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The analysis for the effect of oil molecular contamination on optical system

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ABSTRACT

Some optical load on the spacecraft suffer from the space pollution easily, eventually, the whole system may not work properly. The paper is based on the above-mentioned problem, using the common space oil molecular as the material of the contamination to conduct the experimental study, and draw the conclusions about oil molecular contamination effects on the system optical transmittance accordingly. According to the experimental results can be found that thin film interference will occur in the surface of oil molecular contamination. Transmittance of the entire system would have been affected. Then the paper conducted a correlation analysis demonstrated of the thin film interference situation of oil molecular. According to the results of this study, when the maximum detection wavelength of an optical transmission of the test piece is known, at this time they can be introduced the mass of the oil film contamination.

1. Introduction

With the development of science and technology, many countries have made progress in aerospace and other military affairs [1–6]. Including the development of space technology such as satellites for countries to increase military strength provides an important guarantee. Space optical systems are the important parts of space technology. Therefore, optical systems directly affect the performance of the whole systems. In recent years, the space optical contamination has been researched at home and abroad [7–10]. Including Midcourse Space Experiment MSX, it has installed pollution control system. Our country also began to focus on space optical systems of spacecraft contamination effects [11,12].

Space optical systems are the important parts of spectral imaging in space communications and detections. The degree of space contamination has an influence on spectral imaging quality of space optical systems [13]. Currently, a large number of space passive-contamination will cause serious pollution for optical system, increases stray light, reduces optical transmittance and has an effect on detection sensitivity of the entire system. Among the space contamination, oil, atomic oxygen erosion products such as gas molecules in this class of molecules spacecraft contaminant is the main source of common contamination. This paper is focused on the impact of oil molecular contamination on space optical systems, and use the thin-film optics mirror contaminated to analyze the best detection wavelength, and finally made a number of proposed measures.

2. The research of space contamination

2.1. Classification of space contamination

In general, the space contamination is divided into two main parts [14–16]:

By the propulsion system, attitude control system ejected propellant impurities, incomplete combustion of the propellant, oxidants such as particulate matter deposited on the surface of spacecraft cause pollution. It is known as particle contamination.

The high vacuum out gassing products of spacecraft materials, such as atomic oxygen erosion product gas molecules deposited on the surface in the form of spacecraft contamination, called molecular contamination.

2.2. The research and development of space contamination

2.2.1. Long-term exposure test of LDEF

Long Duration Exposure Facility (LDEF) is the United States during 1984–1990 launched in specialized research LEO environmental the test aircraft, carrying with a total of 57 terms more than 10,000 pieces of material samples, including space atomic

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oxygen erodes the surface material, satellite gaseous contamination and other test of contamination effects. After flight test found that due to contamination, LDEF test carries the solar cell Maximum Power Output has declined. Furthermore, LDEF itself also has a large contamination on external, emerges brown, opaque entirely, a thickness of several hundred nanometers to several hundred micrometers. Research shows that contaminated layer is composite film of silicone and hydrocarbon, mainly composed of carbon from 72% to 74%, 15% to 23% oxygen, 2% to 5% of silicon. According to the analysis, such as the effects of radiation in the ultraviolet, the contaminated layer intermolecular cross linked, generated nonvolatile molecules bonded to the surface. In addition, the darkening effect of UV radiation, make the color of the film contamination deepen, the sun absorption rate increases, which would impact proper work of optics, thermal control coatings, solar panels and other components. Since the large absorption rate of dark contamination will generate localized heat load, but also may result in overheating for the part of the spacecraft surface [17].

2.2.2. MISSE, the exposure test on the international space station

Materials International Space Station Experiments is a series of flight tests, using passive exposure chamber (PECs) make the material exposed to the real outside International Space Station (ISS) space environment. MISSE for a total of seven tests, MISSE 1–4 are passive tests, mainly on the material's atomic oxygen effect, effect of solar radiation together with atomic oxygen and solar radiation's concord effects, etc. [18,19].

2.2.3. The optical properties monitor of Mir orbital station (OPM)

NASA's Marshall Space Flight Center (MSFC) in order to study the long-term effects of the material in space environment, in 1997 in the Russian Mir space station is equipped with optical properties of monitoring instruments (OPM). The instrument can also monitor the environmental effects caused by inducing material outlet molecular contamination [20,21].

