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Test method of solar ultraviolet radiation effects for space non-metallic materials

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Test method of solar ultraviolet radiation effects for space non-metallic materials

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FOREWORD

This standard is proposed by China National Space Administration.

This standard is under the jurisdiction of China Astronautics Standards Institute.

In case of any doubt about the contents of English version, the Chinese original shall be considered authoritative.

Test method of solar ultraviolet radiation effects for space non-metallic materials

1 Scope

This standard specifies the test purpose and principle, facilities and instruments, test conditions, sample requirements, procedures, breakup and treatment, data processing and test report of the solar ultraviolet radiation effects test for space non-metallic materials.

This standard is applicable to the evaluation test of resistance of space non-metallic materials exposed to solar ultraviolet radiation, including thermal control coating, special glass, rubber, plastics, adhesive, film and adhesive tape, resin, fiber and composite materials and special textiles.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1

solar ultraviolet radiation

solar electromagnetic radiation in the wavelength range from 10 nm to 400 nm.

2.2

near ultraviolet radiation

solar electromagnetic radiation in the wavelength range from 200 nm to 400 nm. The near ultraviolet irradiance is defined as 118 W/m^2 at 1 AU (astronomical unit).

2.3

far ultraviolet radiation

solar electromagnetic radiation in the wavelength range from 10 nm to 200 nm. The far ultraviolet irradiance is defined as 0.110 W/m^2 at 1 AU (astronomical unit).

2.4

ultraviolet irradiance

the energy of ultraviolet irradiated upon per unit surface area within per unit time, measured in W/m^2.

2.5

accelerated factor of ultraviolet irradiance

ratio of ultraviolet irradiance between simulation and actual value at space.

2.6

solar constant

solar irradiance, at normal incidence, on a surface in free space at the earth’s mean distance from the sum of 1 AU. The value is 1353±21 W/m^2.

2.7

equivalent solar hour (ESH)

hours of solar radiation (or solar radiation of certain band) equivalent to a solar constant. It is usually short for ESH.

2.8

in-situ measurement

measurement under vacuum pre, post or during the radiation.

2.9

ex-situ measurement

measurement under non-vacuum condition and outside the radiation test facilities.

3 Test purpose and principle

Solar ultraviolet radiation generally has influence on the non-metallic materials used for space. Long-term ultraviolet radiation may lead to discoloration, cracking or degradation in the thermal, optical and mechanical properties of materials. The purpose of this test is to evaluate the resistance of space non-metallic materials exposed to solar ultraviolet radiation.

Test of solar ultraviolet radiation effects for materials is to expose the samples to simulated solar ultraviolet radiation environment which generated by a ground solar ultraviolet radiation facilities. Observe, measure and analyze the change of performances such as appearance, micro-feature, optical properties of samples pre and post exposure test.

4 Facilities and instruments

4.1 General requirements

Test facilities and instruments shall be inspected by the metrological service to be qualified and used within the period of validity.

4.2 Test facilities

4.2.1 Vacuum system

Vacuum system shall meet the following requirements:

a) Vacuum shall be less than 1.0×10^{-3}Pa.

b) Ultraviolet irradiation window shall avoid contamination.

c) Pumping shall adopt oil-free system.

d) Metal-metal or metal-glass seal is recommended for the sealing of vacuum chamber.

4.2.2 Near ultraviolet irradiation source

Near ultraviolet irradiation source shall meet the following requirements:

a) Near ultraviolet irradiation source shall be capable of generating ultraviolet light with wavelength ranging between 200nm~400nm. When xenon arc lamp, xenon-mercury lamp, mercury arc lamp or carbon arc lamp is used, the visible and infrared light should be filtered in the spectrum.

b) Degradation of the ultraviolet irradiance shall not exceed 30% of its initial intensity during the test.

4.2.3 Far ultraviolet irradiation source

Far ultraviolet irradiation source shall meet the following requirements:

a) Far ultraviolet irradiation source shall be capable of generating ultraviolet light with wavelength ranging between 115nm~200nm. The recommended light source is deuterium lamp, hydrogen lamp or other gas-discharge lamps.

b) Degradation of the ultraviolet irradiance shall not exceed 30% of its initial intensity during the test.

4.3 Instrument

Test instruments shall meet the following requirements:

a) Thermocouple: temperature measurement error should be less than 1℃.

b) Ultraviolet irradiance meter: measurement error should be less than 1W/m^2.

5 Test conditions

5.1 Ambient conditions

Ambient conditions are as follows:

a) Temperature: 15℃~35℃.

b) Relative humidity: 20%~80%.

c) Atmospheric pressure: 78kPa~103kPa.

5.2 Test parameters

5.2.1 Near ultraviolet radiation effects test

Test parameters are as follows:

a) Vacuum chamber pressure: less than 1.0×10^{-3}Pa.

b) Wavelength range: 200nm~400nm.

c) Ultraviolet irradiance: 118W/m^2~590W/m^2.

d) Un-uniformity of ultraviolet irradiance: no greater than ±15%.

e) Ultraviolet irradiation total time: subject to the relevant technical documents.

f) Keep the sample temperature below 50℃ to eliminate the additional influence of thermal effects.

