EVALUATION OF VACUUM TRANSFER VESSEL PERFORMANCE TO CONSTRUCT CLUSTER TYPE IN-SITU TEST FACILITIES NETWORK

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ABSTRACT

This study was carried out in an attempt to assess the performance of a vacuum transfer vessel system designed for in-situ ground simulation test. The vacuum transfer vessel is used for transportation between various irradiation test facilities, measurement and analysis equipment, etc., keeping irradiated test sample in vacuum condition referred as ”in situ” conditions. The need of performing the test ”in-situ” comes from the annealing phenomenon that occurs if a polymer sample is exposed to air after irradiation in a vacuum. Consequently, in order to have an accurate representation of the degradation phenomena occurring during space flight, it is necessary to keep the samples in a vacuum during the whole on ground-simulation test and degradation assessment processes. The system is composed of a storage vacuum chamber with remote manipulator for insertion and extraction of a polymer sample into/from the various facilities and equipment, a window to measure the optical properties of irradiated sample using a spectrophotometer, and a portable vacuum pump. It has been found that the vacuum transfer vessel can sustain a vacuum pressure of under 10^{-3}Pa for at least 5 days with a transport. Additionally, the difference between the measurement before and after air exposure of irradiated samples will be evaluated.

***Key words**: Polymer, vacuum transfer, in situ, charged particles radiation, recovery, annealing effect*

INTRODUCTION

Polymeric materials are an important part of the design of a spacecraft as they can have highly varied applications from structural parts to adhesives but also for thermal control systems, thus requiring different specific properties. One of the challenges associated with using such materials is to create a material able to withstand the harsh space environment while keeping said properties [1]. The different regions of space indeed form an environment prone to material degradation with high levels of ultra-violet (UV) and infra-red (IR) radiations as well as ionising charged particles emanating from the solar wind, solar flare, trapped radiation, etc. Spacecrafts are also subjected to high vacuum, thermal cycling and for the lower orbits atomic oxygen (AO). In this context, estimating the resistance of polymers to these conditions is crucial to choose the right material for a certain application and for developing new materials. To measure the degradation of materials there are two different paradigms which are on-orbit testing and on-ground testing [2]. Both present advantages and inconveniences and the latter is the subject of this study. To properly simulate the space environment is a major issue in this sense as the multiple degradation factors are difficult to produce at the same time and in a single place. Some studies suggest the use of a single complex facility [3] including the measurement system but building such facility requires a lot of investment and is rather difficult to adapt to every situations. In an optic of solving these issues, a device referred to as the Vacuum Transport Vessel (VTV) has been designed. This is another approach to *in-situ* measurement that is not limited to a single facility but rather a network of different

resources put in common and shared among the different institutions. The objectives of the VTV are to keep a polymer film sample in a vacuum when transferring it from a part of test facility to another while facilitating the insertion and pick up of said sample in the diverse chambers and measurement instruments. The continuous vacuum conditions kept during the processing of the sample are referred to as *in-situ* conditions as the vacuum pressure to which the sample is subjected is kept under 10^{-3}Pa from the first exposure until measurements of its optical properties. Maintaining the vacuum is crucial as it is known that certain polymer tend to recover from the radiation induced coloration when exposed to air [4] thus making the measurement inaccurate for space conditions. This study is focused on the evaluation of the VTV characteristics for its use within the framework of this new approach to *in-situ* measurements.

1. DESCRIPTION OF THE IN-SITU FACILITIES

1.1. Description of the VTV

The device is composed of a magnetic driven linear/ rotary feedthrough allowing an easy insertion and pick up of a custom-made sample holder in the diverse chambers and apparatus. The system is suited with a gate valve which can easily be connected with a vacuum clamp to a vacuum chamber's port. The optical window authorises spectrophotometer measurements to assess the optical properties of the samples while under vacuum conditions. The vacuum is built using a turbo-molecular pump up to a rough 10^{-4}Pa and can be lowered up to 4.7×10^{-6}Pa with the built-in ion pump. The latter is doubled with a getter unit to sustain the vacuum when the pump is not in operation.

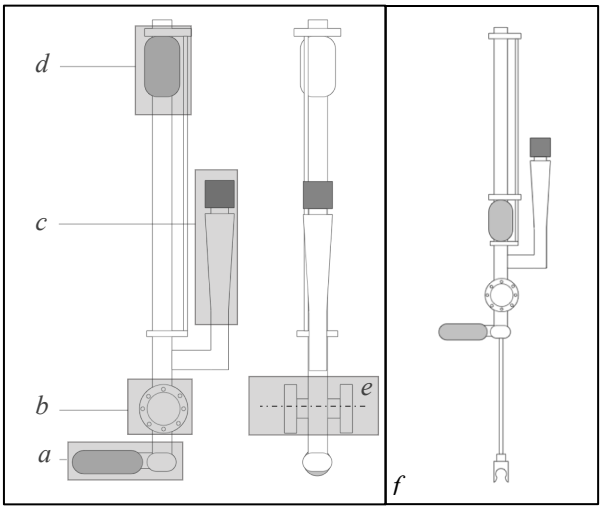

Fig. 1 Diagram of the VTV showing: a) the gate valve b) optical window c) getter unit/ion pump d) magnetic feedthrough with rotation guide e) is the path of the measuring beam in the spectrophotometer f) the system with extended feedthrough arm and sample holder fork.

