

SINGAPORE STANDARD

**Structural characterisation of graphene flakes –
Part 3: Determination of level of defects on
graphene flakes by Raman spectroscopy**

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	Dr Sanjay Thakur	<i>Individual Capacity</i>

The Working Group on Graphene, appointed by the Technical Committee to assist in the preparation of this standard, comprises the following experts who contribute in their *individual capacity*:

	Name
Co-Convenors	: Dr Ricardo Vinicius Oliveira
	: Dr Ramam Akkipeddi
Secretary	: Ms Rosmalinda Tay
Members	: Dr Fan Rongli
	Mr Ng Chun Tat
	Dr Vitali Lipik
	Dr Yu Shengkai

The organisations in which the experts of the Working Group are involved are:

Housing & Development Board

Institute of Materials Research and Engineering

National Metrology Centre

NUS Centre for Advanced 2D Materials and Graphene Research Centre

PUB, Singapore's National Water Agency

Sportmaster

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Foreword

This Singapore Standard was prepared by the Working Group on Graphene appointed by the Technical Committee on Nanotechnology under the purview of the Chemical Standards Committee.

SS 643 consists of the following four parts, under the general title, 'Structural characterisation of graphene flakes':

Part 1: Methods and sample preparation

Part 2: Determination of lateral size of graphene flakes by optical microscopy

Part 3: Determination of level of defects on graphene flakes by Raman spectroscopy

Part 4: Determination of number of layers in graphene flakes by atomic force microscopy

Part 1 is essential for the implementation of the standard and is used with Parts 2, 3 or 4.

In preparing this standard, reference was made to the following publications:

ISO 18115-2:2013	Surface chemicals analysis – Vocabulary – Part 2: Terms used in scanning-probe microscopy
ISO 18466:2016	Stationary source emissions – Determination of the biogenic fraction in CO ₂ in stack gas using the balance method
ISO/TS 80004-13:2017	Nanotechnologies – Vocabulary – Part 13: Graphene and other two-dimensional materials

Acknowledgement is made for the use of information from the above publications.

This standard is expected to be used by manufacturers, buyers, users and testing laboratories involved in the production and commercialisation of graphene, academia and IHLs in Singapore which have formed the nanotechnology research entities, relevant regulatory bodies and conformity assessment bodies.

Attention is drawn to the possibility that some of the elements of this Singapore Standard may be the subject of patent rights. Enterprise Singapore shall not be held responsible for identifying any or all of such patent rights.

NOTE

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Structural characterisation of graphene flakes – Part 3: Determination of level of defects on graphene flakes by Raman spectroscopy

0 Introduction

Graphene is a single layer of carbon atoms with each atom bound to three neighbours in a honeycomb structure [1]. Since its discovery in 2004 by two researchers at the University of Manchester, graphene has been considered a wonder material with the potential to revolutionise industrial sectors, from coatings and composites to electronics and aerospace, due to its properties such as mechanical strength, high electrical and thermal conductivity, flexibility, impermeability, etc. The estimated global market for graphene is expected to reach a minimum of \$500 million by 2025 [2].

However, as in the case of any other revolutionary material, the development of these applications and their introduction into the market strongly depends on the quality of the graphene. There are currently no established international or national standards for graphene although there is currently ongoing work, detailed in ISO/TC 229 *Nanotechnologies* and IEC/TC 113 *Nanotechnology for electrotechnical products and systems*. The lack of an established standard leads to a plethora of producers selling “graphene products” which are essentially fine graphite, and not appropriate for the applications mentioned above.

The development of this Singapore Standard will help to provide manufacturers and users with standard methods for the characterisation of graphene. In addition, this standard is intended to be used to obtain certification of graphene materials.

1 Scope

This part of the standard specifies the principles and procedures to determine the level of defects of graphene flakes by Raman spectroscopy.

2 Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

SS 643 : Part 1	Structural characterisation of graphene flakes – Part 1: Methods and sample preparation
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