Technical

ISO/TS 80004-13

# Nanotechnologies — Vocabulary —

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

*Nanotechnologies — Vocabulaire —*

*Partie 13: Graphène et autres matériaux bidimensionnels (2D)*

Second edition
2024-09

Reference number
ISO/TS 80004-13:2024(en)



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

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

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 document 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 or www.iec.ch/members_experts/refdocs).

ISO and IEC draw attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO and IEC take no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO and IEC had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents and https://patents.iec.ch. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

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. In the IEC, see www.iec.ch/understanding-standards.

This document was prepared jointly by Technical Committee ISO/TC 229, *Nanotechnologies*, and Technical Committee IEC/TC 113, *Nanotechnology for electrotechnical products and systems,* and in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 352, *Nanotechnologies,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement). The draft was circulated for voting to the national bodies of both ISO and IEC.

This second edition cancels and replaces the first edition (ISO/TS 80004-13:2017) which has been technically revised.

The main changes are as follows:

— addition of the term "graphene-related 2D material (GR2M)";

— expansion of defined terms to include "enhanced", "modified", "enabled" and "based", and derivatives thereof;

— indication that use of some terms are deprecated.

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

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.

Over the last decade, huge interest has arisen in graphene, both scientifically and commercially, due to the many exceptional properties associated with this material, 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:

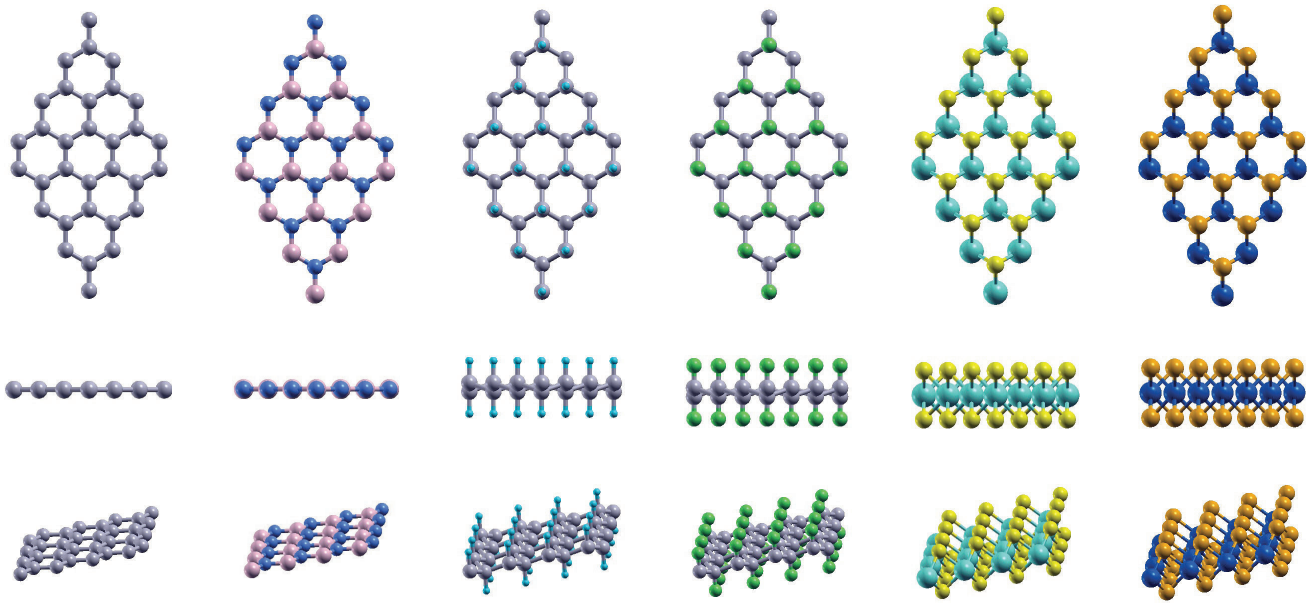
a) monolayer and few-layer versions of hexagonal boron nitride (hBN);

b) transition metal dichalcogenides such as molybdenum disulphide ($MoS_2$) and tungsten diselenide ($WSe_2$);

c) silicene and germanene;

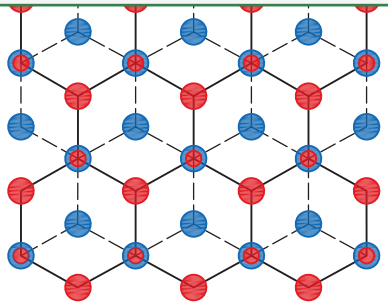
d) layered assemblies of mixtures of these materials.

