PD CEN ISO/TS 80004-13:2020

BSI Standards Publication

Nanotechnologies – Vocabulary

Part 13: Graphene and related two-dimensional (2D) materials

Documents
Document Sharing Hub

Full document details: PD CEN ISO/TS 80004-13:2020

National foreword

This Published Document is the UK implementation of CEN ISO/TS 80004-13:2020. It is identical to ISO/TS 80004-13:2017. It supersedes PD ISO/TS 80004-13:2017, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee NTI/1, Nanotechnologies.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2020
Published by BSI Standards Limited 2020

ISBN 978 0 539 12937 3

ICS 01.040.07; 07.120

Compliance with a British Standard cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 30 September 2017.

Amendments/corrigenda issued since publication

Date	Text affected
30 September 2020	This corrigendum renumbers PD ISO/TS 80004-13:2017 as PD CEN ISO/TS 80004-13:2020

Documents
Document Sharing Hub

Full document details: PD CEN ISO/TS 80004-13:2020

TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

TECHNISCHE SPEZIFIKATION

CEN ISO/TS 80004-13

August 2020

ICS 07.120; 01.040.07

English Version

Nanotechnologies - Vocabulary - Part 13: Graphene and related two-dimensional (2D) materials (ISO/TS 80004-13:2017)

Nanotechnologies - Vocabulaire - Partie 13: Graphène et autres matériaux bidimensionnels (ISO/TS 80004-13:2017)

Nanotechnologien - Fachwörterverzeichnis - Teil 13: Graphen und andere zweidimensionale (2D) Werkstoffe (ISO/TS 80004-13:2017)

This Technical Specification (CEN/TS) was approved by CEN on 10 August 2020 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

CEN members are required to announce the existence of this CEN/TS in the same way as for an EN and to make the CEN/TS available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the CEN/TS) until the final decision about the possible conversion of the CEN/TS into an EN is reached.

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.

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

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

© 2020 CEN All rights of exploitation in any form and by any means reserved worldwide for CEN national Members.

Ref. No. CEN ISO/TS 80004-13:2020 E

Documents
Document Sharing Hub

Full document details: PD CEN ISO/TS 80004-13:2020

European foreword

The text of ISO/TS 80004-13:2017 has been prepared by Technical Committee ISO/TC 229 "Nanotechnologies" of the International Organization for Standardization (ISO) and has been taken over as CEN ISO/TS 80004-13:2020 by Technical Committee CEN/TC 352 "Nanotechnologies" 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.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this Technical Specification: 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 the United Kingdom.

Endorsement notice

The text of ISO/TS 80004-13:2017 has been approved by CEN as CEN ISO/TS 80004-13:2020 without any modification.

Documents
Document Sharing Hub

Full document details: PD CEN ISO/TS 80004-13:2020

Contents

Page

Foreword ..... **iv**
Introduction ..... **v**
1 Scope **1**
2 Normative references **1**
3 Terms and definitions **1**
3.1 Terms related to materials 1
3.1.1 General terms related to 2D materials 1
3.1.2 Terms related to graphene 3
3.1.3 Terms related to other 2D materials 5
3.2 Terms related to methods for producing 2D materials 5
3.2.1 Graphene and related 2D material production 5
3.2.2 Nanoribbon production 8
3.3 Terms related to methods for characterizing 2D materials 8
3.3.1 Structural characterization methods 8
3.3.2 Chemical characterization methods 10
3.3.3 Electrical characterization methods 12
3.4 Terms related to 2D materials characteristics 13
3.4.1 Characteristics and terms related to structural and dimensional properties of 2D materials 13
3.4.2 Characteristics and terms related to chemical properties of 2D materials 15
3.4.3 Characteristics and terms related to optical and electrical properties of 2D materials 16
4 Abbreviated terms **16**
Bibliography **17**
Index **18**

© ISO 2017 – All rights reserved

Documents
Document Sharing Hub
Full document details: PD CEN ISO/TS 80004-13:2020

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 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.

