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Nanomanufacturing – Key control characteristics – Part 2-5: Carbon nanotube materials – Mass density of vertically-aligned carbon nanotubes: X-ray absorption method

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IEC TS 62607-2-5 has been prepared by IEC technical committee 113: Nanotechnology standardization for electrotechnical products and systems. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
113/674/DTS	113/696/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62607 series, published under the general title *Nanomanufacturing – Key control characteristics*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Vertically-aligned carbon nanotubes (VACNTs) are array structures, in which nanotubes are oriented in the perpendicular direction to a substrate surface. VACNTs are useful in many electronic device applications such as field-emission devices, gas and biological sensors, thermal interface materials, supercapacitors, and so on. Chemical vapour deposition (CVD) is one of the common methods for the synthesis of VACNTs, where CNTs can be grown in the presence of metal catalysts, via thermal decomposition of hydrocarbon sources such as methane, ethylene, acetylene, ethanol, and so on.

Physical (electrical, thermal, etc.) properties of VACNT films really depend on their density, which is reflected by distribution and alignment behaviours of individual CNTs. The mass density of nanotubes in VACNT samples was evaluated in various ways. The first choice is measuring the sample mass gain, which is successively divided by the height and the area of the VACNT samples for obtaining density values. However, this mass gain method is a destructive method, and is effective only if the mass of CNTs can be measured with a microbalance, so that the mass density can be estimated from the mass gain during the CVD growth. The second method is counting the number of CNTs in scanning electron microscope (SEM) or transmission electron microscope (TEM) images. However, this counting method is less reliable when the nanotubes are not grown straight on the substrate and the density is low. Liquid-induced compaction can compact the VACNT samples to a maximum density with wetting or drying process of alcohols. However, these methods are destructive analyses (except for SEM) and are not designed for incorporating the wide distribution in size and alignment of nanotubes observed in realistic VACNT samples. Hence, there is strong demand for the development of new reliable methods for evaluating density in VACNTs.

In this context, an X-ray absorption method is proposed as a standard protocol for evaluating density of VACNTs. X-rays can transmit through the film parallel to the substrate surface, and the transmitted X-rays are detected by a high-resolution X-ray imaging apparatus. The observed X-ray projection images can enable the substrate, VACNT film, and air regions to be identified easily. The film density can be calculated from the measured X-ray transmittance of the film. This method is an effective and versatile technique of nondestructive analysis for VACNT film density.

NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

Part 2-5: Carbon nanotube materials – Mass density of vertically-aligned carbon nanotubes: X-ray absorption method

1 Scope

This part of IEC 62607 specifies the protocols for determining the mass density of vertically-aligned carbon nanotubes (VACNTs) by X-ray absorption method. This document outlines experimental procedures, data formats, and some case studies. These protocols are applicable to VACNT films with thickness larger than several tens of micrometres. There are no limitations in materials for substrate.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

There are no normative references in this document.