# IEC TS 62607-2-6

Edition 1.0 2024-08

# TECHNICAL SPECIFICATION

colour inside

## Nanomanufacturing – Key control characteristics – Part 2-6: Carbon nanotube-related products – Thermal diffusivity of vertically-aligned carbon nanotubes: flash method



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IEC TS 62607-2-6 has been prepared by IEC technical committee 113: Nanotechnology 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 |
|---|---|
| 113/823/DTS | 113/845/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- withdrawn, or
- revised.

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# INTRODUCTION

Vertically-aligned carbon nanotubes (VACNTs) possess array structures, in which nanotubes are oriented in the perpendicular direction to a substrate surface. 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. VACNTs are promising as thermal interface materials in electronics assembly owing to their high thermal conductivity, desirable mechanical properties, and good stability. Thermal transport properties in VACNT films really depend on their distribution and alignment behaviours of individual nanotubes, disorders such as defects and impurities.

Thermal diffusivity is one of the key parameters that govern thermal transport properties in solid materials. Flash method is a well-established, standard technique for measuring the thermal diffusivity. Originally, flash method was applicable to homogeneous monolithic (single layer) samples. In fact, some previous works reported thermal diffusivity measurements for self-standing VACNTs that were peeled off from the substrates after the CNT growth. However, VACNT films will be tightly connected to solid substrates in possible practical applications such as thermal interface materials. This means that flash method can not be simply applied to VACNT films grown on solid substrates. Hence, there is a need for new reliable protocols based on flash method for evaluating thermal diffusivity of VACNT films on solid substrates. This document specifies standardized protocols for measuring thermal diffusivity of VACNTs grown on solid substrates with flash method, where the specimen is a bilayer of the VACNT film and the substrate.

# NANOMANUFACTURING –
# KEY CONTROL CHARACTERISTICS –

# Part 2-6: Carbon nanotube-related products –
# Thermal diffusivity of vertically-aligned carbon nanotubes: flash method

## 1 Scope

This part of IEC 62607 specifies a protocol for determining the key control characteristic

- thermal diffusivity

for vertically-aligned carbon nanotube (VACNT) films grown on solid substrates by

- flash method.

A light pulse from a flash lamp or a laser is irradiated onto the front surface (substrate side) of the VACNT film on solid substrates. Then, the temperature change of the other side of the specimen is monitored in real time after the pulse irradiation. The thermal diffusivity of the VACNT film can be analysed from the time variation of this temperature change.

– This method is applicable for evaluating the thermal transport properties of the VACNT films that can be used as thermal interface materials in electronics assembly.



## 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.



IEC TS 62607-2-5:2022, *Nanomanufacturing – Key control characteristics – Carbon nanotube materials – Mass density of vertically-aligned carbon nanotubes: X-ray absorption method*

ISO 18755:2022, *Fine ceramics (advanced ceramics, advanced technical ceramics) – Determination of thermal diffusivity of monolithic ceramics by flash method*

## 3 Terms, definitions and abbreviated terms

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

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

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

## 3.1 Terms and definitions

**3.1.1**
**carbon nanotube**
**CNT**
nanotube composed of carbon

[SOURCE: ISO/TS 80004-3:2020, 3.3.3, modified – Note 1 to entry has been deleted.]

**3.1.2**
**vertically-aligned carbon nanotubes**
**VACNTs**
carbon nanotube bundle grown in the perpendicular direction to a substrate surface

[SOURCE: IEC TS 62607-2-5:2022, 3.1.4]

**3.1.3**
**thickness**
$h$
dimension of the test specimen in the direction of heat transfer measurement

[SOURCE: ISO 19629:2018, 3.3]

**3.1.4**
**mass density**
$\rho$
at a given point within a three-dimensional domain of quasi-infinitesimal volume d$V$, scalar quantity equal to the mass d$m$ within the domain divided by the volume d$V$

$\rho = \mathrm{d}m/\mathrm{d}V$

[SOURCE: IEC 60050-113:2011, 113-03-07, modified – The formula has been moved to a new line.]



**3.1.5**
**specific heat capacity**
$C$
heat capacity divided by mass

[SOURCE: IEC 60050-113:2011, 113-04-48, modified – The formula and Notes have been deleted.]

**3.1.6**
**volumetric heat capacity**
heat capacity divided by volume

**3.1.7**
**thermal diffusivity**
$\alpha$
thermal conductivity divided by the volumetric heat capacity

**3.1.8**
**thermal conductivity**
*k*
density of heat flow rate divided by temperature gradient under steady state condition

Note 1 to entry: Thermal conductivity is calculated by using the equation $k = \alpha\rho C$.

[SOURCE: ISO 18755:2005, 3.2, modified – Note 1 to entry has been added.]

**3.1.9**
**thermal effusivity**
*b*
heat transport property given by the product of volumetric heat capacity and square root of thermal diffusivity

**3.1.10**
**thermal diffusion time**
$\tau$
square of thickness divided by thermal diffusivity

**3.1.11**
**maximum temperature rise**
$\Delta T_{\max}$
difference between the steady temperature before the pulse heating and the maximum temperature of the rear face of the specimen after the pulse heating

[SOURCE: ISO 18755:2022, 3.10, modified – Note 1 to entry has been deleted.]

### 3.2 Abbreviated terms

CVD chemical vapour deposition

SEM scanning electron microscope



## 4 Measurement of thermal diffusivity of vertically-aligned carbon nanotubes on solid substrates with flash method

### 4.1 General

Flash method prevails as a well-established, standard technique for measuring the thermal diffusivity of solid materials [1][1]. A light pulse from a flash lamp or a laser is irradiated onto one side of a monolithic planar specimen under adiabatic conditions. Then, the temperature change of the other side of the specimen is monitored in real time after the pulse irradiation. The thermal diffusivity of the solid can be calculated from the time variation of this temperature change. In this document, flash method is applied to VACNT films grown on solid substrates. In this case, the specimen is a bilayer of the VACNT film and the substrate. Accordingly, it is desirable that the measurement protocols for the transient temperature curve are based on 4.2 to 4.7. Case studies of measuring thermal diffusivity of VACNT films grown on Si substrate are provided in Annex A. In addition, rough estimation of thermal conductivity of VACNT films from the measured thermal diffusivity values is described in Annex B.

1 Numbers in square brackets refer to the Bibliography.