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Test method of atomic oxygen effects for spacecraft materials

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Test method of atomic oxygen effects for spacecraft 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 atomic oxygen effects for spacecraft materials

1 Scope

This standard specifies test facilities and instruments, test conditions, samples preparation and requirements, procedures, data processing and test report of atomic oxygen effects test for spacecraft materials.

This standard is applicable to the evaluation for atomic oxygen effects of spacecraft materials.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

GB 10436-1989 Hygienic standard for microwave radiation in the work environment

3 Terms and definitions

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

3.1

atomic oxygen flux

number of atomic oxygen incident upon per unit surface area within per unit time.

Note: the unit is atoms/ (cm^2·s).

3.2

atomic oxygen (accumulated) fluence

total number of atomic oxygen incident upon the unit surface area.

Note: the unit is atoms/cm^2.

3.3

atomic oxygen erosion yield

change to volume caused by impact of each atomic oxygen on material surface.

Note: the unit is cm^3/atom.

3.4

thickness loss

change to thickness of material caused by atomic oxygen effect.

Note: the unit is cm.

3.5

witness samples

material samples used for witnessing atomic oxygen flux.

3.6

test samples

material samples used for atomic oxygen test.

3.7

control samples

the same material samples as the test samples that are placed on the back of test samples during the test and free from atomic oxygen.

3.8

incidence angle

angle between incoming atomic oxygen beam and surface normal of materials.

4 Test purpose and principle

Atomic oxygen is the dominant species in Low Earth Orbit at altitude ranging 200-700 km, and have a high velocity relative with spacecraft– the atomic oxygen carries about 5.0eV kinetic energy. Spacecraft materials are exposed to a flux of highly reactive atomic oxygen, which can lead to erosion effects.

Test of atomic oxygen effects for materials is to expose the samples to simulated atomic oxygen environment generated by ground atomic oxygen facilities. Observe, measure and analyze the change of material's performances such as appearance, micro-feature, mass of samples pre and post exposure test, calculate atomic oxygen erosion yield and thickness loss etc.

5 General requirements

5.1 Test facilities

Requirements for test facilities are as follows:

a) Atomic oxygen energy: ~5.0eV.

b) Atomic oxygen flux: 10^{14}atoms/ (cm^2·s) ~10^{16}atoms/ (cm^2·s).

c) Un-uniformity of atomic oxygen flux: no greater than ±10%.

d) Incidence angle of atomic oxygen beam: no greater than ±10°.

e) Base pressure (without atomic oxygen beam): less than 1×10^{-3} Pa.

5.2 Instrument

Requirements for test instruments are as follows:

a) Gas flowmeter: control accuracy 0.1SCCM.

b) Balance accuracy: less than 0.1mg.

c) Temperature measurement accuracy of thermocouple: less than 1℃.

5.3 Laboratory condition

Laboratory shall meet the following conditions:

a) Temperature: 15℃~35℃.

b) Relative humidity: 20%~80%.

c) Atmospheric pressure: 78kPa~103kPa.

d) Cleanliness class of test bench: 100000 level.

5.4 Safety protection

Operators shall wear radiation proofing overalls and use other protective devices, as there may be microwave leakage or other radiations during operation of atomic oxygen facilities.

The laboratory shall be equipped with dedicated microwave leak detector to monitor the operating process. Microwave leakage amount of work area shall not exceed the value specified in GB 10436-1989. In case of excessive microwave leakage amount, the microwave source shall be immediately shut off, and the microwave transmission system shall be checked and inspected.

6 Sample preparation and requirements

6.1 Witness samples

Requirements of witness samples are as follows:

a) Use Kapton H or Kapton HN as the witness samples. Its atomic oxygen erosion yield is $3.00\times10^{-24}cm^3$/atom.

b) Witness samples are generally 0.05mm thick. Diameter of round samples shall not be less than 5mm. Side length of square samples shall not be less than 5mm.

c) Time for the witness samples exposed to atomic oxygen is no shorter than 60 minutes. When atomic oxygen fluence exceeds 2×10^{21} atoms/cm^2, Kapton H is used as the witness sample.

6.2 Test samples

Requirements of test samples are as follows:

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

b) For atomic oxygen erosion yield test, test samples shall be round pieces with diameter no less than 5mm or square pieces with length and width no less than 5mm respectively.

c) For properties measure, the dimension of test samples shall be made according to relative technical documents, but the size of test samples shall not exceed the effective radiating area of atomic oxygen beam.

d) Surface status of the test samples shall be the same as those used in space. Samples shall be cleaned according to relative technical documents.

