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inside

Nanomanufacturing – Key control characteristics –
Part 6-16: Two-dimensional materials – Carrier concentration: Field effect transistor method

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

Part 6-16: Two-dimensional materials – Carrier concentration: Field effect transistor method

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

Draft	Report on voting
113/679/DTS	113/698/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 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- withdrawn,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

Atomically thin 2D materials are expected to be used for future electrical sub-systems or electronic device applications. For these applications, the materials need to be doped with dopants to generate carriers. In contrast to 3D bulk materials, carrier concentrations in 2D materials are difficult to measure directly due to their limited thickness.

– Different from conventional 3D bulk materials in which doping effect is induced from activation of substitutional dopant atoms, the doping effect in 2D materials is mostly induced by generation of free carriers, for example electrons by using plasma treatment, chemical treatment, etc.

– In the 3D bulk materials, carrier concentration can be obtained by measuring concentration of dopant atoms under the assumption that both concentrations are the same. Therefore, it is possible to measure the doping concentration in 3D bulk materials using secondary ion mass spectroscopy (SIMS), which measures the concentration of dopant atoms, and using I-V or C-V characterization, which measures the concentration of free charge carriers such as electrons and holes [1][1].

– In contrast, in the 2D materials, carrier concentration needs to be measured for carriers such as electrons and holes which are induced from external means such as plasma treatment or chemical treatment.

For this reason, a standard method to determine the carrier concentration needs to be established for 2D materials.

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

NANOMANUFACTURING –
KEY CONTROL CHARACTERISTICS –

Part 6-16: Two-dimensional materials –
Carrier concentration: Field effect transistor method

1 Scope

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

- carrier concentration

for semiconducting two-dimensional materials by the

- field effect transistor (FET) method.

For semiconducting two-dimensional materials, the carrier concentration is evaluated using a field effect transistor (FET) test by a measurement of the voltage shift obtained from transfer curve upon doping process. The FET test structure consists of three terminals of source, drain, and gate where voltage is applied to induce the transistor action. Transfer curves are obtained by measuring drain current while applying varied gate voltage and constant drain voltage with respect to the source which is grounded.

- The method is applicable to semiconducting two-dimensional materials with a bandgap like that in transition metal dichalcogenides (MoS_2, $MoTe_2$, WS_2, WSe_2, etc.) and black phosphorous. Pristine graphene shows semi-metallic characteristics without bandgap, and therefore this method is not applicable to pristine graphene. However, it can be used for other graphenes with bandgap (for example, semiconducting graphene oxide).
- It is likely that the measurement results will help to qualify technologies if they are usable for future electrical sub-systems or electronic device applications.

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.

There are no normative references in this document.