IEC 62899-203

Edition 2.0 2024-05
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

Printed electronics –
Part 203: Materials – Semiconductor ink

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PRINTED ELECTRONICS –

Part 203: Materials – Semiconductor ink

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62899-203:2018. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 62899-203 has been prepared by IEC technical committee 119: Printed Electronics. It is an International Standard.

This second edition cancels and replaces the first edition published in 2018. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) addition of 6.3.1.2.2 – Normalised on-current measurement of the TFT device;

b) in 6.3.2, correction of formula for calculation of permittivity.

The text of this International Standard is based on the following documents:

Draft	Report on voting
119/485/FDIS	119/489/RVD

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 International Standard 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 62899 series, published under the general title *Printed electronics*, 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- withdrawn, or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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The IEC 62899 series deals mainly with evaluation methods for materials of printed electronics. The series also includes storage methods, packaging and marking, and transportation conditions.

The IEC 62899 series is divided into several parts according to each material. Each part is prepared as a generic specification containing fundamental information for the area of ~~printing~~ printed electronics.

~~The IEC 62899 series consists of the following parts:~~

~~Part 1: Terminology~~

~~Part 201: Materials – Substrates~~

~~Part 202: Materials – Conductive ink~~

~~Part 203: Materials – Semiconductor ink~~

~~Part 250: Material technologies required in printed electronics for wearable smart devices~~

~~Part 301-X: Equipment – Contact printing – Rigid master~~

~~Part 302-X: Equipment – Inkjet~~

~~Part 303-X: Equipment – Roll-to-roll printing~~

~~Part 401: Printability – Overview~~

~~Part 402-X: Printability – Measurement of qualities~~

~~Part 403-X: Printability – Requirements for reproducibility~~

~~Part 502-X: Quality assessment – Organic light emitting diode (OLED) elements~~

~~Furthermore, sectional specifications, blank detail specifications, and detail specifications for each material will be based on these parts.~~

This part of IEC 62899 is prepared for inks containing semiconducting materials used in printed electronics and contains the test conditions, the evaluation methods and the storage conditions.

PRINTED ELECTRONICS –

Part 203: Materials – Semiconductor ink

1 Scope

This part of IEC 62899 defines terms and specifies standard methods for characterization and evaluation of semiconductor inks and semiconductive layers that are made from semiconductor inks.

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 62860, *Test methods for the characterization of organic transistors and materials*

ISO 5-2, *Photography and graphic technology – Density measurements – Part 2: Geometric conditions for transmittance density*

ISO 5-3, *Photography and graphic technology – Density measurements – Part 3: Spectral conditions*

ISO 124, *Latex, rubber – Determination of total solids content*

ISO 291, *Plastics – Standard atmospheres for conditioning and testing*

~~ISO 304, *Surface active agents – Determination of surface tension by drawing up liquid films*~~

ISO 489:~~1999~~2022, *Plastics – Determination of refractive index*

ISO 758, *Liquid chemical products for industrial use – Determination of density at 20 °C*

ISO 1183-1, *Plastics – Methods for determining the density of non-cellular plastics – Part 1: Immersion method, liquid pycnometer method and titration method*

ISO 2555, *Plastics – Resins in the liquid state or as emulsions or dispersions – Determination of apparent viscosity ~~by the Brookfield Test~~ using a single cylinder type rotational viscometer method*

ISO 2592, *Petroleum and related products – Determination of flash and fire points – Cleveland closed cup method*

ISO 2719, *Determination of flash point – Pensky-Martens closed cup method*

ISO 2811-1, *Paints and varnishes – Determination of density – Part 1: Pycnometer method*

ISO 2811-2, *Paints and varnishes – Determination of density – Part 2: Immersed body (plummet) method*

ISO 2884-1, *Paints and varnishes – Determination of viscosity using rotary viscometers – Part 1: Cone-and-plate viscometer operated at a high rate of shear*

ISO 3219, *Plastics – Polymers/resins in the liquid state or as emulsions or dispersions – Determination of viscosity using a rotational viscometer with defined shear rate*

ISO 3251, *Paints, varnishes and plastics – Determination of non-volatile-matter content*

ISO 3664, *Graphic technology and photography – Viewing conditions*

ISO 3679, ~~*Determination of flash no-flash and flash point – Rapid equilibrium closed cup method*~~ *Determination of flash point – Method for flash no-flash and flash point by small scale closed cup tester*

