



**SLOVENSKI STANDARD**  
**SIST-TP CEN/TR/ISO/ASTM 52912:2020**

**01-december-2020**

---

**Dodajalna izdelava - Konstruiranje - Proizvodnja delov s funkcijsko porazdeljenimi lastnostmi (ISO/ASTM/TR 52912:2020)**

Additive manufacturing - Design - Functionally graded additive manufacturing  
(ISO/ASTM/TR 52912:2020)

Technischer Bericht für die Gestaltung von additiv gefertigten, gradierten Bauteilen  
(ISO/ASTM/TR 52912:2020)

Fabrication additive - Conception - Fabrication additive à gradient fonctionnel  
(ISO/ASTM/TR 52912:2020)

**Ta slovenski standard je istoveten z: CEN ISO/ASTM/TR 52912:2020**

[SIST-TP CEN/TR/ISO/ASTM 52912:2020](https://standards.iteh.org/standards/sist/60645/774/cen-iso-astm-52912-2020)

**ICS:**

25.030            3D-tiskanje            Additive manufacturing

**SIST-TP CEN/TR/ISO/ASTM 52912:2020 en,fr,de**



TECHNICAL REPORT  
RAPPORT TECHNIQUE  
TECHNISCHER BERICHT

CEN/TR/ISO/ASTM  
52912

October 2020

ICS 25.030

English Version

Additive manufacturing - Design - Functionally graded  
additive manufacturing (ISO/ASTM/TR 52912:2020)

Fabrication additive - Conception - Fabrication additive  
à gradient fonctionnel (ISO/ASTM/TR 52912:2020)

Technischer Bericht für die Gestaltung von additiv  
gefertigten, gradierten Bauteilen (ISO/ASTM/TR  
52912:2020)

This Technical Report was approved by CEN on 31 August 2020. It has been drawn up by the Technical Committee CEN/TC 438.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

iTeh Standards  
(<https://standards.itih.ai>)  
Document Preview

[SIST-TP CEN/TR/ISO/ASTM 52912:2020](https://standards.itih.ai/catalog/standards/sist/d88a3474-cdf9-457c-be43-5029cb97665b/sist-tp-cen-tr-iso-astm-52912-2020)

<https://standards.itih.ai/catalog/standards/sist/d88a3474-cdf9-457c-be43-5029cb97665b/sist-tp-cen-tr-iso-astm-52912-2020>



EUROPEAN COMMITTEE FOR STANDARDIZATION  
COMITÉ EUROPÉEN DE NORMALISATION  
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

**CEN/TR/ISO/ASTM 52912:2020 (E)**

<b>Contents</b>	<b>Page</b>
<b>European foreword.....</b>	<b>3</b>

**iTeh Standards**  
**(<https://standards.itih.ai>)**  
**Document Preview**

[SIST-TP CEN/TR/ISO/ASTM 52912:2020](https://standards.itih.ai/catalog/standards/sist/d88a3474-cdf9-457c-be43-5029cb97665b/sist-tp-cen-tr-iso-astm-52912-2020)

<https://standards.itih.ai/catalog/standards/sist/d88a3474-cdf9-457c-be43-5029cb97665b/sist-tp-cen-tr-iso-astm-52912-2020>

## **European foreword**

This document (CEN/TR/ISO/ASTM 52912:2020) has been prepared by Technical Committee ISO/TC 261 "Additive manufacturing" in collaboration with Technical Committee CEN/TC 438 "Additive Manufacturing" the secretariat of which is held by AFNOR.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

## **Endorsement notice**

The text of ISO/ASTM/TR 52912:2020 has been approved by CEN as CEN/TR/ISO/ASTM 52912:2020 without any modification.

**iTeh Standards**  
**(<https://standards.iteh.ai>)**  
**Document Preview**

[SIST-TP CEN/TR/ISO/ASTM 52912:2020](https://standards.iteh.ai/catalog/standards/sist/d88a3474-cdf9-457c-be43-5029cb97665b/sist-tp-cen-tr-iso-astm-52912-2020)

<https://standards.iteh.ai/catalog/standards/sist/d88a3474-cdf9-457c-be43-5029cb97665b/sist-tp-cen-tr-iso-astm-52912-2020>



TECHNICAL  
REPORT

ISO/ASTM TR  
52912

First edition  
2020-09

---

---

**Additive manufacturing — Design  
— Functionally graded additive  
manufacturing**

*Fabrication additive — Conception — Fabrication additive à gradient  
fonctionnel*

iTeh Standards  
(<https://standards.iteh.ai>)  
Document Preview

[SIST-TP CEN/TR/ISO/ASTM 52912:2020](https://standards.iteh.ai/catalog/standards/sist/d88a3474-cdf9-457c-be43-5029cb97665b/sist-tp-cen-tr-iso-astm-52912-2020)

<https://standards.iteh.ai/catalog/standards/sist/d88a3474-cdf9-457c-be43-5029cb97665b/sist-tp-cen-tr-iso-astm-52912-2020>



Reference number  
ISO/ASTM TR 52912:2020(E)

© ISO/ASTM International 2020

iTeh Standards  
(<https://standards.iteh.ai>)  
Document Preview

[SIST-TP CEN/TR/ISO/ASTM 52912:2020](https://standards.iteh.ai/catalog/standards/sist/d88a3474-cdf9-457c-be43-5029cb97665b/sist-tp-cen-tr-iso-astm-52912-2020)

<https://standards.iteh.ai/catalog/standards/sist/d88a3474-cdf9-457c-be43-5029cb97665b/sist-tp-cen-tr-iso-astm-52912-2020>



**COPYRIGHT PROTECTED DOCUMENT**

© ISO/ASTM International 2020

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. In the United States, such requests should be sent to ASTM International.

