IEC TR 62899-302-5

Edition 1.0 2023-07

TECHNICAL REPORT

Printed electronics –
Part 302-5: Equipment – Inkjet – Significant characteristics of inkjet printing

IEC TR 62899-302-5:2023-07(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC TR 62899-302-5

Edition 1.0 2023-07

TECHNICAL REPORT

Printed electronics –
Part 302-5: Equipment – Inkjet – Significant characteristics of inkjet printing

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 19.080; 37.100.10

ISBN 978-2-8322-7173-5

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

PRINTED ELECTRONICS –

Part 302-5: Equipment – Inkjet – Significant characteristics of inkjet printing

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TR 62899-302-5 has been prepared by IEC technical committee 119: Printed Electronics. It is a Technical Report.

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

Draft	Report on voting
119/421/DTR	119/439/RVDTR

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 Report 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,
- replaced by a revised edition, or
- amended.

INTRODUCTION

Until recently, inkjet technologies were used only for imaging printing (conventional ‘graphic printing’). However, the recent development of inkjet technologies, such as technologies for inkjet print-head, functional ink, or print-head driving technologies, now makes it possible to apply these technologies for another area called functional printing, such as printed electronics.

Unlike conventional imaging printing, functional printing requires to have a very precise ink drop position so as to bring a functionality to what is produced. If the ink drop position is not exact, the expected function cannot be realized because the electronic connection secured by the ink drop position is vital for the electronic function of the final product. For example, when producing 2 000 imaging pixels by 1 000 imaging-pixels display, that display would have at least 2 000 × 1 000 = 2 000 000 active-matrix circuitries in order to show an image by that display. In addition, and because of the complexity of the above-mentioned circuitries, functional printing requires a higher resolution. Usually, an active-matrix circuitry consists of several active and passive electrical components, such as transistors and capacitors. Each component is usually made (or printed) using certain layers of different printed materials. Any printing defect in an active-matrix circuitry will be catastrophic for the performance of the printed device, such as shorted circuitry; when that display shows a uniform image, such as whole white or whole black image, that image shown by a display with a defect would be pretty obvious for a viewer because human eyes are very keen for a small number of detects in a uniform image. From that sense, a defect in a complex circuitry would be a big issue for an entire printed electronics device.

On the other hand, for imaging printing, a dropped ink position would not affect the image quality of that image as much as for functional printing, because usually a defect (for example, one dot does not have a dropped ink at all in the whole black image) will not be so obvious for human eyes.

Another important difference between functional printing and imaging printing by inkjet printing technologies is due to the fragmentation in the supply chain of the functional printing electronics markets. For imaging printing, until recently a vendor would provide inks, printing equipment including inkjet heads, and sometimes a printing substrate, paper. That means that the vendor could directly control the quality of all these elements. However, for functional printing, the functions come from inks, and inks usually come from ink vendors that are specialized for inks, and inkjet heads come from an inkjet head vendor that is specialized in inkjet heads. Sometimes, a printing equipment vendor makes their own printing equipment by using several inkjet heads. Obviously, a substrate is not always paper, but can consist of several kinds of film, such as plastic films, or metal foils, or both. That means vendors cannot control the whole process of printing but have to work closely with other vendors. Thus, for inkjet printing especially for printed electronics, it is extremely useful to have certain ways of evaluating functions of each component that compose functional printing.

This document explores what kind of characteristics of inkjet printing will be considered to obtain functionable printed electronics device(s), for example detailed characteristics of inkjet head(s).

PRINTED ELECTRONICS –

Part 302-5: Equipment – Inkjet – Significant characteristics of inkjet printing

1 Scope

This part of IEC 62899 provides the significant characteristics, parameters and system properties that are relevant for functional inkjet printing for printed electronics. Where possible, existing measurement standards and specifications are cited.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological 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

4 Inkjet printing

4.1 General

Generally, the purpose of printing is to put some material onto other materials. In that sense, ”printing” is sometimes called ”deposition”.

For imaging purposes, ”printing” means putting pigments or dye, which can contain colour, onto a substrate. A pigment and dye can reflect or sometimes emit light to form an image.

For electrically functional printing, ”printing” means putting electrically functional material onto a substrate. A functional material can show function(s), somehow. For printed electronics, ”printing” means putting electrically functional material(s) onto a substrate; for example,

1) an organic material that emits light when a correct electric current is applied,
2) a passive layer that protects the material under that layer, and
3) an insulating layer that electrically insulates between other materials or layers, or both.

