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Standard Practices for Ground Laboratory Atomic Oxygen Interaction Evaluation of Materials for Space Applications[1]

This standard is issued under the fixed designation E2089; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The intent of these practices is to define atomic oxygen exposure procedures that are intended to minimize variability in results within any specific atomic oxygen exposure facility as well as contribute to the understanding of the differences in the response of materials when tested in different facilities.

1.2 These practices are not intended to specify any particular type of atomic oxygen exposure facility but simply specify procedures that can be applied to a wide variety of facilities.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 *Definitions:*

2.1.1 *atomic oxygen erosion yield*—the volume of a material that is eroded by atomic oxygen per incident oxygen atom reported in cm^3/atom.

2.1.2 *atomic oxygen fluence*—the arrival of atomic oxygen to a surface reported in atoms/cm^2

2.1.3 *atomic oxygen flux*—the arrival rate of atomic oxygen to a surface reported in atoms·cm^{-2}·s^{-1}.

2.1.4 *effective atomic oxygen fluence*—the total arrival of atomic oxygen to a surface reported in atoms/cm^2, which would cause the observed amount of erosion if the sample was exposed in low Earth orbit.

2.1.5 *effective atomic oxygen flux*—the arrival rate of atomic oxygen to a surface reported in atoms·cm^{-2} ·s^{-1}, which would cause the observed amount of erosion if the sample was exposed in low Earth orbit.

2.1.6 *witness materials or samples*—materials or samples used to measure the effective atomic oxygen flux or fluence.

2.2 *Symbols:*

A_k	=	exposed area of the witness sample, cm^2
A_s	=	exposed area of the test sample, cm^2
E_k	=	in-space erosion yield of the witness material, cm^3/atom
E_s	=	erosion yield of the test material, cm^3/atom
f_k	=	effective flux, atoms/cm^2/s
F_k	=	effective fluence, total atoms/cm^2
ΔM_k	=	mass loss of the witness coupon, g

3. Significance and Use

3.1 These practices enable the following information to be available:

3.1.1 Material atomic oxygen erosion characteristics.

3.1.2 An atomic oxygen erosion comparison of four well-characterized polymers.

[1] These practices are under the jurisdiction of ASTM Committee E21 on Space Simulation and Applications of Space Technology and are the direct responsibility of Subcommittee E21.04 on Space Simulation Test Methods.

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3.2 The resulting data are useful to:

3.2.1 Compare the atomic oxygen durability of spacecraft materials exposed to the low Earth orbital environment.

3.2.2 Compare the atomic oxygen erosion behavior between various ground laboratory facilities.

3.2.3 Compare the atomic oxygen erosion behavior between ground laboratory facilities and in-space exposure.

3.2.4 Screen materials being considered for low Earth orbital spacecraft application. However, caution should be exercised in attempting to predict in-space behavior based on ground laboratory testing because of differences in exposure environment and synergistic effects.

4. Test Specimen

4.1 In addition to the material to be evaluated for atomic oxygen interaction, the following four standard witness materials should be exposed in the same facility using the same operating conditions and duration exposure within a factor of 3, as the test material: ~~Kapton~~Kapton(R)[2] ~~polyimide~~ H or ~~HN, TFE-fluorocarbon~~ HN polyimide, tetrafluoroethylene (TFE)-fluorocarbon fluorinated ethylene propylene (FEP), low-density polyethylene (PE), and pyrolytic graphite (PG). The atomic oxygen effective flux (in atoms·cm^{-2}·s^{-1}) and effective fluence (in atoms/cm^2) for ~~polyimide~~ Kapton H or HN polyimide should be reported along with the mass or thickness loss relative to ~~polyimide~~ Kapton H or HN polyimide for the test material, TFE-fluorocarbon FEP, PE, and PG. For atomic oxygen interaction testing at effective fluences beyond 2 × 10^{21} atoms/cm^2, ~~polyimide Kapton H should be used and not~~ Kapton H polyimide has been recommended in the past, however E. I. du Pont de Nemours and Company (DuPont (TM[2] ~~Kapton HN because Kapton HN contains atomic oxygen resistant~~)) has discontinued its manufacture. Kapton H polyimide is the preferred replacement, but Kapton HN polyimide contains atomic oxygen-resistant inorganic particles which begin to protect the underlying polyimide, thus resulting in ~~incorrect fluence prediction.~~an atomic oxygen erosion yield in low Earth orbit (2.81 × 10^{-24} cm^3/atom) that is slightly less than that of Kapton H (3.00 × 10^{-24} cm^3/atom)) (**1**)[3].

4.2 It is not necessary to test the four standard witness samples for each material exposure if previous data exists at the same exposure conditions and if the fluence for the test sample is within a factor of 3 of the standard witness exposure. When possible, the recommended standard witness polymer materials should be 0.05 mm thick and of a diameter greater than 5 mm. It is recommended that the pyrolytic graphite witness sample be 2 mm thick and of a diameter greater than 5 mm. High-fluence tests, which may erode through the full thickness of the standard polymer witness, can use the recommended thickness sample materials by stacking several layers of the polymer on top of each other.

5. Procedure

5.1 *Sample Preparation:*

5.1.1 *Cleaning:*

5.1.1.1 The samples to be evaluated for atomic oxygen interactions should be chemically representative of materials that would be used in space. Thus, the surface chemistry of the samples should not be altered by exposure to chemicals or cleaning solutions which would not be representatively used on the functional materials to be used in space.

5.1.1.2 Wiping samples or washing them may significantly alter surface chemistry and atomic oxygen protection characteristics of materials, and is therefore not recommended. However, if the typical use in space will require preflight solvent cleaning, then perform such cleaning to simulate actual surface conditions expected.

5.2 *Handling*—The atomic oxygen durability of materials with protective coatings may be significantly altered as a result of mechanical damage associated with handling. In addition, unprotected materials can become contaminated by handling, resulting in anomalous consequences of atomic oxygen exposure. It is recommended that samples be handled such as to minimize abrasion, contamination and flexure. The use of soft fluoropolymer tweezers is recommended for handling polymeric films with protective coatings. For samples too heavy to be safely held with tweezers, use clean vinyl, latex, or other gloves which will not allow finger oils to soak through and which are lint-free to carefully handle the samples.

5.3 *Exposure Area Control:*

5.3.1 *Masking*—Frequently it is desirable to limit the exposure of atomic oxygen to one side of a material or a limited area on one side of the material. This can be done by wrapping metal foil (such as aluminum foil) around the sample, covering an area with a sacrificial polymer (such as ~~Kapton),~~ a polyimide), salt-spraying to produce sites of atomic oxygen protection, or by using glass to cover areas not to be exposed. It is recommended that the protective covering be in intimate contact with the material to prevent partial exposure of the masked areas. When using metal foil within the RF or microwave excitation region of an atomic oxygen source, it is likely that electromagnetic interactions could take place between the metal and the plasma that could cause anomalous atomic oxygen fluxes or shielding from charged species, or both. It is important to expose the four standard witness coupons in this configuration before any other testing to determine the effects of the masking on the atomic oxygen flux.

5.3.2 *Cladding*—Samples which are coated with protective coatings on one side can be clad together by means of adhesives to allow the protective coating to be exposed on both sides of the sample. The use of thin polyester adhesives (or other non-silicone

[2] Kapton(R) and DuPont (TM) are trademarks or registered trademarks of E. I. DuPont de Nemours and Company.

[3] The boldface numbers in parentheses refer to a list of references at the end of this standard.