ISO 13468-1:~~1996~~2019, *Plastics – Determination of the total luminous transmittance of transparent materials – Part 1: Single-beam instrument*

ISO 13468-2:1999, *Plastics – Determination of the total luminous transmittance of transparent materials – Part 2: Double-beam instrument*

ISO 13655, *Graphic technology – Spectral measurement and colorimetric computation for graphic arts images*

ISO 14488, *Particulate materials – Sampling and sample splitting for the determination of particulate properties*

ISO 14782, *Plastics – Determination of haze for transparent materials*

ISO 15212-1, *Oscillation-type density meters – Part 1: Laboratory instrum*ents

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62860 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

NOTE The terms in italic font are those defined in Clause 3.

3.1
semiconductive material
ingredient of a printing or coating material, which itself is electrically semiconductive

Note 1 to entry: The ingredient can be one or more small molecules, precursors, polymers, or particles.

Note 2 to entry: The ingredient can require post treatment to provide semiconductive properties.

3.2
semiconductor ink
liquid in which one or more inorganic particles, ions, salts, organic small molecules or organic polymers are dissolved or dispersed, and which becomes an electrically *semiconductive layer* (3.3) through solvent removal or post treatment such as UV, photonic, or thermal processing

[SOURCE: IEC 62899-101:2019, 3.121]

3.3
semiconductive layer
film-like semiconductive body of material made of *semiconductor ink* (3.2), which is printed or coated on a substrate, followed, as necessary, by using a post treatment such as UV, photonic, or thermal processing

[SOURCE: IEC 62899-101:2019, 3.119]

3.4
semiconductor film
substrate (sheet or roll) with *semiconductive layer* (3.3)

[SOURCE: IEC 62899-101:2019, 3.120]

3.5
solid content
mass fraction of an ingredient which effectively functions as a *semiconductive material* (3.1) dissolved or dispersed in a solvent to form a *semiconductor ink* (3.2)

Note 1 to entry: In some instances the ink ~~may~~ can include insulating materials, sometimes referred to as binders, or other additives included to improve the film formation during coating or printing.

3.6
non-volatile content
mass fraction of residue obtained by evaporation of the volatile solvent under specific conditions, in *semiconductor ink* (3.2)

3.7
dispersion
heterogeneous system in which fine separated materials are distributed uniformly in other materials

3.8
flash point
lowest liquid temperature at which, under certain standardized conditions, a liquid gives off vapours in quantity such as to be capable of forming an ignitable vapour/air mixture

[SOURCE: IEC 60050-212:2010, 212-18-05]

3.9
field effect mobility
majority carrier mobility of *semiconductive material* (3.1) derived through the transfer curve measurement of a fabricated *TFT* (3.10) device

Note 1 to entry: The field effect mobility is usually derived from either saturation or linear approximations.

Note 2 to entry: Field effect mobility is given in units of $cm^2/V{\cdot}s$.

3.10
thin-film transistor
TFT
switching device made from three electrodes (source, drain and gate) and semiconducting and insulating layers, wherein potentials applied to a gate electrode modulate charge carriers on the opposite side of the insulating layer situated between the gate and *semiconductive layer* (3.3)

Note 1 to entry: The change in charge density in the *semiconductive layer* changes its conductivity, and this in turn allows a modulation in current flow between the source and drain electrodes for a given source-drain potential difference.

Note 2 to entry: TFTs are found in a wide variety of electronic devices such as integrated circuits and display backplanes.

4 Atmospheric conditions for evaluation and conditioning

The standard atmosphere for evaluation (test and measurement) and storage of the specimen shall be a temperature of (23 ± 2) °C and relative humidity of (50 ± 10) %, ~~conforming to~~ in accordance with standard atmosphere class 2 as specified in ISO 291. If a polymer substrate is used for a test piece coated with a semiconductive layer, the standard atmosphere for evaluation shall be a temperature of (23 ± 1) °C and relative humidity of (50 ± 5) %, ~~conforming to~~ in accordance with standard atmosphere class 1 as specified in ISO 291.

If conditioning is necessary, the same standard atmosphere as specified above shall apply.