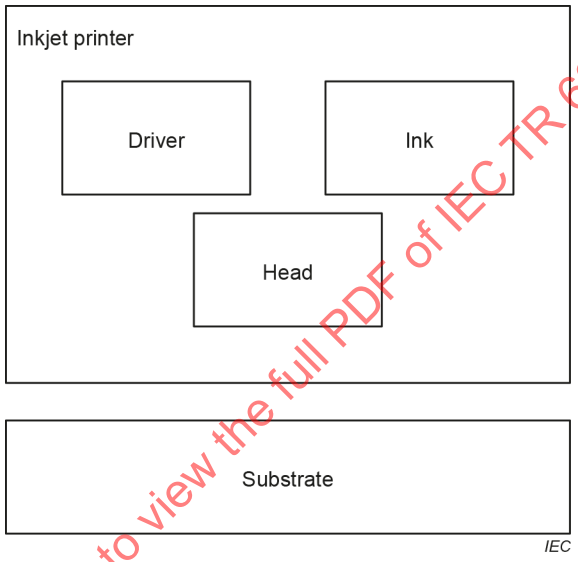
Material put onto a substrate can realize function(s). In order to have (a) proper function(s) by a printed material, the printed position of the material is very important

4.2 Issues of functional printing

As stated in the introduction, functional printing will have highly accurate printed positions for printed electronics applications. For example, a thin-film-transistor (TFT) made by printed electronics consists of several active components and passive components. Each component consists of several layers of printed or non-printed materials. In order to have a proper functional device, it is important that each component will have a proper function. In order to have a proper functional component, each material will show the proper function. In order to have a proper functional material, a proper material will be placed at the proper position. In order to have the proper material at the proper position, each material will be accurately placed. Thus, the accuracy of the placement of the printed material is one of the important key parameters for functional printing especially in printed electronics.

4.3 Components of inkjet printer

Figure 1 shows the typical example of an inkjet printer configuration.



NOTE Figure 1 shows only the major components. There are other components in an inkjet printer.

Figure 1 – Example of inkjet printer configuration

In 4.4 to 4.7 the physical parameters related to printed quality, especially dot placement, are described.

4.4 Characteristics of inkjet head

4.4.1 General

There are two major ink dropping (jetting) types, the one is called a continuous dropping (jetting) type that an inkjet head drops ink continuously, not stopping, and the other is called an intermittent dropping (jetting) type that an inkjet head does not drop ink continuously, but intermittently.

The inkjet head has several properties related to printed quality. The major ones are static physical properties and others are dynamic physical properties.

4.4.2 Static physical properties

4.4.2.1 General

Typical static physical properties that affect printing quality are shown in Table 1.

Table 1 – Static physical properties of inkjet head

Property	Subclause
Nozzle position	4.4.2.2
Nozzle layout	4.4.2.3
Shape of nozzle	4.4.2.4
Size and number of nozzles	4.4.2.5
Mounting position	4.4.2.6
Distance between print head(s) and substrate	4.4.2.7

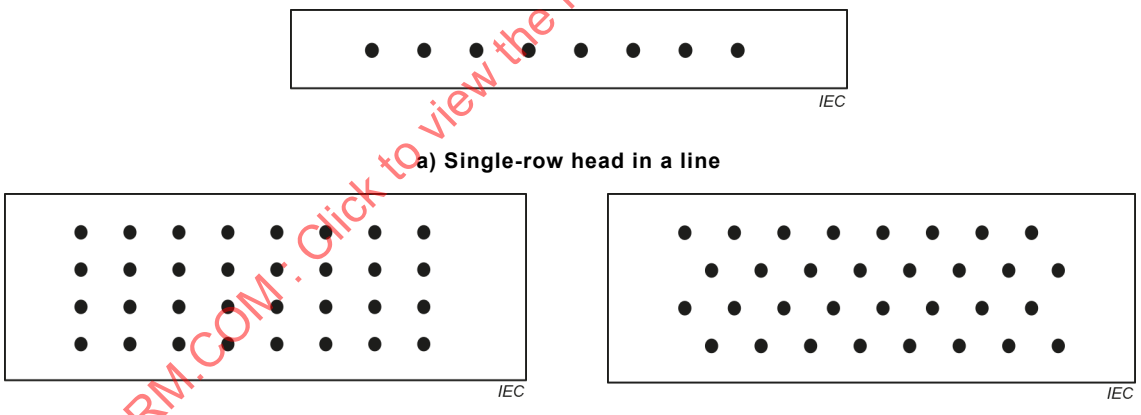
4.4.2.2 Nozzle position

The accuracy of the nozzle position directly affects the dot placement. In order to obtain an accurate print, accurate nozzle positions are maintained.

