



BSI Standards Publication

**Space environment (natural and artificial) —
Modelling of space environment impact on
nanostructured materials — General principles**

National foreword

This Published Document is the UK implementation of ISO/TS 22295:2021.

The UK participation in its preparation was entrusted to Technical Committee ACE/68, Space systems and operations.

A list of organizations represented on this committee can be obtained on request to its committee manager.

Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

This publication is not to be regarded as a British Standard.

© The British Standards Institution 2021
Published by BSI Standards Limited 2021

ISBN 978 0 580 98361 0

ICS 49.140

Compliance with a Published Document cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 30 June 2021.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

**TECHNICAL
SPECIFICATION**

**ISO/TS
22295**

First edition
2021-05

**Space environment (natural
and artificial) — Modelling of
space environment impact on
nanostructured materials — General
principles**

*Environnement spatial (naturel et artificiel) — Modélisation de
l'impact de l'environnement spatial sur les matériaux nanostructurés
— Principes généraux*



Reference number
ISO/TS 22295:2021(E)



COPYRIGHT PROTECTED DOCUMENT

© ISO 2021

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

	Page
Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions and abbreviated terms	1
3.1 Terms and definitions.....	1
3.2 Abbreviated terms.....	2
4 Nanostructured materials	2
5 Main space environment components and processes	3
5.1 General.....	3
5.2 Space radiation.....	3
5.2.1 General.....	3
5.2.2 Special features of nanostructured materials response.....	3
5.3 Atomic oxygen of the Earth's upper atmosphere.....	4
5.3.1 General.....	4
5.3.2 Special features of nanostructured materials.....	5
5.4 Hot magnetosphere plasma.....	5
5.4.1 General.....	5
5.4.2 Special features of nanostructured materials response.....	5
5.5 Heating, cooling and thermal cycling.....	6
5.5.1 General.....	6
5.5.2 Special features of nanostructured materials.....	6
5.6 Meteoroids and space debris.....	6
5.6.1 General.....	6
5.6.2 Special features of nanostructured materials.....	6
5.7 Solar UV and VUV radiation.....	6
5.7.1 General.....	6
5.7.2 Special features of nanostructured materials.....	7
6 Multiscale approach to simulation of space components impact on nanostructured materials	7
6.1 Multiscale simulation methods.....	7
6.1.1 General.....	7
6.1.2 Quantum (electronic) scale.....	8
6.1.3 Atomistic scale (molecular dynamics and Monte Carlo).....	12
6.1.4 Mesoscale.....	13
6.1.5 Macroscale (continuum methods).....	14
6.2 Radiation damage modelling.....	15
6.2.1 General.....	15
6.2.2 Quantum scale.....	15
6.2.3 Atomistic scale.....	16
6.2.4 Mesoscale.....	16
6.2.5 Macroscale.....	17
6.3 Modelling of atomic oxygen impact.....	17
6.3.1 General.....	17
6.3.2 Quantum scale.....	18
6.3.3 Atomistic scale.....	19
6.3.4 Mesoscale.....	19
6.3.5 Macroscale.....	19
6.4 Modelling of charging effects.....	20
6.4.1 General.....	20
6.4.2 Quantum scale.....	20
6.4.3 Atomistic scale.....	20

6.4.4	Mesoscale	21
6.4.5	Macroscale	21
6.5	Modelling of heating/cooling and thermal cycling effects	21
6.5.1	General	21
6.5.2	Atomistic scale	21
6.5.3	Mesoscale	22
6.5.4	Macroscale	22
6.6	Modelling of meteoroids and space debris impact	22
6.6.1	General	22
6.6.2	Atomistic scale	22
6.6.3	Mesoscale	23
6.6.4	Macroscale	23
6.7	Modelling of solar UV and VUV radiation effects	23
6.7.1	General	23
6.7.2	Quantum scale	23
7	Outlook	23
Annex A (informative) Multiscale simulation methods: software for simulation in different space and time scales		24
Bibliography		27

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

In the near future nanomaterials and nanoelements will be widely applied in spacecraft and space engineering. Nanomaterials superiority in mechanical, thermal, electrical and optical properties over conventional materials will evidently inspire a wide range of applications in the next generation spacecraft intended for the long-term (~15 to 20 years) operation in near-Earth orbits and the automatic and manned interplanetary missions as well as in the construction of inhabited bases on the Moon.

