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colour inside

Nanomanufacturing – Key control characteristics –
Part 6-6: Graphene – Strain uniformity: Raman spectroscopy

INTERNATIONAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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IEC TS 62607-6-6 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
113/579/DTS	113/605/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 of 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- withdrawn,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, a single layer of carbon atoms arranged in a honeycomb lattice, has a high potential for future nanoelectronic applications thanks to the excellent conductivity and high flexibility of the material. As there is a strong connection between nanoscale lattice deformations and carrier mobility, the uniformity of strain and flatness of the graphene lattice is a key control characteristic for the fabrication of high-quality graphene layers for electronic devices.

One of the most useful methods to evaluate the structural properties of graphene is Raman spectroscopy (see, for example, [1][1]). The method is simple, fast, non-destructive and well understood so that the Raman spectrum can be used as a fingerprint for graphene especially if the sample under evaluation consists of single-layer graphene not too far away from perfection. Things become more complicated if the sample consists of more than one layer, perhaps with different stacking angles and many lattice defects. As this document is intended to support the fabrication of nearly defect-free high-quality single-layer graphene, the interpretation of the Raman spectrum remains relatively simple.

As recently reported [2], nanometre-scale strain variations in graphene give rise to a pseudo-vector disorder potential which allows the pseudo-spin in graphene to flip and thus enables intra-valley backscattering. This scattering mechanism has been identified to be the responsible mechanism for limiting the carrier mobility in high-quality graphene [2]. Interestingly these nanometre-scale strain variations are directly connected to the experimentally observed linewidth of the Raman 2D-peak [3], making this quantity a very interesting measure for estimating the possibility of getting very high mobility graphene devices.

It is important to note that although graphene is a truly two-dimensional material, consisting exclusively of surface atoms, it is embedded in our three-dimensional world. This has the consequence that the properties of graphene are in all cases intrinsically influenced by its intimate surrounding. Thus, substrates or contact gases (in the case of suspended graphene) play a very crucial role when fabricating, transferring and characterizing graphene. Most crucially, substrates, contact gases and moisture are actually becoming part of the graphene system under investigation and there is no way (in practice) of eliminating their influence on the two-dimensional graphene layer.

1 Numbers in sqaure brackets refer to the Bibliography.

NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

Part 6-6: Graphene – Strain uniformity: Raman spectroscopy

1 Scope

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

- strain uniformity

for single-layer graphene by

- Raman spectroscopy.

The width of the 2D-peak in the Raman spectrum is analysed to calculate the strain uniformity parameter which is a figure of merit to quantify the influence of nano-scale strain variations on the electronic properties of the layer. The classification will help manufacturers to classify their material quality to provide an upper limit of the electronic performance of the characterized graphene, to decide whether or not the graphene material quality is potentially suitable for various applications.

- The uniformity of strain measured by this method is applicable for nearly defect free, high-quality single-layer graphene, e.g. synthesized by chemical vapour deposition or graphene integrated into 2D-material heterostructures.
- The method is used if the Raman spectrum shows a visible D-peak with an integrated intensity ratio $A(D)/A(G) < 0,1$.
- Confocal Raman spectroscopy is used to consistently evaluate the graphene layer according to strain variations on the nanoscale.

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 62607-6-11, *Nanomanufacturing – Key control characteristics – Part 6-11: Graphene film – Defect density: Raman spectroscopy* [2]

[2] Under preparation. Stage at the time of publication: IEC DTS 62607-6-11.