
**Nanotechnologies — Characterization
of multiwall carbon nanotubes —
Mesoscopic shape factors**

*Nanotechnologies — Caractérisation des nanotubes en carbone
multicouches — Facteurs de forme mésoscopique*

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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*.

This second edition cancels and replaces the first edition (ISO/TS 11888:2011), which has been technically revised.

Introduction

Multiwall carbon nanotubes (MWCNTs) synthesized by chemical vapour deposition (CVD) are of growing interest for use in polymer composites and conductive coatings. In many cases, MWCNTs synthesized by CVD have static (permanent) bend points randomly distributed along their axis. Physical and chemical properties of mass-produced MWCNTs are strongly dependent on the statistical distribution of mesoscopic shapes and sizes of the individual MWCNT (see ISO/TS 80004-3), among other parameters, that comprise the product.^{[4][6]} It is therefore crucial to characterize the mesoscopic shapes of MWCNTs in order to ensure that the final properties are reproducible for use in a wide range of materials, including composites and other dispersions, as well as for Environment, Health and Safety (EHS) issues.^[7]

This document provides methods for the characterization of mesoscopic shape factors of MWCNTs, including sample preparation procedures. In particular, it provides a statistical method for characterizing MWCNTs produced by the CVD method. During MWCNT synthesis, axial structures are not perfectly linear but include static bend points.

This document provides methods for determining a statistical quantity, representing a maximum straight length that is not deformed by permanent bending called the “static bending persistence length” (SBPL). The SBPL gives information regarding the relationship between the MWCNT mesoscopic shape and size. If two MWCNTs of equal length have different SBPLs, their overall sizes (e.g. radius of gyration or an equivalent diameter such as a hydrodynamic diameter) will also be different from one another. In practical applications, the variation in SBPL affects both chemical reactivity and physical properties.^{[4][5][6]}

Electrical conductivity and dimensional stability of MWCNT-polymer compounds are also strongly dependent on the SBPL of the MWCNT used to make them.^{[4][5][6]} Various properties might be affected by SBPL, including electrical percolation threshold,^{[6][8]} toxicity,^[7] thermal conductivity,^[9] rheological property^[10] and field emission property.^[11] SBPL could be useful for estimating the loading of a MWCNT-polymer matrix to achieve electrical conductivity (percolation limit) and should also assist with modelling the mechanical properties of MWCNT-polymer composites with different loadings.

Prior to commencing any work, users are advised to familiarize themselves with the latest guidance on handling and disposal of MWCNTs, particularly in relation to the use of appropriate personal protective equipment. Information on current practices is available in ISO/TR 12885.

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Nanotechnologies — Characterization of multiwall carbon nanotubes — Mesoscopic shape factors

1 Scope

This document describes methods for the characterization of mesoscopic shape factors of multiwall carbon nanotubes (MWCNTs). Techniques employed include scanning electron microscopy (SEM), transmission electron microscopy (TEM), viscometry, and light scattering analysis.

This document also includes additional terms needed to define the characterization of static bending persistence length (SBPL). Measurement methods are given for the evaluation of SBPL, which generally varies from several tens of nanometres to several hundred micrometres.

Well-established concepts and mathematical expressions, analogous to polymer physics, are utilized for the definition of mesoscopic shape factors of MWCNTs.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

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

NOTE Formulae for some of these terms and definitions are given in [Annex A](#).

3.1.1

mesoscopic shape

description of shape at the observation scale for an individual multiwall carbon nanotube (MWCNT)

Note 1 to entry: Mesoscopic shape factors describe the average size and shape of individual MWCNTs, while “macroscopic” describes the shape and size of MWCNT aggregates or agglomerates. “Atomic scale resolution” describes the shape of an MWCNT at the atomic level (see [Figure 1](#)).

Note 2 to entry: See Reference [\[4\]](#).