International Conference on Space Optics—ICSO 2008

Toulouse, France

14–17 October 2008

Edited by Josiane Costeraste, Errico Armandillo, and Nikos Karafolas

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icso proceedings

International Conference on Space Optics — ICSO 2008, edited by Josiane Costeraste, Errico Armandillo,
Nikos Karafolas, Proc. of SPIE Vol. 10566, 105662N · © 2008 ESA and CNES
CCC code: 0277-786X/17/$18 · doi: 10.1117/12.2308242

NARROW-BAND FILTERS FOR OCEAN COLOUR IMAGER

Hélène Krol[1], Frédéric Chazallet[2], Julien Archer[3], Laurent Kirchgessner[1], Didier Torricini[1], Catherine Grèzes-Besset[1]

[1] CILAS Etablissement de Marseille, ZI St Mitre - Avenue de la Roche Fourcade, 13400 Aubagne – France, krol@cilas.com
[2] SHAKTI SA, 27, Bd Charles Moretti, 13014 Marseille – France
[3] EADS ASTRIUM, 31 rue des Cosmonautes, 31402 Toulouse Cedex 4 – France

ABSTRACT

During the last few years, the evolution of deposition technologies of optical thin films coatings and associated in-situ monitoring methods enables us today to successfully answer the increasingly request of space systems for Earth observation.

Geostationary satellite COMS-1 (Communication, Ocean, Meteorological Satellite-1) of Astrium has the role of ensuring meteorological observation as well as monitoring of the oceans. It is equipped with a colour imager to observe the marine ecosystem through 8 bands in the visible spectrum with a ground resolution of 500m. For that, this very high technology instrument is constituted with a filters wheel in front of the oceanic colour imager with 8 narrow band filters carried out and qualified by Cilas.

1. INTRODUCTION

The required functions for Earth observation are particularly complex as they must present a very narrow bandwidth as well as a broad band of high level of rejection. In addition to those severe optical performances, insensitivity to environmental conditions is necessary. For this purpose, robust solutions with particularly stable performances have to be proposed [1, 2].

The first part of this paper reviews the specifications of the Narrow-band Filters required for the colour imager instrument of geostationary satellite COMS-1.

The second part presents the development and manufacturing of such optical functions. In particular, filters specifications concerning spectral bandwidth and wavelength centring require an accurate monitoring of deposited thicknesses [3] and a good master of thickness uniformity within the deposition chamber. Moreover, in order to guarantee a total insensitivity to temperature and pressure conditions, the multidielectric coatings are manufactured with Dual Ion Beam Sputtering (DIBS) technology.

Many experimental results of qualification tests in temperature, humidity, thermal vacuum, radiations,… are presented and show the reliability of these multidielectric components in space environment.

2. SPECIFICATIONS

COMS-1 (Communication, Ocean, Meteorological Satellite-1) geostationary satellite from ASTRIUM aims to perform meteorological observation as well as monitoring of the oceans. It is equipped with a colour imager that will allow feeding the databases of fishing industry (chlorophyl, etc) and observing the marine ecosystem in the short and medium term.

The advanced Ocean Imager has a sophisticated focal plane providing for the first time ever, ocean data from geostationary orbit through 8 imaging bands in the visible spectrum with a ground resolution of 500m. For that, this very high technology instrument is equipped with a filters wheel constituted with 8 narrow band filters carried out and qualified by Cilas.

Fig. 1. COMS-1

End-of-life Filters spectral specifications are:

- 8 channels between 400 and 900nm
- Wavelength centring : ± 2 nm
- Filter Bandwidths : 10, 20 and 40 nm ± 2 nm
- Mean Transmittance : T > 60 to 75%
- Rejection < 1.10^{-2}
- Incidence : 2.6° to 4.4°

3. COATINGS DEVELOPMENT AND MANUFACTURING

3.1 Thin film Synthesis

Broad band functions constituted with more than one hundred multidielectric layers combined with coloured glasses are necessary to be in adequacy with the required specifications as well for the maximum transmission value or spectral centring as for the out-of-band rejection value.

The band-pass functions are based on multiple half wave Fabry-Perot structures and rejection is ensured by a combination of blocking multilayer stacks (typically high pass and low pass functions) deposited either on Bk7G18 substrate or on coloured glass substrate.

We present such an example in “Fig.2.” that leads to an 18.3nm band pass and 2.10^{-3} level of rejection with a mean transmission higher than 89%.