The near-Earth's space is described as an extreme environment for materials due to high vacuum, space radiation, hot and cold plasma, micrometeoroids and space debris, temperature differences, etc. Existing experimental and theoretical data demonstrate that nanomaterials response to various space environment effects can differ substantially from the one of conventional bulk spacecraft materials. Therefore, it is necessary to determine the space environment components, critical for nanomaterials, and to develop novel methods of the mathematical and experimental simulation of the space environment impact on nanomaterials.

Modelling is a very important scientific tool for explaining various phenomena and predicting the behaviour of existing and designing materials under different conditions. In the case of nanotechnologies, modelling and simulations become even a more significant method of studying nanomaterials and processes in the nanoscale due to difficulties of observing and measuring many nanoscale phenomena experimentally. In computational nanotechnology, it is necessary to develop new integrated approaches for different length and time scales that enable explaining mechanisms of mesoscale phenomena and predicting emerging material macro-properties.

The changes in the materials properties, caused by the space environment impact, are determined with structural parameters and processes that are related to different spatial scales: from the size of atoms and molecules to the size of macroobjects. There are a variety of simulation methods but most of them can be applied only for a special space and time range/scale because of underlying approximations. To estimate the durability of nanostructured materials to the space environment impact it is necessary to investigate both fundamental effects of incident atom/particle interaction with nanosized structures within very short time intervals and resulting effects of material damage and changes in their properties, that can be observed at micro- and macroscale within much longer periods. Thus, in general case to study the whole set of elementary processes and resulting effects it is necessary to apply the multiscale simulation approach.

The main concept of this document is:

- for main space environment components to choose the most important space and time scales;
- for every scale to choose the most important physical and chemical processes that occur in nanostructured materials under the influence of the given space environment component and can be considered as elementary for the chosen scale;
- for every process to determine a method (or a group of methods) that can be used for their simulations under space environment conditions;
- for every chosen method to describe necessary and possible approximations as well as its limitation when used for simulation of the given process.

Space environment (natural and artificial) — Modelling of space environment impact on nanostructured materials — General principles

1 Scope

The document considers peculiarities of the space environment impact on a special kind of materials: nanostructured materials (i.e. materials with structured objects which size in at least one dimension lies within 1 nm to 100 nm) and specifies the methods of mathematical simulation of such processes. It emphasizes the necessity of applying multiscale simulation approach and does not include any special details concerning concrete materials, elements of spacecraft construction and equipment, etc.

This document provides the general description of the methodology of applying computer simulation methods which relate to different space and time scales to modelling processes occurring in nanostructured materials under the space environment impact.

The document can be applied as a reference document in spacecraft designing, forecasting the spacecraft lifetime, conducting ground-based tests, and analysing changes of material properties during operation.

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 10795, *Space systems — Programme management and quality — Vocabulary*

ISO 17851, *Space systems — Space environment simulation for material tests — General principles and criteria*

ISO/TS 18110, *Nanotechnologies — Vocabularies for science, technology and innovation indicators*

ISO/TS 80004-1, *Nanotechnologies — Vocabulary — Part 1: Core terms*

ISO/TS 80004-2, *Nanotechnologies — Vocabulary — Part 2: Nano-objects*

ISO/TS 80004-6, *Nanotechnologies — Vocabulary — Part 6: Nano-object characterization*

3 Terms and definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10795, ISO/TS 18110, ISO/TS 80004-1, ISO/TS 80004-2, ISO/TS 80004-6 and ISO 17851 apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>