



BSI Standards Publication

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

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## National foreword

This Published Document is the UK implementation of ISO/TS 11888:2017. It supersedes DD ISO/TS 11888:2011, which is withdrawn.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 secretary.

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© The British Standards Institution 2017  
Published by BSI Standards Limited 2017

ISBN 978 0 580 92438 5

ICS 07.120

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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
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TECHNICAL  
SPECIFICATION

**ISO/TS**  
**11888**

Second edition  
2017-07

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

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



Reference number  
ISO/TS 11888:2017(E)



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ISO copyright office  
Ch. de Blandonnet 8 • CP 401  
CH-1214 Vernier, Geneva, Switzerland  
Tel. +41 22 749 01 11  
Fax +41 22 749 09 47  
copyright@iso.org  
www.iso.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, definitions and abbreviated terms</b> .....	<b>1</b>
3.1 Terms and definitions.....	1
3.2 Abbreviated terms.....	3
<b>4 Sample preparation methods</b> .....	<b>3</b>
4.1 Ball mill cutting.....	3
4.2 Dispersion method.....	3
4.3 Sample preparation for SEM.....	3
4.4 Alternative sample preparation method.....	3
<b>5 Experimental procedure</b> .....	<b>4</b>
5.1 Measurements of the SBPL using SEM.....	4
5.1.1 SEM.....	4
5.1.2 Measurement methods for the SBPL.....	4
5.2 Measuring inner and outer diameters of MWCNTs using SEM.....	5
<b>6 Test report</b> .....	<b>5</b>
<b>Annex A (normative) Formulae for terms and definitions in <a href="#">Clause 2</a>, <a href="#">Annex B</a>, <a href="#">Annex C</a> and <a href="#">Annex D</a></b> .....	<b>6</b>
<b>Annex B (informative) Viscometry</b> .....	<b>11</b>
<b>Annex C (informative) Dynamic light scattering and depolarized dynamic light scattering</b> .....	<b>12</b>
<b>Annex D (informative) Case study and reports</b> .....	<b>14</b>
<b>Bibliography</b> .....	<b>18</b>

## 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 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.[5][6] Various properties might be affected by SBPL, including electrical percolation threshold,[6][7] 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.

# 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 [\[4\]](#).