IEC TS 62607-6-4

Edition 2.0 2024-02

TECHNICAL SPECIFICATION

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Nanomanufacturing – Key control characteristics – Part 6-4: Graphene-based materials – Surface conductance: non-contact microwave resonant cavity method

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 07.120

ISBN 978-2-8322-8317-2

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NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

Part 6-4: Graphene-based materials – Surface conductance: non-contact microwave resonant cavity method

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IEC TS 62607-6-4 has been prepared by IEC technical committee 113: Nanotechnology for electrotechnical products and systems. It is a Technical Specification.

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) changed the document title to better reflect its purpose and application:

old title: Graphene – Surface conductance measurement using resonant cavity

new title: Graphene based materials – Surface conductance: non-contact microwave resonant cavity method.

b) replaced former Figure 1 with new Figure 1 and Figure 2, to better illustrate the method's fundamentals and its implementation for a non-technical reader.

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

Draft	Report on voting
113/756/DTS	113/809/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- withdrawn, or
- amended.

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INTRODUCTION

The microwave cavity test method for surface conductance is non-contact, fast, and accurate. It is well suited for standards development, research and development (R&D), and for quality control in the manufacturing of two-dimensional (2D) nano-carbon materials. These sheet-like or flake-like carbon forms can be assembled into atomically thin monolayer or multilayer graphene materials. They can be stacked, folded, crumpled, or pillared into a variety of nano-carbon architectures with the vertical dimension limited to a few tenths of a nanometre. Many of these 2D materials, and their derivatives, are new and exhibit extraordinary physical and electrical properties such as optical transparency, anisotropic heat diffusivity, and charge transport that are of significant interest to science, technology, and commercial applications [1][1], [2], [3].

Depending on particular morphologies, density of states, and structural perfection, the surface conductance of these materials can vary from1 S to about 10^{-5} S. Conventional direct current (DC) surface conductance measurement techniques require a complex test vehicle and interconnections for making electrical contacts to such materials, which affect and distort the measurement, thus, making it difficult to resolve the intrinsic properties of the material from the artifacts associated with the electrical contact formation.

In comparison, the resonant cavity measurement method is non-contact, fast, and avoids the artifacts associated with the electrical contact formation. Thus, it is well suited for use in R&D and manufacturing environments where the surface conductance is a critical functional parameter. Moreover, it can be employed to measure electrical characteristics of other nano-size structures without the need for establishing electrical contacts or sample thickness.

[1] Numbers in square brackets refer to the Bibliography.

NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

Part 6-4: Graphene-based materials – Surface conductance: non-contact microwave resonant cavity method

1 Scope

This part of IEC 62607 establishes a standardized method to determine the key control characteristic

- surface conductance

for films of graphene and graphene-based materials by the

- non-contact microwave resonant cavity method

The non-contact microwave resonant cavity method monitors the microwave resonant frequency shifts and changes in the cavity's quality factor during the insertion of the specimen into the microwave cavity, as a function of the specimen surface area. The empty cavity is an air-filled standard R100 rectangular waveguide operated at one of the resonant frequency modes, typically at 7,5 GHz [4].

– The method is applicable for graphene materials which are synthesized by chemical vapour deposition (CVD) on metal substrates, epitaxial growth on silicon carbide (SiC), obtained from reduced graphene oxide (rGO), or mechanically exfoliated from graphite [5].

– This measurement does not explicitly depend on the thickness of the nano-carbon layer. The thickness of the specimen does not need to be known, but it is assumed that the lateral dimensions are uniform over the specimen area.

NOTE In some countries, the R100 standard waveguide is referenced as WR-90.

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.

ISO/TS 80004-13, *Nanotechnologies – Vocabulary – Part 13: Graphene and related two-dimensional (2D) materials*