Cryogenic System for Optical Characterization at Low Temperature

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Cryogenic temperature cycles are a useful technique to investigate the behaviour of optics operating in rapid temperature variation environment. The reflectance and transmittance of GaAs material and Fabry-Perot narrow band filter were on-line measured for temperature values between 315K and 80K. The cryogenic experimental set-up was developed in ENEA laboratories.

1 Introduction

Optics submitted to rapid thermal cycling can decrease their lifetime. In particular, for components operating in the hostile environment the synergistic combination of different agents can enhance detrimental effects.

In this paper is described the cryogenic set-up developed in ENEA to measure the transmittance and the reflectance of optical coatings at low temperature. The measurement procedure and some preliminary results are reported.

2 Cryogenic System Setup

Measurement setup is based on a cryostat “Oxford mod. CF1204”. The temperature of the samples can vary in the range from 30K to 315K with a heating or cooling rate that can be defined by the user. Depending on the required cryogenic temperature, nitrogen or helium can be used as coolant. Before starting the measurements the cryostat sample chamber is evacuated by a turbomolecular pump group. In the transmittance configuration an optical fibre is connected by a collimating lens to the cryostat window whereas a second one collects the transmitted signal to the spectrometer to be analyzed. In reflectance configuration, the incident light is directed towards the sample (angle of incidence 8°) and collected by an integrating sphere (output fibre port at 90° from the normal to the sample surface).

In Tab. 1 are reported the characteristics of the cryogenic system described in this paper.

Wavelength Range	230-1000 nm
Temperature Range	30-315 K
Typical Heating/Cooling Rate	1-10 K/min
Temperature Controller Accuracy	± 0.1 K
Vacuum	$1x10^{-4}$ mbar

Tab. 1 *Parameters of the Cryogenic set-up.*

3 Thermal Cycling Tests

During the thermal cycling tests, the samples are cooled from 315K to 80K. For all cycles, optical response were on-line monitored during the temperature variation. Typical duration of the cryogenic tests vary from 4 to 24 hours depending on the requirements of the specifications.

4 Experimental Results

The behaviour of different kind of samples (GaAs substrate and multilayer optical coating) were tested during thermal cycles. In Fig. 1 are displayed the reflectance measurements for temperature varying from 315K to 85K. Such a behaviour is in agreement with the data reported in literature [1].

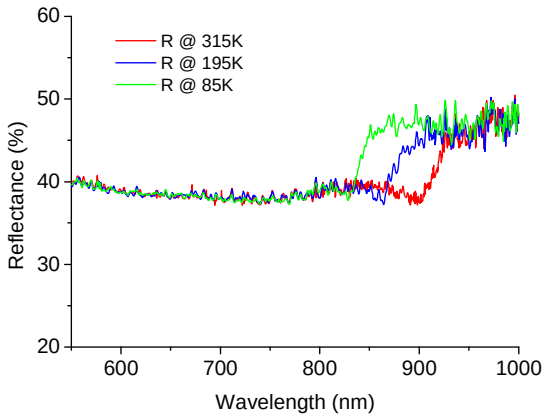

Fig. 1 *Thermal cycle results on GaAs sample.*

In the transmittance configuration, Fabry-Perot filters has been investigated in thermal cycling test measuring the on-line transmittance to check the eventual wavelength peak shift. The optical response of a 12-layer filter on fused silica substrate is reported in Fig. 2. Wavelength peak shift of

0.49nm towards higher wavelengths was observed together with a transmittance reduction of 4.72%.

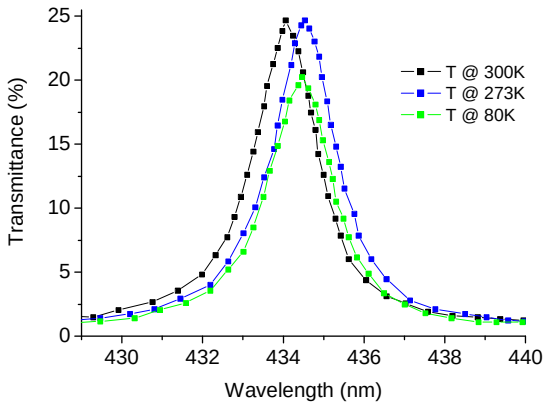

Fig. 2 *Thermal cycle results on a 12-layer Fabry-Perot filter.*

The shift of the wavelength peak for a second FP centred at 452 nm, is shown in Fig. 3. As for the sample of Fig. 2, the shift of the transmittance peak happens for temperature values in between 300K and 273K, afterwards the peak position remains at the same wavelength within the experimental errors.

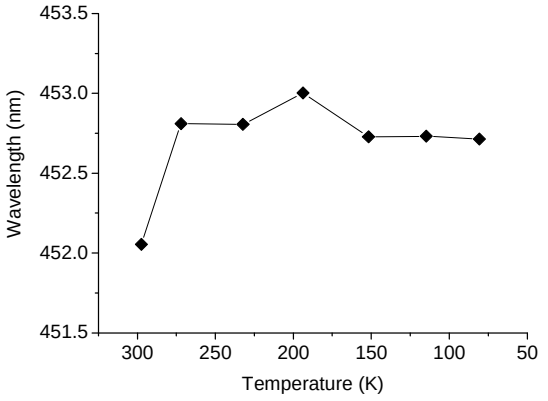

Fig. 3 *12-layer filter peak shift during cryogenic cycle.*

5 Conclusions

Transmittance and reflectance behaviour of optical materials at cryogenic temperature are not easy to find in literature. In some applications (Space and Heart hostile environment) the lifetime and the performances of the optical components can be influenced by rapid temperature variations.

The cryogenic experimental set-up developed in ENEA, is used to simulate the operational environment conditions and test the on-line behaviour of optical response during the vacuum thermal cycles.

The reflectance of a GaAs substrate measured in the wavelength range from 550nm to 1000nm shifts towards greater wavelengths as the temperature vary from 315K to 85K. Similar shift is noticed measuring the transmittance wavelength peak of two Fabry-Perot narrow band filters at temperature values between 300K and 80K.

References

[1] F.K. Reinhart, J. of Applied Phys. 97:123534 (2005).