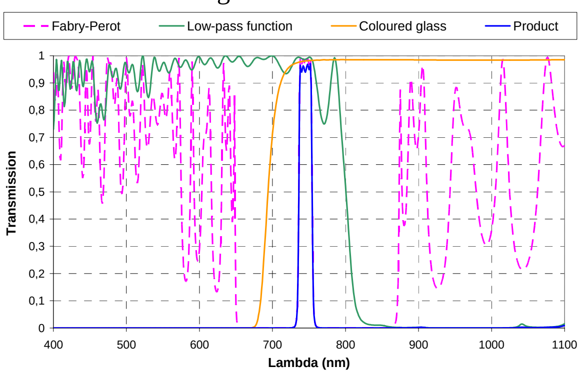

Fig. 2. Theoretical spectral responses

3.2 Uniformity optimization

The filters specifications concerning spectral bandwidth and wavelength centring require an accurate monitoring of deposited thicknesses and a good master of thickness uniformity within the deposition chamber. Indeed, a difference of uniformity between two separate locations on the samples-holder leads to a spectral shift in the optical response.

A multidielectric coating is typically composed with layers of alternative high and low index materials with different thicknesses that give the filter transmittance shape. At first order, if we neglect the index dispersion, a change of each layer thickness by the same factor leads to a similar spectral response but spectrally shifted.

Substrates are generally mounted on a rotating substrates-holder and the distance with the target material moves in a periodic way. The quantity of deposited material maybe considered as nearly proportional to the square of the substrate-target distance. So, as the substrates have generally a flat shape, all the points of the filter cannot be strictly at the same distance from the source and then will exhibit non-uniformity. Such non-uniformity is generally quite small and one will only obtain a shifted spectral response from one point of the filter to another. It is thus necessary to predict and control the uniformity curve in the deposition chamber.

Spectral measurements of the filter along X and Y axis permit to obtain a cartography of the central filter wavelength variations (“Fig.3.”) and to adjust the substrates position inside the chamber in order to minimize the non-uniformity.

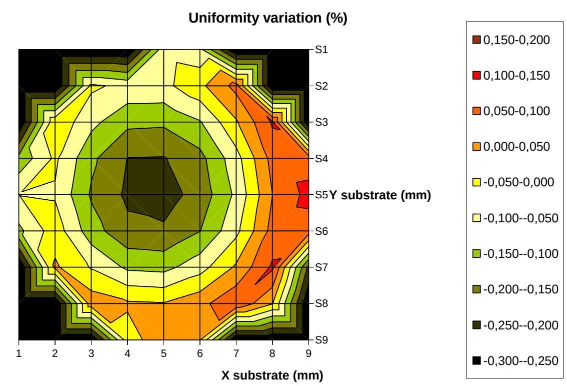

Fig. 3. Uniformity cartography

In the case presented above, a ± 0.17% non-uniformity over 40mm diameter is obtained that leads for example to a spectral shift of about 2.5nm at 740nm wavelength.

3.3 Coating deposition

The technology used for filters manufacturing is Dual Ion Beam Sputtering (D.I.B.S.). This technology involves one ion beam gun for sputtering a target and a second one for compacting the sputtered material. This technology leads to very dense layers and high quality coatings and is intensively used for manufacturing very narrow band filters for optical telecommunication market. The density of deposed layer is very close to the bulk material and enables the filter to be nearly insensitive to environmental parameters [4].

It enables to have very smooth interfaces too, that lead to very low scattering levels [5]. This is a privilegied technology for space applications as there is no measurable spectral shift between air and vacuum and versus temperature variations, and as coatings show very low ageing effects. The second ion beam is also used for cleaning the substrate before coating, leading to better adhesion.

The overall process is very stable and enables, together with an in-situ optical monitoring system carried out directly on one of the final parts to reach the required performances on all the samples.

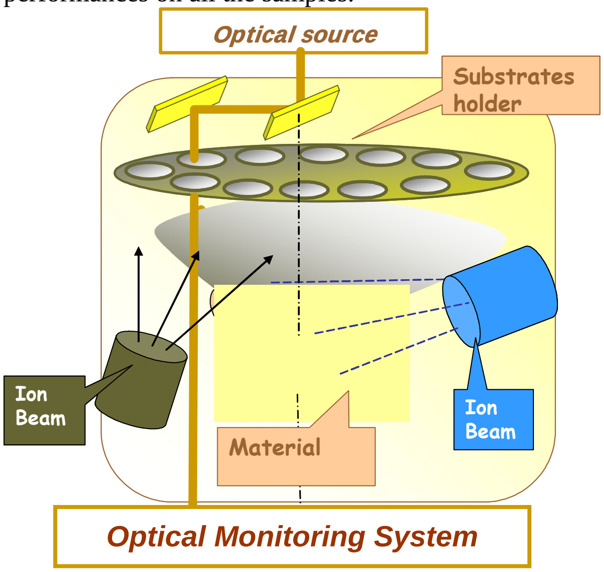

Fig. 4. Dual Ion Beam Sputtering principle

On "Fig.5.", a comparison between theoretical spectral responses and filter measurements after deposition shows a good agreement in coating manufacturing with DIBS technology and in-situ real-time optical monitoring.