5 Evaluation of properties of semiconductor ink

5.1 Specimen

The specimen for evaluation shall be prepared in accordance with ISO 14488 or an equivalent method. If necessary, dilution by a compatible solvent ~~may be allowed~~ is permitted. For semiconductor inks, in many cases the properties to be evaluated ~~could~~ can be influenced by the choice of solvent and method of deposition. Consideration of the likely effects of solvent choice and ink deposition should be made in light of the semiconductor chemistry ~~and/or~~, the ink composition or both.

5.2 Contents

5.2.1 Solid content

5.2.1.1 Determination of solid content

Solid content of semiconductive materials and non-semiconductive materials shall be determined by the theoretical mass fraction (expressed as a percentage) of functional ingredients to the total ink mass. Functional ingredients include semiconductive materials, their precursors or binders, or any additives.

5.2.1.2 Report of the results

The report shall include the following items:

a) unique specimen identification;
b) date of test;
c) atmospheric conditions of test;
d) solid content.

5.2.2 Non-volatile content

5.2.2.1 Principle

Non-volatile content is determined by measuring the mass of residue after evaporation of the volatile ingredients and calculating the mass fraction (expressed as a percentage) to the total ink mass.

5.2.2.2 Test method

The test method shall be as specified in ISO 3251 with the following exceptions:

a) Air pressure: 86 kPa to 106 kPa.

b) If specified by the manufacturer, the test ~~may~~ can be performed under reduced pressure. The conditions and procedures for reducing the pressure shall be as specified in ISO 124 or by the manufacturer.

c) Materials which do not react with the ink during an examination shall be used.

d) Repeat the test until the weight becomes constant within 5 %.

5.2.2.3 Report of the results

The report shall include the following items:

a) specimen identification;

b) test conditions (air pressure if reduced, drying temperature and time);

c) specimen mass;

d) results.

5.3 Physical properties

5.3.1 Density

5.3.1.1 ~~Measuring~~ Measurement method

The ~~measuring~~ measurement method shall either be the pyknometer method as specified in ISO 758, ISO 1183-1 and ISO 2811-1, the method using oscillation-type density meters as specified in ISO 15212-1, or the immersed body (plummet) method as specified in ISO 2811-2. The detailed product specifications shall specify the ~~measuring~~ measurement method to be used.

5.3.1.2 Equipment

Equipment shall be as specified in the measurement method (see 5.3.1.1) or shall be equipment considered equivalent or superior.

5.3.1.3 Report of the results

The report shall include the following items:

a) specimen identification;

b) measurement method;

c) measurement atmosphere (temperature and relative humidity);

d) results.

5.3.2 Rheology

5.3.2.1 ~~Measuring~~ Measurement method

Viscosity shall be measured using a Brookfield type rotational viscometer as specified in ISO 2555, cone-and-plate viscometer as specified in ISO 2884-1, or rotational viscometer as specified in ISO 3219.

The detailed product specifications shall specify the ~~measuring~~ measurement method and measuring temperature to be used.

5.3.2.2 Report of the results

The report shall include the following items:

a) standard number of the measurement method;

b) specimen identification;

c) measuring temperature;

d) viscometer model;

e) viscosity expressed in millipascal second (mPa·s) at (a) shear rate(s) appropriate to the printing method(s) for which the ink is proposed to be used by the supplier.

5.3.3 Surface tension

5.3.3.1 ~~Measuring~~ Measurement method

Surface tension ~~shall~~ can be measured using the drawing up liquid film (Wilhelmy) method as specified in ISO 304 with the following exceptions:

a) equipment considered equivalent to that in ISO 304 ~~may~~ can be used;

b) the test jig shall be made of platinum;

c) the equipment shall be calibrated using pure water and a hanging weight.

Other methods of measuring surface tension can be used such as the Du Noüy method and the pendant drop method.

5.3.3.2 Report of the results

The report shall include the following items:

a) specimen identification;

b) measuring temperature;

c) measurement method used to evaluate the surface tension;

d) surface tension expressed in millinewton per metre (mN/m).

5.3.4 Flash point

5.3.4.1 ~~Measuring~~ Measurement method

Flash point shall be measured in accordance with ISO 2592 in the case of an open system. The method of "open system" is preferable for safety, however "closed systems" are also widely used. The measurement method based on ISO 2719 (closed system) and ISO 3679 (closed system) ~~may~~ can be applied if a closed system is required.