The measurement method of the nozzle position is the generic measurement method of the relative position from a reference point.

4.4.2.3 Nozzle layout

Typically, an inkjet head has multiple nozzles arranged in a line, or other shapes. In most cases, the nozzles are arranged in a line at a fixed interval. In order to achieve a resolution higher than the pitch of nozzles that can be arranged in a row, there is a multi-row inkjet head design in which multiple nozzle rows are arranged in a row in a single head (see Figure 2). Apparently, this property can affect the accuracy of the printed result.



a) Single-row head in a line

b) Multi-row head in lattice arrangement

c) Multi-row head in staggered arrangement

Figure 2 – Examples of nozzle layout

4.4.2.4 Shape of nozzle

The accuracy and type of shape of the nozzle (of the inkjet head) directly affect the dot placement. In order to obtain accurate inkjet print, the accurate shape of the nozzle is adequately maintained.

4.4.2.5 Size and number of nozzles

The accuracy of the size of the nozzle (of the inkjet head) directly affects the placement of dots. the number of nozzles will also affect the placement. In order to obtain accurate inkjet print, the accurate size of the nozzle is adequately maintained, and the proper number of nozzles is obtained to have proper printing speed and accuracy.

4.4.2.6 Mounting position

The accuracy of the mounting position (of the inkjet head) directly affects the dot placement. In order to obtain accurate inkjet print, the accurate mounting position is adequately maintained.

The measurement method of the mounting position is the generic measurement method of the relative position from a reference point.

4.4.2.7 Distance between print head(s) and substrate

The accuracy of the distance between the print head(s) and the substrate directly affects the dot placement. In order to obtain accurate inkjet print, an adequate distance between the print head(s) and the substrate is maintained. The proper distance between the print head(s) and the substrate is dependent upon many parameters of the inkjet head(s), for example ink, temperature, humidity. In order to keep the proper distance, those parameters are studied, and the distance is maintained throughout the printing duration.

4.4.3 Dynamic physical properties

4.4.3.1 General

The typical dynamic physical properties that can affect the printed result are shown in Table 2.

Table 2 – Dynamic physical properties of inkjet head

Parameter	Subclause
Print sequence	4.4.3.2
Head movement	4.4.3.3

4.4.3.2 Print sequence

Depending upon the inkjet printer apparatus, the print sequence is set as you wish as far as the inkjet printer apparatus can print. Print sequence means the order in which an inkjet printer dispenses ink onto the substrate.

4.4.3.3 Head movement

The accuracy of movement of the printing substrate relative to the inkjet head directly affects dot placement. This can be achieved in two ways. The first is to keep the head stationary and move the substrate, the second to move the print head, often on a reciprocating pattern.

In order to obtain accurate inkjet print in this second case it is necessary to maintain accurate movement of inkjet head. In order to facilitate this, there are several parameters to consider, such as the moving profile and the moving mechanism, among others.

The measuring methods of movement are generic measuring methods of movement, such as gyro sensor.

4.5 Controlling inkjet head

4.5.1 General

4.5.1.1 Overview

The parameters of the controlling inkjet head (driving inkjet head) that affect the dot placement are shown in Table 3.

Table 3 – Parameters of controlling inkjet head

Parameter	Subclause
Driving waveform	4.5.1.2
Driving timing	4.5.1.4
Print head pressure (meniscus pressure)	4.5.1.5
Ink temperature (head temperature)	4.5.1.5

4.5.1.2 Driving waveform

The driving waveform of inkjet head directly affects a dot placement. An accurate and stable driving waveform is therefore maintained. Parameters such as driving frequency, driving voltage are important.

4.5.1.3 Driving timing

The timing of printing relative to substrate position is important in any dispensing process and in this case directly affects a dot placement.