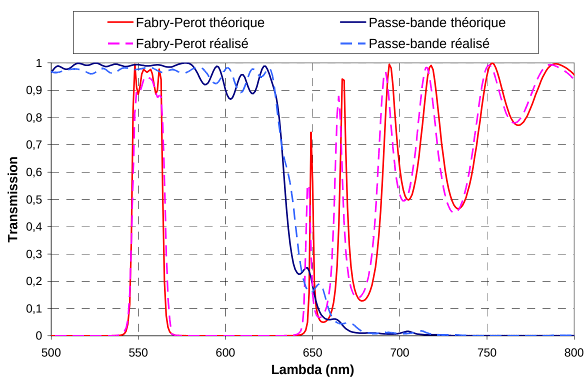

Fig. 5. Comparison between theoretical and measured spectral responses

Fig. 6. A 49mm diameter double face coated filter

For each channel of the filters wheel in the Ocean Imager instrument, three filters have been manufactured together at all stages: a Flight Model, a Spare Model and a Qualification Model.

4. SPACE QUALIFICATION

Qualification tests have been realized on representative samples to validate processes and materials used.

We present here the results of Radiations, Air/Vacuum and Environmental tests.

4.1 <u>Gamma radiation</u>

The transmission degradation under Gamma radiations has been measured for each type of uncoated substrate involved.

On the following figure ("Fig.7."), we present the spectral responses measured on uncoated 3mm-thick coloured glasses substrates before and after irradiation tests. We can notice transmission degradation after 100krads dose which corresponds to cumulated End-of-Life dose.

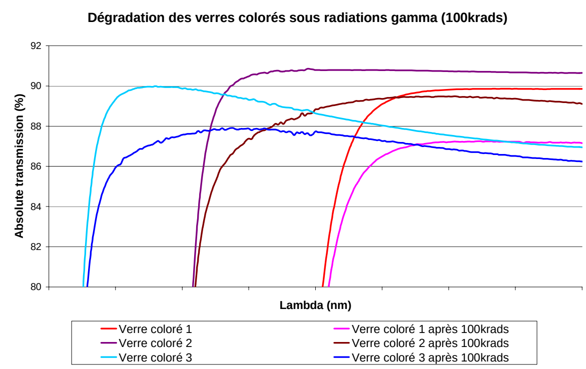

Fig. 7. Degradation of coloured glasses under Gamma radiations

4.2 <u>Air/Vacuum spectral measurement</u>

Spectral measurements in transmission have been realized under normal atmosphere and in vacuum, with the following parameters:

- spectral measurement with an optical system coupled with a vacuum chamber
- vacuum of 10-5 mbar
- in-situ transmittance measurements in the channel band at 0° incidence
- temperature of the sample at 25°C

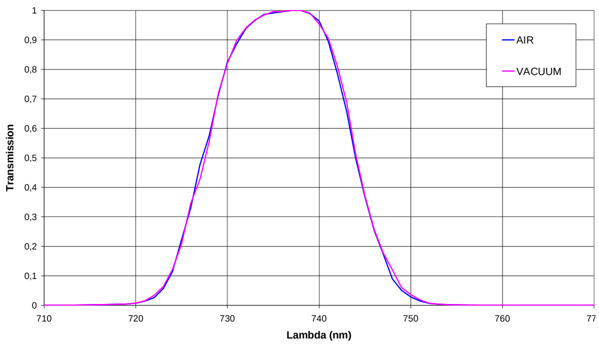

Fig. 8. Spectral measurement under normal atmosphere and in vacuum

On the graph "Fig.8.", it is shown that the spectral shift of DIBS filters between air and vacuum is very low, and less than the measurement precision (0.5nm).

4.3 <u>Humidity and Thermal cycling</u>

Environmental tests have been performed according to the following list :

- Thermal cycling qualification: 20 cycles -40 / +60 °C with 3°/mn slope and 2 hours min/max stage at ambient pressure
- Humidity qualification: 48 hours exposure to 50°C and 95% humidity.
- Thermal vacuum qualification realized after humidity: 5 cycles -20/+60 °C with 3°/mn slope and 2 hours min/max stage under vacuum.

Visual inspection and spectral measurements have been performed on each component before and after the tests that showed no physical degradation and no variation in the spectral responses.

Moreover such tests have been successfully performed on Qualification Models including gluing in a blackened barrel.

5. CONCLUSION

In conclusion, we have shown that complex optical specifications can be achieved with the help of multidielectric coatings with a very good agreement between theory and experiment.
Moreover, Dual Ion Beam Sputtering technology has been demonstrated to be particularly well adapted to the production of very stable optical functions, compatible with severe environment. In the scope of COMS-1 Ocean Imager, we have successfully produced and qualified eight narrow band filters that are currently mounted in the Instrument whose tests are in progress and that will be launched in 2009.

6. REFERENCES

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