIREFLECTION COATING TRANSMISSION CURVE ON GLASS FOR SWIR

Measured by Perkin Elmer Spectrophotometer ‘Lambda 950’

Result

The experimental transmission curve is measured in Perkin-Elmer Lambda 950 spectrophotometer. Practically is 95% average transmission achieved from 650 to 1700 nm waveband for both side coated sample (sample thickness is around 3 mm).

This coating also act as contrast reversal filter for 590 to 660 nm wavelength. Average reflection is 50% in this region.

The coating is also stable environmentally as it pass ENVIRONMENTAL TEST: MIL –C-48497

Thanx