The samples are attached to a sample holder which is then mounted on a fork on the end of the feedthrough's rod.

1.2. Description of the insertion and pick up mechanism

The insertion and pick up is done using a system of hook to hold the sample holder in place during the exposure. The release is done by sliding the sample holder upward and pulling it back in the VTV.

2. EXPERIMENTAL RESULTS

Several aspects of the VTV were evaluated, namely its ability to protect the sample from exposure to air, the quality of the vacuum achieved and the feasibility of the spectrophotometer measurement. These are the critical characteristics required for its use as a transportation and measurement device between the different clusters in the in-situ test facilities network.

2.1.Spectra measurements for optical window and Kapton-H sample

To evaluate the influence of the device on the measurement of optical properties (transmittance) of Kapton-H film, we measured the spectra with and without sample in a vacuum. We then compared them to the spectrum of the Kapton alone (in air).

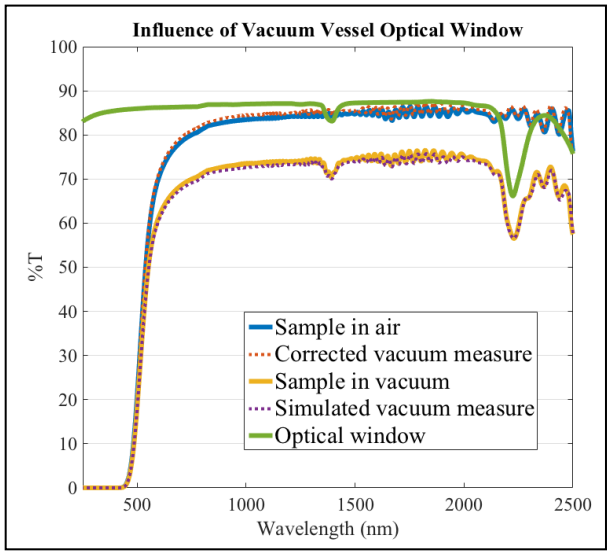

Fig 2 Spectra of transmittance for optical window with and without sample in a vacuum and the calculated corrections. The correction of the spectrum in a vacuum fits the spectrum of the sample alone showing that the correction allows us to determine the spectrum of the pristine sample without interference from the optical window. Data were smoothed 50 times using the MATLAB smooth function.

By multiplying the spectrum of the empty vessel with the result of the sample alone we obtain a rather accurate emulation of the sample in the VTV. On the other hand, dividing by the empty vessel spectrum allows us to correct the peaks caused by the optical window. This premise warrants the presentation of corrected results for the rest of this present paper to better represent the actual properties of the studied material.

2.2.Vacuum quality and sustainability

In order to check the quality of the vacuum achievable with the present system and the durability of said vacuum, a series of test were run. After a rough pumping to about 10^{-5}Pa using an external turbo-molecular pump we monitored through the built-in ion pump the pressure achieved while pumping for a week. The system can build up to 10^{-6}Pa in under 3 days and the lowest pressure registered is 4.7×10^{-6}Pa after a week of pumping.

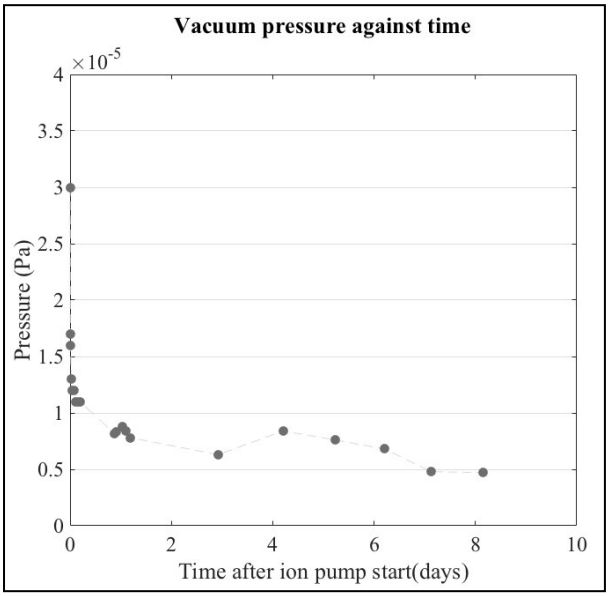

Fig 3 Pressure monitoring of the VTV.