5.2.2 Far ultraviolet radiation effects test

Test parameters are as follows:

a) Vacuum chamber pressure: less than 1.0×10^{-3}Pa.

b) Wavelength range: 115nm~200nm.

c) Ultraviolet irradiance: 0.1W/m^2~10W/m^2.

d) Un-uniformity of ultraviolet irradiance: no greater than ±20%.

e) Ultraviolet irradiation total time: subject to the relevant technical documents.

6 Safety protection

Safety protection requirements are as follows:

a) Protective approaches should be adopted to prevent the skin and eyes from ultraviolet radiation or avoid the body injury caused by explosion of light source during the test.

b) Keep the laboratory ventilating and let out ozone.

7 Sample preparations

Sample requirements are as follows:

a) Surface status of sample shall be the same as it’s used in the space.

b) Test samples shall be solid state and no less than 3 pieces with the same materials of the same batch.

c) Sample area shall be less than radiation area.

8 Test procedures

8.1 Preparations

Preparation requirements are as follows:

a) Determine the in-situ or ex-situ measurement items which should be specified in the test programs.

b) Clean the vacuum chamber and ultraviolet irradiation window using analytical pure alcohol.

c) Adjust the distance between sample and light by measuring the ultraviolet irradiance suffered from samples until it meets the requirements of test documents.

d) Take photos of samples.

8.2 Test steps

8.2.1 In-situ measurement

Measurement steps are as follows:

a) Record properties of samples according to relevant technical documents before irradiation.

b) Mount the samples and the holder at the radiation position inside the vacuum chamber.

c) Start pumping until the vacuum chamber pressure reaches the value specified in 5.2.1a).

d) Turn on the in-situ measurement device to measure the sample properties and make records.

e) Turn on the ultraviolet light source, adjust facility parameters based on the test requirements and commence the radiation after the requirements are met.

f) Record ultraviolet irradiance, irradiance time, sample temperature and pressure of vacuum chamber periodically.

g) Measure the sample properties using in-situ measurement device according to test program.

h) End test when ultraviolet irradiance total time reaches the requirements of technical documents.

i) Shut off the vacuum valves and vent. Open the vacuum chamber when pressure restores to atmospheric pressure.

j) Take out the sample, take photos and make records, conduct other properties tests and make

records according to relevant technical documents.

8.2.2 Ex-situ measurement

Measurement steps are as follows:

a) Record properties of samples before irradiation according to relevant technical documents.

b) Mount the samples and the holder at the radiation position inside the vacuum chamber.

c) Start pumping until the vacuum chamber pressure reaches the value specified in 5.2.1a).

d) Turn on the ultraviolet light source, adjust facility parameters based on the test requirements and commence the radiation after the requirements are met.

e) Record ultraviolet irradiance, irradiance time, sample temperature and pressure of vacuum chamber periodically.

f) End test when setting ultraviolet irradiance time reaches the requirements of technical documents.

g) Shut off the vacuum valves and vent. Open the vacuum chamber when pressure restores to atmospheric pressure.

h) Take out the sample, take photos and make records, conduct other properties tests and make records according to relevant technical documents.

i) Repeat steps 8.2.2b)~8.2.2h) until tests of all test points are completed.

9 Unexpected breakup and treatment

In case of facility failure or other accidents during the test, suspend the test promptly and take the following measures:

a) If test breakup leads to no significant vacuum change, continue the test after troubleshooting.

b) If test breakup leads to vacuum change and expose the samples to the atmosphere, stop the test.

10 Test data processing

Properties to be measured are different. An example of thermal control coating data processing requirements is as following.

a) Relative change of solar absorptance before and after the ultraviolet irradiation of sample is calculated according to the formula (1).

$$\frac{\Delta\alpha_s}{\alpha_{s0}} = \frac{\alpha_{s1} - \alpha_{s0}}{\alpha_{s0}} \times 100\% \quad \text{..... (1)}$$

Wherein:

$\frac{\Delta\alpha_s}{\alpha_{s0}}$ ——Change of solar absorptance before and after the ultraviolet irradiation of sample.

α_{s0} ——Solar absorptance before the ultraviolet irradiation of sample.

α_{s1} ——Solar absorptance after the ultraviolet irradiation of sample.

b) Relative change of emissivity before and after the ultraviolet irradiation of sample is calculated according to the formula (2).

$$\frac{\Delta\varepsilon}{\varepsilon_0} = \frac{\varepsilon_1 - \varepsilon_0}{\varepsilon_0} \times 100\% \quad \text{..... (2)}$$

Wherein:

$\frac{\Delta\varepsilon}{\varepsilon_0}$ ——Change of emissivity before and after the ultraviolet irradiation of sample.

ε_0 ——Emissivity before the ultraviolet irradiation of sample.

ε_1 ——Emissivity after the ultraviolet irradiation of sample.

11 Test report

Test report shall include the following contents:

a) Test purpose, principle, date, facilities and instruments, and other related information.

b) Test conditions: vacuum, temperature, ultraviolet wavelength, ultraviolet irradiance and ultraviolet irradiation dose (ESH).

c) Test instruments and results.

d) Test unexpected breakup and treatment.

e) Test photos, data and curves.

f) Test conclusion.

g) Testers, auditors and test date.