



TECHNICAL SPECIFICATION



**Nanomanufacturing – Key control characteristics –
Part 6-4: Graphene – Surface conductance measurement using resonant cavity**

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CONTENTS

FOREWORD.....	3
INTRODUCTION.....	5
1 Scope.....	6
2 Normative references.....	6
3 Terms and definitions	6
3.1 Graphene layers	6
3.2 Measurement terminology	8
4 Microwave cavity test fixture	9
5 Test specimen	10
6 Measurement procedure	10
6.1 Apparatus	10
6.2 Calibration	11
6.3 Measurements	11
6.3.1 General	11
6.3.2 Empty cavity	11
6.3.3 Specimen.....	11
6.3.4 Repeated procedure.....	12
6.3.5 Substrate.....	12
7 Calculations of surface conductance	12
8 Report.....	12
9 Accuracy consideration.....	13
Annex A (informative) Case study of surface conductance measurement of single-layer and few-layer graphene	14
A.1 General.....	14
A.2 Cavity perturbation procedure.....	14
A.3 Experimental procedure	15
A.4 Results	15
A.5 Surface conductance of single-layer graphene and few-layer graphene	16
A.6 Summary	17
Bibliography	18
Figure 1 – Microwave cavity test fixture	10
Figure A.1 – S_{21} magnitude of the resonant peak TE_{103} as a function of frequency at several specimen insertions (h_x)	16
Figure A.2 – Plots of $1/Q_x - 1/Q_0$ as a function of the normalized specimen area (wh_x).	16

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**NANOMANUFACTURING –
KEY CONTROL CHARACTERISTICS –****Part 6-4: Graphene – Surface conductance
measurement using resonant cavity**

FOREWORD

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

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

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

Enquiry draft	Report on voting
113/295/DTS	113/324/RVC

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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 "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- transformed into an International Standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

The microwave resonant cavity test method for surface conductance is non-contact, fast, sensitive and accurate. It is well suited for standards, 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, which can be stacked, folded, crumpled or pillared into a variety of nano-carbon architectures with the lateral dimension limited to a few tenths of a nanometre. Many of these materials 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, 2]¹.

Depending on particular morphologies, density of states and structural perfection, the surface conductance of these materials may vary from 1 S to about 10^{-4} S. Conventional direct current (DC) surface conductance measurement techniques require a complex test vehicle and interconnections for making electrical contacts, which affect and alter the measurement, making it difficult to decouple the intrinsic properties of the material.

In comparison, the resonant cavity measurement method is fast and non-contact. 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.

¹ Numbers in square brackets refer to the Bibliography

NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

Part 6-4: Graphene – Surface conductance measurement using resonant cavity

1 Scope

This part of IEC 62607 establishes a method for determining the surface conductance of two-dimensional (2D) single-layer or multi-layer atomically thin nano-carbon graphene structures. These are synthesized by chemical vapour deposition (CVD), epitaxial growth on silicon carbide (SiC), obtained from reduced graphene oxide (rGO) or mechanically exfoliated from graphite [3]. The measurements are made in an air filled standard R100 rectangular waveguide configuration, at one of the resonant frequency modes, typically at 7 GHz [4].

Surface conductance measurement by resonant cavity involves monitoring the resonant frequency shift and change in the quality factor before and after insertion of the specimen into the cavity in a quantitative correlation with the specimen surface area. 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 dimension is uniform over the specimen area.

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 60153-2, *Hollow metallic waveguides – Part 2: Relevant specifications for ordinary rectangular waveguides*