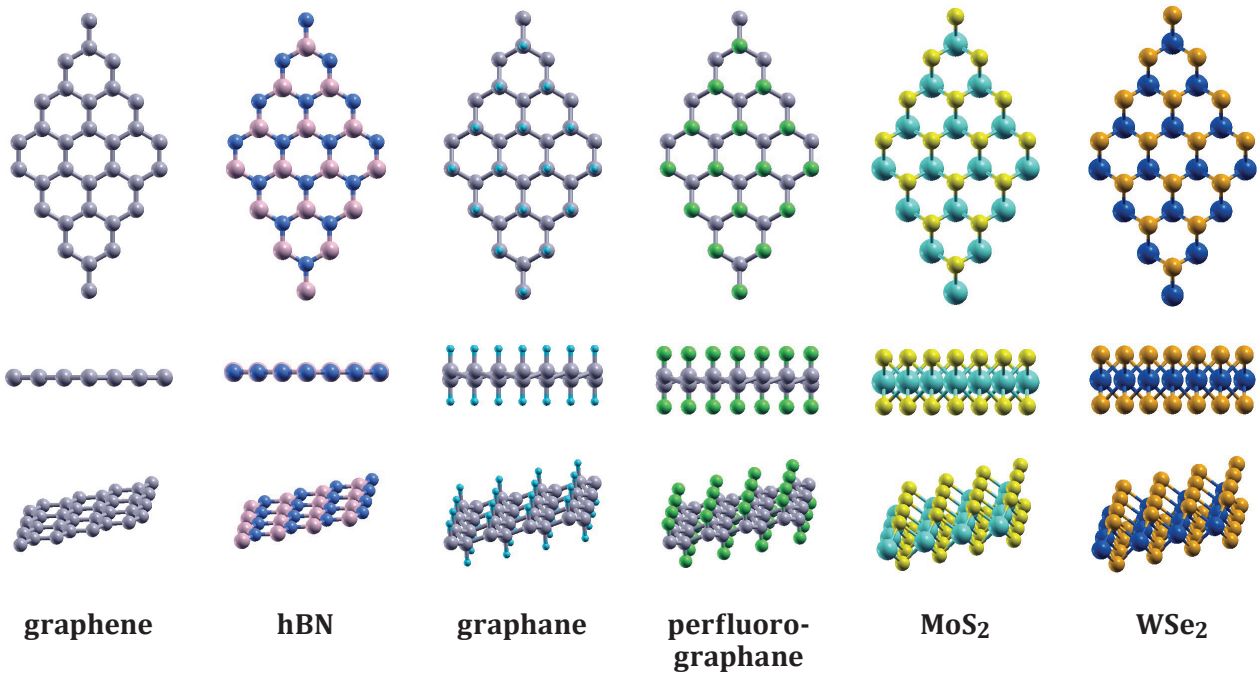
This document was prepared by Technical Committee ISO/TC 229, *Nanotechnologies*, and IEC/TC 113, *Nanotechnology for electrotechnical products and systems*.

A list of all parts in the ISO 80004 series can be found on the ISO website.

© ISO 2017 – All rights reserved
Documents
Document Sharing Hub
Full document details: PD CEN ISO/TS 80004-13:2020

Introduction

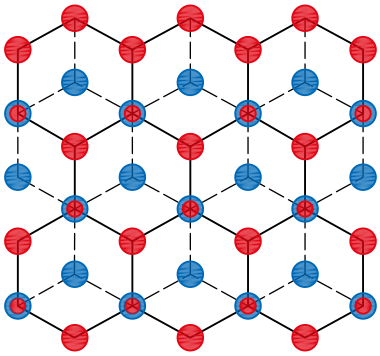
Over the last decade, huge interest has arisen in graphene both scientifically and commercially, due to the many exceptional properties associated with this material, properties such as the electrical and thermal conductivity. More recently, other materials with a structure similar to that of graphene have also shown promising properties including monolayer and few-layer versions of hexagonal boron nitride (hBN), molybdenum disulphide (MoS_2), tungsten diselenide (WSe_2), silicene and germanene and layered assemblies of mixtures of these materials. These materials have their thickness constrained within the nanoscale or smaller and consist of between one and several layers. These materials are thus termed two-dimensional (2D) materials as they have one dimension at the nanoscale or smaller, with the other two dimensions generally at scales larger than the nanoscale. A layered material consists of two-dimensional layers weakly stacked or bound to form three-dimensional structures. Examples of 2D materials and the different stacking configurations in graphene are shown in Figure 1. It should be noted that 2D materials are not necessarily topographically flat in reality and can have a buckled structure. They can also form aggregates and agglomerates which can have different morphologies. Two-dimensional materials are an important subset of nanomaterials.



