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Nanotechnologies — Characterization of multiwall carbon nanotubes — Mesoscopic shape factors

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National foreword

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Foreword

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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).

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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.

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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].

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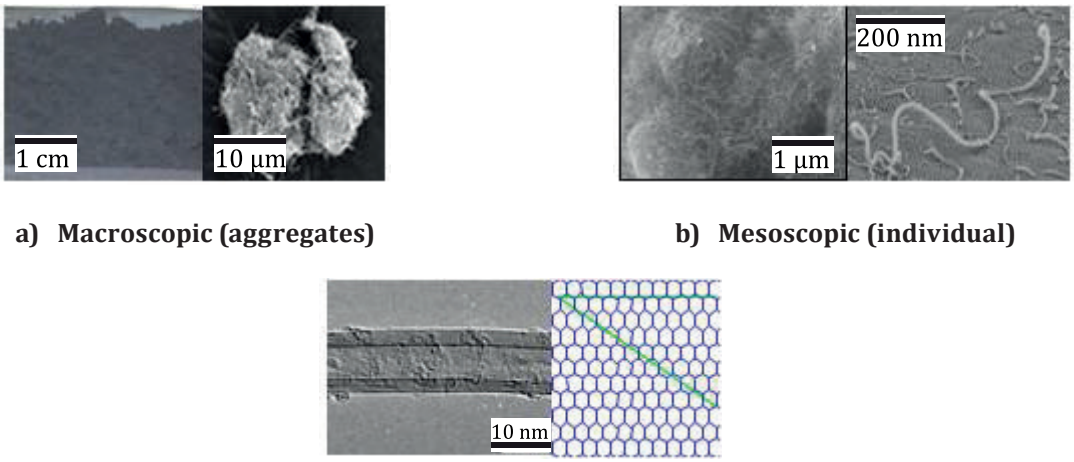

a) Macroscopic (aggregates)

b) Mesoscopic (individual)

c) Atomic scale resolution

NOTE SOURCE: 2010 ACS

Figure 1 — Shape of MWCNTs at various scales

3.1.2
regular shape
⟨MWCNTs⟩ property of having a regular pattern along the tube axis

Note 1 to entry: Correlations in the direction of the tangent show a periodical shape for MWCNTs of regular shape. Both straight and coil-shaped MWCNTs are typically classified as MWCNTs of regular shape.

3.1.3
random shape
⟨MWCNTs⟩ property of having static or permanent bend points distributed randomly (Gaussian) along their tube axis

3.1.4
static bending persistence length
SBPL
l_{sp}
maximum straight length without static bending

3.1.5
contour length
L
total length of an MWCNT along its axis

3.1.6
weighted average contour length
$\bar{L}_w$
average of contour length which is assigned a weight

3.1.7
end-to-end distance
R
straight distance between the two ends of an MWCNT

3.1.8
bending ratio
D_b
ratio between mean-squared end-to-end distance and squared contour length

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