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TECHNICAL SPECIFICATION

Nanomanufacturing - Key control characteristics -
Part 6-28: Graphene-related products - Number of layers for graphene films on a substrate: Raman spectroscopy

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CONTENTS

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Nanomanufacturing - Key control characteristics - Part 6-28: Graphene-related products - Number of layers for graphene films on a substrate: Raman spectroscopy

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IEC TS 62607-6-28 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
113/897/DTS	113/923/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– withdrawn, or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.

INTRODUCTION

Graphene-related products have appealing performance in electrical, optical, mechanical and thermal properties, which have aroused widespread interests in both academic and industrial communities. The number of layers of graphene-related products is one of the key control characteristics (KCCs) affecting their performance. Therefore, the accurate measurement of the number of layers is a critical issue in related research and applications. Raman spectroscopy is a fast, non-destructive and highly sensitive characterization tool used in graphene-related research. The most prominent Raman peaks in graphene layers are the D-peak (~1 350 cm^{-1}), the G-peak (~1 580 cm^{-1}), and the 2D-peak (also known as the G'-peak, ~ 2 700 cm^{-1}, which depends on the excitation energy and number of layers). Their peak positions, peak intensities and peak shapes can be used to determine the number of layers [1][1]. For example, the intensity ratio of 2D-peak and G-peak (I_{2D}/I_G) of roughly 2 or higher provides a good identification of monolayer graphene. As the number of graphene layers increasing, the I_{2D}/I_G ratio decreases rapidly.

As for multilayer graphene layers with Bernal stacking (AB stacking) and rhombohedral stacking (ABC stacking) prepared by mechanical exfoliation, the spectral characteristics of their Raman peaks show certain relationships with the number of layers. For example, the 2D-peak of graphene-related products with AB stacking less than 5 layers has a distinctive peak shape that is related to the number of layers but independent of the substrate. The Raman peak intensity of the silicon substrate underneath the graphene-related products with AB and ABC stacking is also related to the number of layers. The $I_G(Si)/I_0(Si)$ intensity ratio declines linearly with the number of layers, where $I_G(Si)$ is the Raman peak intensity of silicon substrate underneath the graphene layers while $I_0(Si)$ is that of the bare silicon substrate [2] [3]. Therefore, the number of graphene layers up to 10 can be precisely determined using only Raman spectroscopy based on these two criteria.

Both methods employ Raman spectroscopy to characterize the number of layers of graphene-related products. Method A is based on the Raman shape of 2D-peak and is suitable for mechanical exfoliated graphene-related products with AB stacking and less than 5 layers. Method B is based on the intensity ratio of the $I_G(Si)/I_0(Si)$ and is applicable to mechanical exfoliated and chemical vapor deposition grown graphene-related products with AB and ABC stacking and the number of layers up to 10. The purpose of this document is to provide scientific and reliable technical guidance for the electronic products and research of graphene-related products.

Since the crystallinity and structure of graphene-related products prepared by different processes can vary greatly, no existing characterization method is general. In practical applications, it is important to select or combine multiple characterization methods based on the crystallinity and structure of the graphene-related products under study that best meets the specific needs.

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

1 Scope

This part of IEC 62607 establishes two standardized methods to determine the key control characteristic

- number of layers

for graphene layers by

- Raman spectroscopy.

This document presents two complementary methods for determining the number of layers in graphene-related products: Method A, which analyzes the lineshape of the 2D-peak in the Raman spectrum, and Method B, which measures the Raman intensity from the underlying silicon substrate. The two methods can be employed individually but combining both methods enhances accuracy and extends the detection range for the number of layers and stacking configurations.

– The method is intended to be used for graphene layers prepared by mechanical exfoliation, but also can be used with care for other high quality graphene layers, such as graphene layers prepared by chemical vapor deposition.

– The method can be used for graphene layers with AB and ABC stacking on a substrate. Its lateral size should be at least 2 μm.

– Method A is effective for AB stacked graphene up to 4 layers but becomes less reliable with more layers due to peak overlap.

– Method B can detect up to 10 layers in AB and ABC stacking but oxidized silicon substrate (SiO_2 on silicon substrate) is required.

– The comparison of Method A and Method B can be found in Annex A.

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 TR 63258, *Nanotechnologies - A guideline for ellipsometry application to evaluate the thickness of nanoscale films*