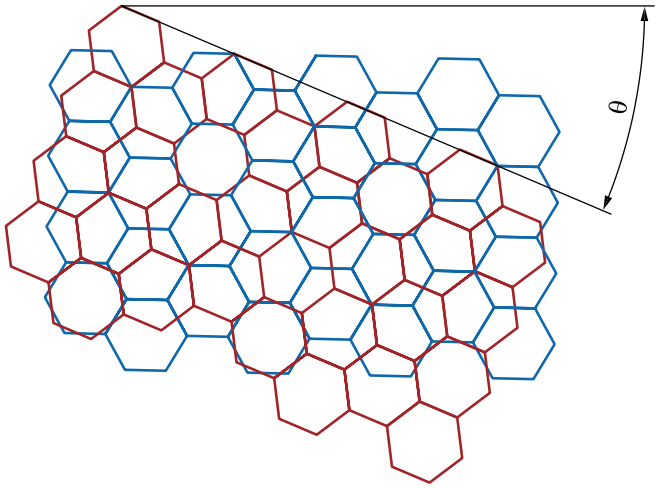
a) Examples of different two-dimensional materials consisting of different elements and structures, as shown by the different coloured orbs and top-down and side views

© ISO 2017 – All rights reserved

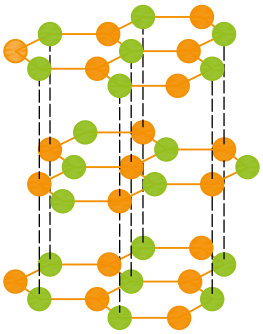
Documents
Document Sharing Hub
Full document details: PD CEN ISO/TS 80004-13:2020



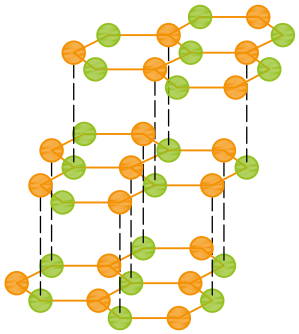
b) Bernal stacked bilayer graphene (3.1.2.6)



c) turbostratic bilayer or twisted bilayer graphene with relative stacking angle, θ, (3.1.2.7)



ABA trilayer



ABC trilayer

d) Bernal stacked (AB) (3.4.1.10) tri-layer graphene (3.1.2.9) and Rhombohedral (ABC) (3.4.1.11) stacked tri-layer graphene (3.1.2.9)

Figure 1 — Examples of 2D materials and the different stacking configurations in graphene layers

It is important to standardize the terminology for graphene, graphene-derived and related 2D materials at the international level, as the number of publications, patents and organizations is increasing rapidly. Thus, these materials need an associated vocabulary as they become commercialized and sold throughout the world.

This document belongs to a multi-part vocabulary covering the different aspects of nanotechnologies. It builds upon ISO/TS 80004-3, ISO/TS 80004-11 and ISO/TS 80004-6 and uses existing definitions where possible.

© ISO 2017 – All rights reserved
Documents
Document Sharing Hub
Full document details: PD CEN ISO/TS 80004-13:2020

Nanotechnologies — Vocabulary —

Part 13: Graphene and related two-dimensional (2D) materials

1 Scope

This document lists terms and definitions for graphene and related two-dimensional (2D) materials, and includes related terms naming production methods, properties and their characterization.

It is intended to facilitate communication between organizations and individuals in research, industry and other interested parties and those who interact with them.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

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

3.1 Terms related to materials

3.1.1 General terms related to 2D materials

3.1.1.1
two-dimensional material
2D material
material, consisting of one or several *layers* (3.1.1.5) with the atoms in each layer strongly bonded to neighbouring atoms in the same layer, which has one dimension, its thickness, in the nanoscale or smaller and the other two dimensions generally at larger scales

Note 1 to entry: The number of layers when a two-dimensional material becomes a bulk material varies depending on both the material being measured and its properties. In the case of *graphene layers* (3.1.2.1), it is a two-dimensional material up to 10 layers thick for electrical measurements[10],beyond which the electrical properties of the material are not distinct from those for the bulk [also known as *graphite* (3.1.2.2)].

Note 2 to entry: Interlayer bonding is distinct from and weaker than intralayer bonding.

Note 3 to entry: Each layer may contain more than one element.

Note 4 to entry: A two-dimensional material can be a *nanoplate* (3.1.1.2).

© ISO 2017 – All rights reserved

Documents
Document Sharing Hub
Full document details: PD CEN ISO/TS 80004-13:2020