The vacuum sustainability was assessed when the proton irradiation was carried out. After irradiation the sample was retrieved using the VTV and put in a vacuum (around 10^{-6}Pa), after 5 days and a transport the pressure was under 10^{-4}Pa.

2.3.Proton exposure and annealing effect

Proton beam radiation exposure was carried out at an energy of 2MeV and an intensity of 0.35µA applied on a surface of 56mm×49mm for one hour resulting in a dose of just under 10MGy using the Tandem accelerator at the National Institute of Advanced Industrial Science and Technology (AIST). Particular precautions were taken for the dose rate in order to not exceed a sample temperature of 50°C as excessive temperature rise can promote recuperation of the radiation induced coloration[5].

After irradiation the sample was retrieved and shipped back to Kyushu Institute of Technology in order to analyse it. The transmittance spectrum was measured through the optical window of the VTV, first with the gate valve still sealed and then sequentially after opening the valve. The most representative spectra are shown in **fig 4**. It is clear that quickly after exposure to air the radiation induced coloration fades and seems to be completely annealed after about an hour. To better visualise the two types of degradation, the difference between the pristine sample and the different time of air exposure was calculated and plotted in **fig 5**. As mentioned in an earlier study[5], there are indeed two types of degradation occurring with charged particles exposure : non-annealable and annealable. This figure shows that even after over 10 hours of air exposure there is still an increase of absorbance around 550nm, but more importantly, the great difference without air exposure has almost completely disappeared. This shows that without protecting the sample from air exposure most of the degradation cannot be measured hence underlining the importance of *in-situ* measurement.

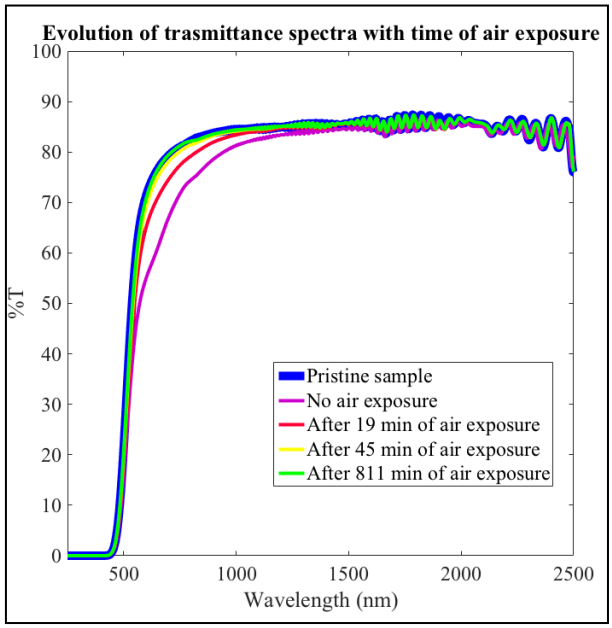

Fig 4 Evolution of transmittance after air exposure. Data were smoothed.

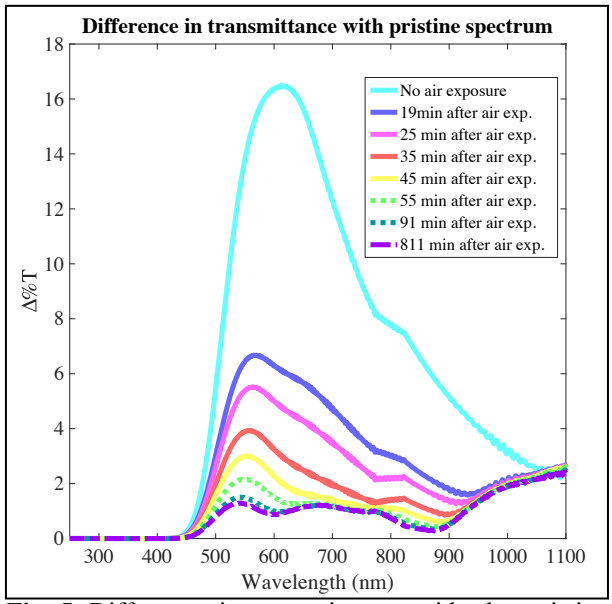

Fig 5 Difference in transmittance with the pristine sample spectrum before and after air exposure. Data were smoothed.

CONCLUSION

The development of an *in-situ* test facilities network constitutes an alternative to bigger and more complex centres such as the SEMIRAMIS facility at ONERA and can prove cheaper and more flexible for different purposes. Its key element, the VTV, has shown its compliance with the basic requirements for its intent. It was able to hold a good vacuum for over 5 days and allows the measurement of transmittance spectra through its optical window. In addition, sample insertion and pick up are fast and easy and it can be fitted with a portable battery to extend the duration of the vacuum. This system is still under development and needs to be standardised in odder to make it more versatile and thus more efficient.

ACKNOWLEDGEMENTS

Part of this work was supported by the Coordination Funds for Promoting Aerospace Utilization from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

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