6.3 Control samples

Both control samples and test samples shall be the same batch of materials and made according to the requirements in 6.2.

6.4 Samples preservation

Samples shall be placed in the desiccator for 24 hours. Non-metallic material samples shall be preserved under the pressure lower than 2×10^{-1}Pa for 48 hours.

7 Test procedures

7.1 Preparations

7.1.1 Facility inspection

Facility inspection as follows:

a) Clean test facilities use analytical pure alcohol.

b) Check if test facilities work properly.

7.1.2 Witness of atomic oxygen flux

The witness samples are used to witness the atomic oxygen flux of test facilities. See 7.2 for witness steps (regarding witness samples as test samples).

7.1.3 Determination of atomic oxygen fluence

Determination of the atomic oxygen fluence shall be specified by relevant technical documents.

7.2 Test steps

Test steps are as follows:

a) Take the test samples and control samples out of the desiccator and weigh its mass.Mass of test samples and control samples is recorded as m_0 and m_{c0} respectively.

b) Place the test samples and control samples in the sample holder together. Control samples shall be placed at the back of test samples and free from atomic oxygen exposure. Mask the part that not needed to be exposed with aluminum foil. Bond thermocouple to the back of samples, lead the signal wire out of vacuum chamber and connect with thermocouple to monitor the samples' temperature.

c) Start pumping until the pressure is less than 1×10^{-3} Pa.

d) Turn on the gas flowmeter. The oxygen with purity higher than 99.9% is delivered.

e) Adjust parameters of the atomic oxygen facilities.

f) Record the starting time (t_0) when the exposure test begins. Generally, test should be conducted continuously until required atomic oxygen fluence is reached. Keep parameters stable during the test.

g) Turn off the atomic oxygen facilities and record the ending time (t_1) when atomic oxygen fluence meets the specified values.

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

i) Take the samples out of the vacuum chamber and weigh the mass of test samples (m_1) and control samples (m_{c1}) respectively within 5 minutes and make records.

j) Take photos of samples.

8 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.

9 Data processing

9.1 Calculation of atomic oxygen fluence suffered by the test samples

Atomic oxygen fluence suffered by the test samples is calculated according to formula (1).

$$F = \phi \times \Delta t \quad \text{(1)}$$

Wherein:

F——atomic oxygen fluence suffered by the test samples, atoms/cm^2.

φ——atomic oxygen flux, atoms/(cm^2·s).

Δt——duration of exposure, s.

9.2 Calculation of atomic oxygen erosion yield

Atomic oxygen erosion yield of materials is calculated according to formulae (2)~(6).

$$E_y = \frac{\Delta m}{\rho \times \phi \times \Delta t \times A} \quad \text{(2)}$$

$$\Delta m = \Delta m_1 - \Delta m_c \quad \text{(3)}$$

$$\Delta m_1 = m_0 - m_1 \quad \text{(4)}$$

$$\Delta m_c = m_{c0} - m_{c1} \quad \text{(5)}$$

$$\Delta t = t_1 - t_0 \quad \text{(6)}$$

Wherein:

Ey —erosion yield of test samples, cm^3/atom.

Δm —mass change of test samples under the action of atomic oxygen, g.

ρ——density of test samples, g/cm^3.

A——exposed area of test samples, cm^2.

Δm_1——mass change of test samples pre and post the test, g.

Δm_c ——mass change of control samples pre and post the test, g.

m_0 ——mass weighed after the test samples is taken out of desiccator, g.

m_1——mass of test samples weighed within 5 minutes after the samples is taken out of vacuum chamber, g.

m_{c0} ——mass of control samples before the test, g.

m_{cl} ——mass of control samples after the test, g.

t_1——ending time, s.

t_0——beginning time, s.

9.3 Calculation of thickness loss

Thickness loss of test samples is calculated according to formula (7).

$$\Delta X = F \times E_y \quad \text{(7)}$$

Wherein:

ΔX——thickness loss of test samples, cm.

10 Test report

Test report shall include the following contents:

a) Test introduction (test purpose and conditions).

b) Samples information (name, shape, size, quantity, treatment process etc.).

c) Test data (atomic oxygen flux, atomic oxygen fluence, samples mass and properties parameters pre and post the test).

d) Test results and analysis (calculated atomic oxygen erosion yield of materials used for spacecraft, data, curve and charts of the samples properties change).

e) Test conclusion.

f) Testers, auditors and test date.