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Space systems — Thermal control coatings for spacecraft — Atomic oxygen protective coatings on polyimide film

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document describes technical information for the selection and application of atomic oxygen protective coatings as required to confirm conformity with the requirements for the protection of polyimide film.

Satellites in low Earth orbit are bombarded by high-energy radiation particles and gas particles such as atomic oxygen (AO). In particular, AO corrodes certain materials, thereby weakening a spacecraft's exterior and potentially damaging its instruments. Polymers are significantly eroded.

Polyimide films are widely used as multilayer insulation materials on a spacecraft's exterior, which is exposed directly to the space environment. Despite these interesting properties, polyimide shows poor resistance to AO. Therefore, polyimide is often coated with an additional protective coating for resistance to AO. Such films have unique characteristics that are relevant for different applications. This document summarizes the coating properties, as well as a comparison or consideration of the pros and cons for selection.

This document provides a property map of the types of AO protective coatings available to spacecraft designers and thermal control film manufacturers. It enhances coating selection, indicates selection guidelines, and improves the reliability of spacecraft.

Requirements for coating properties and quality control are also defined, so as to eliminate defective products, improve the quality and function of films, accelerate the exchange and distribution of coating techniques, invite new providers to the market, introduce competition, and enhance international trade.

Space systems — Thermal control coatings for spacecraft — Atomic oxygen protective coatings on polyimide film

1 Scope

This document defines the general requirements for atomic oxygen (AO) protective coatings that are applied on polyimide thermal control films. It also describes the different properties of coated polyimide films such as indium tin oxide (ITO), SiO_x, germanium, and silicone, property measurement test methods, and selection guidelines.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 16378, *Space systems — Measurements of thermo-optical properties of thermal control materials*

ISO 27025:2010, *Space systems — Programme management — Quality assurance requirements*

ASTM D257, *Standard Test Methods for DC Resistance or Conductance of Insulating Materials*

ASTM E595, *Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment*

ASTM E1559, *Standard Test Method for Contamination Outgassing Characteristics of Spacecraft Materials*

ECSS-ST-Q70-02, Thermal vacuum outgassing test for the screening of space materials

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1.1
atomic oxygen
oxygen molecules separated by ultraviolet light from the sun, which are main atmospheric constituents in the range of about 200 km to 700 km

Note 1 to entry: As a spacecraft orbits the Earth at high speed, atomic oxygen can collide with the spacecraft's surface at high speed and degrade the surface material.

3.1.2
coating
continuous layer formed from a single or multiple application of a *coating material* (3.1.3) to a *substrate* (3.1.8)

[SOURCE: ISO 4618:2014, 2.50.1, modified — "continuous" has been added at the beginning.]

3.1.3
coating material
product, in liquid, paste or powder form, that, when applied to a *substrate* (3.1.8), forms a film possessing protective and/or other specific properties

Note 1 to entry: Coating materials are often applied using a chemical or plasma vapour deposition process from solid source materials. General types of AO protective *coatings* (3.1.2) are listed in Annex A.

[SOURCE: ISO 4618:2014, 2.51, modified — "layer" has been replaced by "film"; "decorative" after "protective" has been removed; the original note 1 to entry has been removed and replaced by a new one.]

3.1.4
coating process
process of applying a *coating material* (3.1.3) to a *substrate* (3.1.8), such as dipping, spraying, roller *coating* (3.1.2), and brushing

Note 1 to entry: A chemical or plasma vapour deposition process is also commonly applied.

3.1.5
emittance
emissivity
ε
$\varepsilon = M/M_b$
where

M is the radiant exitance of a thermal radiator;

M_b is the radiant exitance of a blackbody at the same temperature

Note 1 to entry: The following adjectives should be added to define the conditions (see ISO 9288):

— total: when related to the entire spectrum of thermal radiation (this designation can be considered as implicit);

— spectral or monochromatic: when related to a spectral interval centred on wavelength λ;

— hemispherical: when related to all directions along which a surface element can emit or receive radiation.

— directional: when related to the directions of propagation defined by a solid angle around the defined direction;

— normal: when related to the normal direction of propagation or incidence to the surface.

Note 2 to entry: See ISO 80000-7: 2019, item 7-30.1.

3.1.6
polyimide
generic name of a polymer that contains imide monomers

3.1.7
solar absorptance
α_s
ratio of the solar radiant flux absorbed by a material (or body) to the radiant flux of the incident radiation

[SOURCE: ISO 16378:2013, 3.12, modified — Note 1 to entry has been removed.]

3.1.8
substrate
surface to which a *coating material* (3.1.3) is applied or is to be applied

[SOURCE: ISO 16691:2014, 3.1.14]

3.1.9
witness sample
sample pieces that represent the coated product

Note 1 to entry: These samples are made in the form of flat plates using the same *coating material* (3.1.3) as used with the product, and then coated simultaneously. They are used for destructive tests and testing that requires a limited specimen size.

