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TECHNICAL SPECIFICATION

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Nanomanufacturing – Key control characteristics – Part 6-11: Graphene – Defect density: Raman spectroscopy

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FOREWORD

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IEC TS 62607-6-11 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
113/591/DTS	113/626/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/standardsdev/publications.

A list of all parts in the IEC TS 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- withdrawn,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

Graphene is a single layer of carbon atoms arranged in a honeycomb lattice. Due to its outstanding properties such as high mobility and flexibility, it has high potential for future applications. Structural defects, e.g. anything that changes the regularity of the lattice, have a huge influence on the properties of graphene, especially the mobility. For most electronic applications having high quality, almost defect-free graphene is crucial. Thus the defect density as a measure of the structural quality of graphene is a key control characteristic of graphene.

Raman spectroscopy is one of the most widely used characterization techniques in carbon science and technology. There are two main peaks in the Raman spectrum of graphene, the G peak located around 1 580 cm^{-1} and the 2D peak located around 2 680 cm^{-1} for an excitation wavelength of 514 nm. Raman spectroscopy can be used to extract valuable information about the sample properties such as the number of layers, doping level, amount and type of strain as well as defect density [1][1]. Quantifying defects in graphene is crucial for both gaining insight in fundamental properties and for applications. Defects strongly affect the mobility of graphene. It is thus important for device fabrication and optimization as well as a quality check to know the defect density in a sample.

Disorder of the graphene lattice can be described [2] in a three-stage classification, leading from graphite to amorphous carbons, that allows to simply assess all the Raman spectra of carbons:

- Stage 1: graphene to nanocrystalline graphene.
- Stage 2: nanocrystalline graphene to low-sp^3 amorphous carbon.
- Stage 3: low-sp^3 amorphous carbon to high-sp^3 amorphous carbon.

This classification is illustrated in Figure 1.

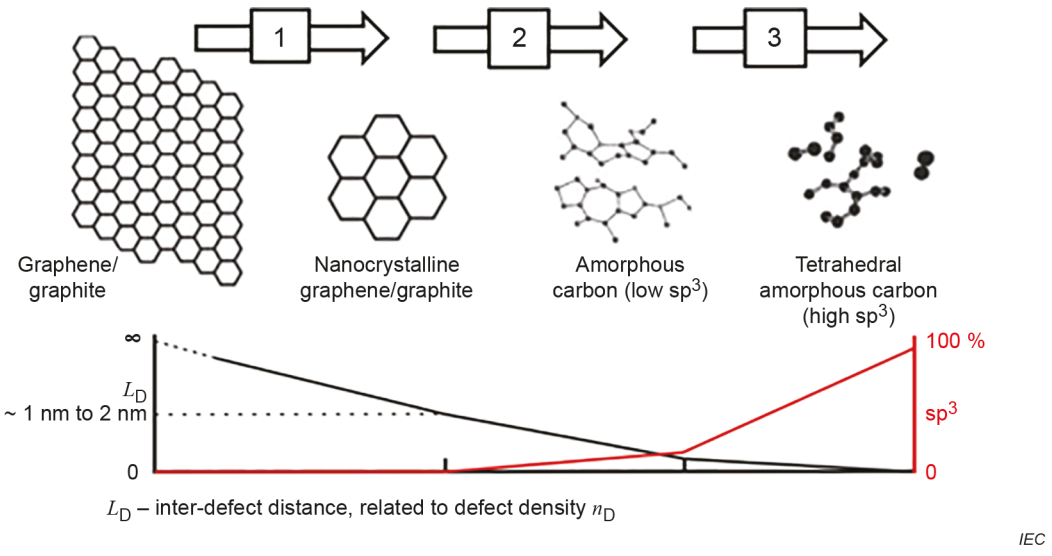

Figure 1 – Three-stage classification to describe graphene lattice disorder

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

NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

Part 6-11: Graphene – Defect density: Raman spectroscopy

1 Scope

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

- defect density n_D

of graphene films grown by chemical vapour deposition as well as exfoliated graphene flakes by

- Raman spectroscopy.

The defect density n_D is derived from the intensity ratio of the D-peak and the G-peak $I(D)/I(G)$ in the Raman spectrum based on the three-stage model for amorphization.

- The classification helps manufacturers to classify their material quality and customers to provide an expectation of the electronic performance of the classified graphene and more specifically to decide whether or not the graphene material quality is potentially suitable for various applications.
- The defect density n_D determined in accordance with this document is listed as a key control characteristic in the blank detail specification for graphene IEC 62565-3-1. The inter-defect distance L_D can be calculated from the defect density n_D and is an equivalent measure of defects in the graphene lattice.
- The method is applicable for exfoliated graphene and graphene grown on or transferred to a substrate with $I(D)/I(G)$ in the range of 0,1 to 3, which corresponds to a defect density of $2{,}46 \times 10^{10}$ cm^{-1} up to $7{,}39 \times 10^{11}$ cm^{-2} for an excitation energy of 2,41 eV (514 nm), corresponding to stage 1 of the three-stage model for amorphization.
- The spatial resolution is in the order of 1 µm given by the spot size of the exciting laser.
- The method is complementary to the method described in IEC 62607-6-6 and is used if the Raman spectrum shows a visible D-peak with an intensity ratio $I(D)/I(G)$ in the range of 0,1 to around 3.

2 Normative references

There are no normative references in this document.