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

Email: [copyright@iso.org](mailto:copyright@iso.org)  
Website: [www.iso.org](http://www.iso.org)

Published in Switzerland

ASTM International  
100 Barr Harbor Drive, PO Box C700  
West Conshohocken, PA 19428-2959, USA  
Phone: +610 832 9634  
Fax: +610 832 9635  
Email: [khooper@astm.org](mailto:khooper@astm.org)  
Website: [www.astm.org](http://www.astm.org)



# Contents

Page

<b>Foreword</b> .....	<b>iv</b>
<b>Introduction</b> .....	<b>v</b>
<b>1 Scope</b> .....	<b>1</b>
<b>2 Normative references</b> .....	<b>1</b>
<b>3 Terms and definitions</b> .....	<b>1</b>
<b>4 Abbreviations</b> .....	<b>1</b>
<b>5 Concept of Functionally Graded Additive Manufacturing (FGAM)</b> .....	<b>3</b>
5.1 General.....	3
5.2 Homogeneous compositions — Single Material FGAM.....	3
5.3 Heterogeneous compositions — Multi-material FGAM.....	4
<b>6 Advances of functionally graded additive manufacturing</b> .....	<b>8</b>
6.1 General.....	8
6.2 AM and FGAM process.....	8
6.3 Material extrusion.....	9
6.4 Powder bed fusion.....	12
6.5 Directed energy deposition.....	13
6.6 Sheet lamination.....	14
<b>7 Current limitations of FGAM</b> .....	<b>16</b>
7.1 General.....	16
7.2 Material limitations.....	16
7.2.1 General.....	16
7.2.2 Defining the optimum material property distribution.....	17
7.2.3 Predicting the material properties of manufactured components.....	17
7.2.4 Material selection.....	17
7.2.5 Understanding differences and defining tolerances.....	17
7.3 Limitations of current additive manufacturing technologies.....	17
7.4 CAD Software limitations.....	18
7.4.1 General.....	18
7.4.2 Data exchange formats.....	19
<b>8 Potential applications of FGAM</b> .....	<b>20</b>
8.1 General.....	20
8.2 Biomedical applications.....	21
8.3 Aerospace applications.....	21
8.4 Consumer markets.....	21
<b>9 Summary</b> .....	<b>22</b>
<b>Bibliography</b> .....	<b>23</b>

## ISO/ASTM TR 52912:2020(E)

### 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](http://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](http://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 on 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 the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

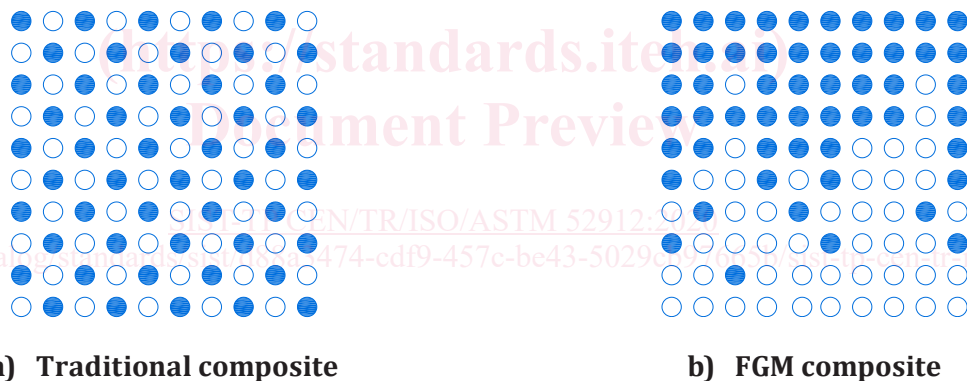
This document was prepared by ISO/TC 261, *Additive manufacturing*, in cooperation with ASTM F 42, *Additive manufacturing technologies*, on the basis of a partnership agreement between ISO and ASTM International with the aim to create a common set of ISO/ASTM standards on additive manufacturing and in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 438, *Additive manufacturing*, in accordance with the agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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](http://www.iso.org/members.html).

## Introduction

Functionally Graded Materials (FGMs) were developed in 1984 for a space plane project to sustain high thermal barriers to overcome the shortcomings of traditional composite materials (AZO Materials, 2002). Traditional composites [Figure 1 a)] are homogeneous mixtures, therefore involving a compromise between the desirable properties of the component materials. Functionally Graded Materials (FGMs) are a class of advanced materials with spatially varying composition over a changing dimension, with corresponding changes in material properties built-in<sup>[56]</sup>. FGMs attain their multifunctional status by mapping performance requirements to strategies of material structuring and allocation [Figure 1 b)].

The manufacturing processes of conventional FGMs include shot peening, ion implantation, thermal spraying, electrophoretic deposition and chemical vapour deposition. Since additive manufacturing processes builds parts by successive addition of material, they provide the possibility to produce products with Functionally Graded properties, thereby introducing the concept often known as Functionally Graded Additive Manufacturing (FGAM). As this area of work is new, driven by academic research, and lacks available standardisation, there have been multiple different names proposed by different researchers in different publications as terms for this area, for example, functionally graded rapid prototyping (FGRP)<sup>[56]</sup>, varied property rapid prototyping (VPRP)<sup>[57]</sup> and site-specific properties additive manufacturing<sup>[72]</sup>. However, even if there clearly is a great need for clarification of key terms associated with FGAM, this document does not include any attempts of alignment in terminology. This document is an overview of state of the art and the possibilities for FGAM enabled by present AM process technology and thus a purely informative document. Since this overview is based on available publications, and in order to facilitate cross referencing from these publications, this document has used the terms concerning FGAM as they are used in the original publications.



**Figure 1 — Allocation of materials in a traditional composite and an FGM composite**