[SOURCE: ISO 16691:2014, 3.1.17, modified — Note 1 to entry has been updated editorially.]

3.2 Abbreviated terms

This document uses the following abbreviated terms:

AO	atomic oxygen
CVCM	collected volatile condensable materials
CVD	chemical vapor deposition
EB	electron beam
EMI	electromagnetic interference
EOL	end-of-life
ESH	equivalent solar hours
ITO	indium tin oxide
LEO	low Earth orbit
MLI	multi layer insulation
RF	radio frequency
RML	recovered mass loss
TML	total mass loss
UV	ultraviolet
VUV	vacuum ultraviolet

4 General requirements and recommendations

4.1 General

This clause defines the requirements and recommendations regarding the fundamental properties of coated film. The related data and test methods are provided to the customer for spacecraft design. Table 1 lists the general test provisions.

Table 1 — Overview of general test provisions

Tests	Requirement	Recommendation
Visual characteristics	X	
Coating thickness	X	
Thermo-optical properties	X	

Table 1 *(continued)*

Tests	Requirement	Recommendation
Thermal vacuum stability	X	
AO resistance	X	
UV resistance		X
Radiation resistance		X
Adhesion		X
Volume resistance		X
Surface resistance	X	
Secondary electron emission yield		X
Photoelectron emission yield		X
Thermal cycling		X

4.2 Visual characteristics

The coated film as received by the customer shall be smooth, continuous, free from delamination within the coating, uniform in appearance, and free from imperfections detrimental to usage of the coated film. Coated film shall be visually free from scratches, cracks, separation and any unallowable discoloration. Annex D provides the guideline to a visual inspection.

4.3 Coating thickness

The coating thickness range shall be provided. The thickness of AO protective coating shall be within the allowable range defined in the product specifications. Excessive thickness would cause cracks and/or separation.

Base film with perforations is more vulnerable due to coating failure around the holes. Coating shall be applied on the section edge of a perforation to prevent AO erosion. Annex B lists the typical values of the general coating thickness of AO protective coatings.

4.4 Thermo-optical properties

The thermo-optical properties of coated film shall be submitted. Annex B lists the typical values of the general properties of AO protective coatings.

AO, UV, and energetic particles can cause changes in thermo-optical properties. Any changes in the thermo-optical properties of coated film shall be measured when requested by project. AO protection coating shall not increase the magnitude of a change in base film properties.

4.5 Thermal vacuum stability

Effused gas from coated film under a vacuum condition shall be low. Annex B lists the typical values of the general properties of AO protective coatings.

4.6 AO resistance

AO protective coating shall guard its base film up to a spacecraft's EOL without any openings penetrating the coating layer. Erosion of the base film due to cracks, separation, degradation and erosion of AO protective coating shall not occur. Annex B lists the typical mass loss values after AO irradiation.

4.7 UV resistance

Coated film applied to the outer surface of a spacecraft is subject to strong UV rays. Thermo-optical properties are degraded by UV. The thermo-optical properties of AO protective coating should be maintained within the allowable range. Annex B lists the typical thermo-optical properties after UV irradiation.

4.8 Radiation resistance

Coated film is subject to protons and electrons. Thermo-optical properties are degraded by radiation. The thermo-optical properties of AO protective coating should be maintained within the allowable range. Annex B lists the typical thermo-optical properties after radiation exposure.

4.9 Adhesion

AO protection coating should have no peeling after the tape stripping test as defined in Clause 5.

4.10 Volume resistance

AO protective coating should not increase volume resistance of the base film.

Coated film that can have an adverse effect on spacecraft systems and hardware due to their electrical characteristics and properties shall be reviewed by EMI engineering for conformity with program specifications, and specifically approved for use on the program.

4.11 Surface resistance

Surface resistance data shall be provided to the customer. Annex B lists the surface resistance values of typical coated films.

Coated film that can have an adverse effect on spacecraft systems and hardware due to their electrical characteristics and properties shall be reviewed by EMI engineering for conformity with program specifications, and specifically approved for use on the program.

4.12 Secondary electron emission yield

Secondary electron emission yield data should be provided to the customer when requested.

4.13 Photoelectron emission yield

Secondary electron emission yield data should be provided to the customer when requested.

4.14 Thermal cycling

Coated film should function in the temperature range of -190 °C to +200 °C, unless otherwise stated in the standard for each coated film.

4.15 Repair/Retouch

When the coated film is repairable, the coating supplier shall provide the repair/retouch procedure.

4.16 Cleaning

Coated film shall be easy for cleaning. The coating supplier shall provide the cleaning procedure, including compatible cleaning agent and prohibited chemicals.