TECHNICAL SPECIFICATION

ISO/TS 10797

First edition
2012-06-01

Nanotechnologies — Characterization of single-wall carbon nanotubes using transmission electron microscopy

Nanotechnologies — Caractérisation des nanotubes de carbone monofeuillet par microscopie électronique à transmission

Reference number
ISO/TS 10797:2012(E)

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of document:

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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.

ISO/TS 10797 was prepared by Technical Committee ISO/TC 229, *Nanotechnologies*.

Introduction

Carbon nanotubes (CNTs) are nanomaterials composed of concentric layers of graphene sheets in the form of cylindrical tubes placed along the longitudinal fibre axis. Single-wall carbon nanotubes (SWCNTs) are seamless cylinders derived from the honeycomb lattice representing just a single atomic layer of graphene sheet. The transmission electron microscope (TEM), and especially its high-resolution version (HRTEM), were the first instruments that revealed the unique structural features of carbon nanotubes. TEM/HRTEM has played an essential role in the research and development of carbon nanotube materials. It has the advantage of being a “direct” technique that avoids the imposition of physical or mathematical assumptions. At the same time, it provides a variety of experimental results and information-rich images that make the investigation of a wide variety of samples possible. Beyond imaging, TEM, along with other techniques described in this Technical Specification, can provide qualitative purity assessment of SWCNT samples. In addition, it can also reveal detailed morphological and structural features of carbon nanotubes such as graphene wall structure, defects, diameter, length, bundle size and orientation, and the existence of materials and nanoparticles[8] besides SWCNTs. In other operational modes, it is also possible to study the chirality and thermal and mechanical characteristics of individual nanotubes. It is important to develop a systematic protocol for using TEM in order to acquire reliable and comprehensive information about a sample containing SWCNTs.

The transmission electron microscope operates on similar basic principles as the optical microscope but uses electrons instead of light. A beam of electrons is focused onto a thin, electron-transparent sample, allowing an enlarged version to appear on a fluorescent screen, a layer of photographic film, or on an array detector that is sensitive to electrons. Modern instruments are equipped with a computer-linked digital imaging system that can also record real-time images.

The HRTEM can investigate crystal structure by phase contrast imaging, where images are formed due to differences in the phase of electron waves scattered through a thin sample. Resolution of the TEM is limited by spherical and chromatic aberrations, but new generations of instruments with advanced electron-optical columns have significantly lowered these aberrations. Software correction of spherical aberration has allowed the production of meaningful images with sufficient resolution at magnifications of many millions times. The ability to determine the positions of atoms within materials has made the HRTEM an indispensable tool for nanotechnology research and development.

Nanotechnologies — Characterization of single-wall carbon nanotubes using transmission electron microscopy

1 Scope

This Technical Specification establishes methods for characterizing the morphology of single-wall carbon nanotubes (SWCNTs) and identifying the elemental composition of other materials in SWCNT samples, using transmission electron microscopy and chemical analysis by energy dispersive X-ray spectrometry.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 22493, *Microbeam analysis — Scanning electron microscopy — Vocabulary*

ISO 29301, *Microbeam analysis — Analytical transmission electron microscopy — Methods for calibrating image magnification by using reference materials having periodic structures*

ISO/TS 80004-3, *Nanotechnologies — Vocabulary — Part 3: Carbon nano-objects*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*