2.2.4. Midcourse Space Experiment MSX

Midcourse Space Experiment MSX is a pollution monitoring test satellite. It designed by America aiming at space optical systems contamination. Launched in 1996, the exploration satellites equipped with pollution monitoring instruments. Pollution monitoring instruments made an analytical test to optical molecular contamination and particle contamination encountered with satellites in space [22].

3. Experimental study of oil molecular contamination

3.1. Principle and experimental design

As we can see from Fig. 1, when a beam of light is incident into the surface of oil film molecular contamination, some of the light is reflected, part of the light is absorbed and the other light is transmitted. According to the law of conservation of energy,

$$\rho + \alpha + \tau = 1 \quad (1)$$

where ρ is the reflectivity, α the rate of absorption, and τ is the transmittance.

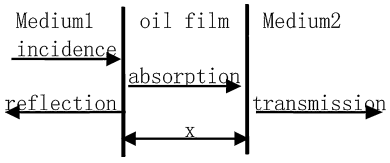

Fig. 1. The relationship of different light.

When the contaminations deposited on the surface of infrared optical system, the transmission of optical system, the transmission of optical surfaces will change. Because reflection and absorption change the results, the particulate contamination of optical systems will degrade the detection ability. We call it the optical damage. In order to analyze oil paint contaminations damage degree of the entire optical system, the experiments were tested. In the experiment, we used transmission decay factor to stand for the optical damage factor. Changes in spectral transmittance could be measured with a spectrophotometer.

To reduce the measurement error, the light transparent material mass should be used as optical lens. Depending on conditions, a polyester film was chosen to be an optical substrate in the experiment. D was defined as mass thickness, which was the mass of contamination in unit area. Due to the mass of contaminants is very small, the high precision electronic must be used to measure the mass thickness of contaminants. Mass thickness $D = (m - m_0)/S$, where m is the mass after polyester film contaminated, m_0 is not contaminated substrate's mass, S is the area of the polyester film. Experimental use of electronic analytical balance for the Denver TP-114 series, the weighing range is 0–110 g, the smallest scale is 0.1 mg. Transmittance measurements use a UV-2450 ultraviolet visible spectrophotometer.

Film molecular contaminants used in this experiment is silicone oil, the substance is less volatile, high temperature resistance, good insulation, surface tension, the metal non-corrosive, non-toxic and other characteristics, can be used as lubricants for spacecraft. The experiment produced a total of 12 samples of the substrate, including an uncontaminated substrate. After testing, the mass of the sample substrate is 0.3435 g. Then, another 11 substrates is sprayed a small amount of dimethyl silicone oil in different concentrations, to obtain final test pieces. After that, 12 contaminated samples produced were tested by a spectrophotometer each, and obtain experimental results [23].

3.2. Experimental results of data processing

According to the experimental results of the test samples can be derived the corresponding relationship among contaminants wavelength, transmittance and mass thickness contaminated. Then make the data fitting by the relationship of them, the dimensional relationship among the fitted data shown in Fig. 2:

3.3. Conclusion and analysis of the experimental data

Due to space spacecraft film contamination belongs to molecular contamination and the mass of contaminant is not too much,

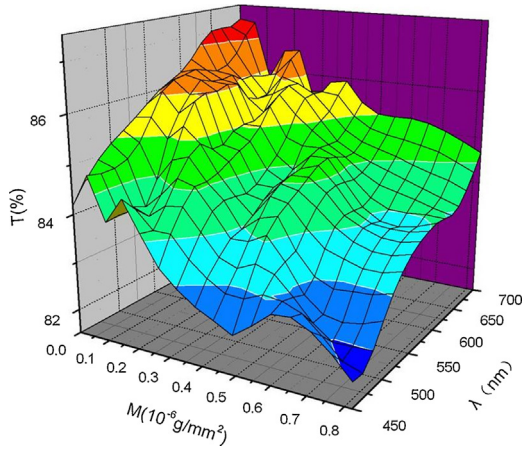

Fig. 2. Three-dimensional map of contaminated film.