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 2D 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. 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. 2D materials are an important subset of nanomaterials.

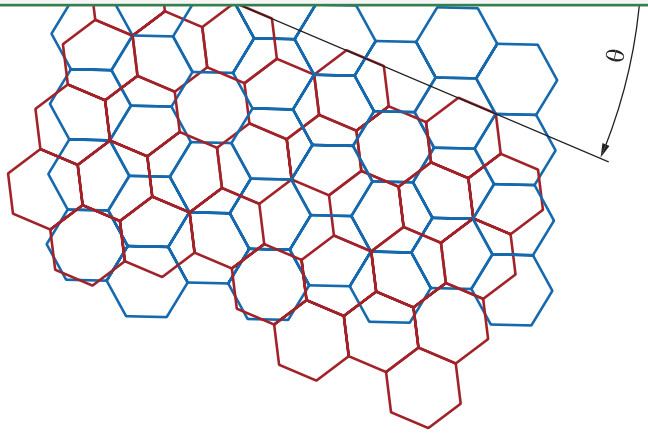


**graphene** | **hBN** | **graphane** | **perfluoro-graphane** | **$MoS_2$** | **$WSe_2$**

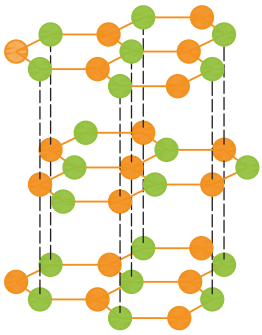
**a) Examples of different 2D materials consisting of different elements and structures, as shown by the different coloured orbs and top-down and side views**



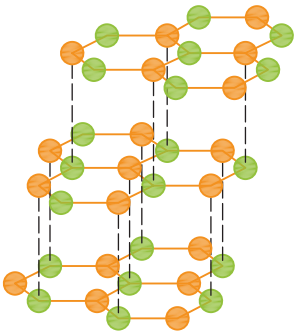
**b) Bernal stacked bilayer graphene (3.1.2.7)**




**c) Turbostratic bilayer or twisted bilayer graphene with relative stacking angle ($\theta$)(3.1.2.8)**



**ABA trilayer**



**ABC trilayer**

**d) Bernal stacked (AB) (3.4.1.12) tri-layer graphene (3.1.2.10) and rhombohedral (ABC) (3.4.1.13) stacked tri-layer graphene (3.1.2.10)**

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

It is important to standardize the terminology for graphene, graphene-related and other 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.

The document contains general terms related to 2D materials, those related to graphene, and those related to other 2D materials. It provides terms related to commonly used methods for producing and characterising 2D materials along, with terms related to 2D materials characteristics. It also includes performance related terms, such as “-enhanced” and “-enabled”, and those related to composition, such as “-based” and “-modified”, as shown in Figure 2.

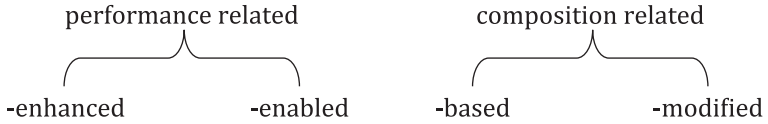



**Figure 2 — General terms to describe 2D materials split into performance and composition related terms**

This document belongs to a multi-part vocabulary, covering the different aspects of nanotechnologies. It builds upon ISO 80004-1, ISO/TS 80004-3 and ISO/TS 80004-6, and uses existing definitions where possible.