An accurate and stable timing system for the commencement of printing relative to the substrate position is therefore maintained.

4.5.1.4 Print head pressure (meniscus pressure)

Print head pressure (meniscus pressure) (of the inkjet head) directly affects the dot placement. In order to obtain accurate inkjet print, maintaining proper pressure is key. In order to maintain proper pressure, proper pressure control mechanism and controlling system are key.

4.5.1.5 Ink temperature (head temperature)

Ink temperature (head temperature) (of the inkjet head) directly affects the dot placement because the characteristics of the ink are highly dependent on temperature. In order to obtain accurate inkjet print, maintaining proper temperature is key. In order to maintain proper temperature, proper temperature control mechanism and system are key.

4.5.2 Characteristics of the droplet

4.5.2.1 General

The important characteristics of the droplet that directly affect the dot placement are shown in Table 4.

Table 4 – Characteristics of droplet

Characteristic	Subclause
Jetting speed	4.5.2.2
Droplet volume	4.5.2.3
Drop direction	4.5.2.4
Head scanning speed (for scanning type printer)	4.5.2.5
Head scanning direction (for scanning type printer)	4.5.2.6
Airflow	4.5.2.7

4.5.2.2 Jetting speed

Accurate manipulation of the jetting speed directly affects the dot placement. In order to obtain accurate inkjet print, proper jetting speed is maintained.

The measurement methods of the jetting speed are defined in IEC 62899-302-1 [1][1].

4.5.2.3 Droplet volume

Accurate manipulation of the droplet volume directly affects the dot placement. In order to obtain accurate inkjet print, proper droplet volume is maintained.

The measurement methods of droplet volume are defined in IEC 62899-302-2 [2].

4.5.2.4 Drop direction

Accurate manipulation of drop direction directly affects the dot placement. In order to obtain accurate inkjet print, proper droplet direction is maintained.

The measurement methods of droplet direction are defined in IEC 62899-302-3 [3].

4.5.2.5 Head scanning speed (for scanning type printer)

Accurate manipulation of head scanning speed directly affects the dot placement. In order to obtain accurate inkjet print, proper head scanning speed is maintained.

The measurement methods of head scanning speed are the generic measurement methods of the relative position from a reference point and the duration of that movement.

4.5.2.6 Head scanning direction (for scanning type printer)

Accurate manipulation of head scanning direction directly affects the dot placement. In order to obtain accurate inkjet print, proper head scanning direction is maintained.

The measurement methods of head scanning direction are the generic measurement methods of the relative position from a reference point.

4.5.2.7 Airflow

Airflow between head and substrate directly affects a dot placement. In order to obtain accuracy in inkjet printing it is necessary to maintain consistent airflow.

Magnitude and direction of airflow in this area can be a complex system, dependent on a number of parameters.

4.6 Characteristics of substrate

4.6.1 General

Since the functions of inkjet printing are realized on substrates, the characteristics of substrates are important to ensure that the functional material shows that intended function. In the combination of droplet liquid and substrate, the substrate is primarily classified into a non-penetrating substrate in which the droplet stays on the surface of the substrate and a penetrating substrate in which the droplet penetrates from the surface of the substrate to the inside. Significant characteristics of substrate are shown in Table 5.

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

Table 5 – Characteristics of substrate

Characteristic	Subclause
Wettability	4.6.2
Chemical resistance	4.6.3
Surface homogeneity	4.6.4
Surface flooding	4.6.5
Thermal conductance	4.6.6
Temperature (of substrate)	4.6.7

The characteristic of the substrate is described in IEC 62899-201 [4].

4.6.2 Wettability

Wettability is how the substrate is covered with liquid. Wettability is depended upon the surface of the substrate itself and also depended upon any surface treatment, such as coating.

Wettability of the surface of the substrate will directly affect the dot placement because when liquid hits the surface of the substrate, a drop of that liquid moves or is absorbed, based upon the surface characteristics. These characteristics are described in the ISO 19403 series [5].

4.6.3 Chemical resistance

Chemical resistance will affect the dot placement when ink contains chemical materials. If chemicals in ink react with material(s) in the substrate, that will change the function of the ink, or some other phenomena, such as swelling or burning can happen.

4.6.4 Surface homogeneity

Chemical and physical properties such as smoothness and roughness affect dot placement when ink is dropped onto the surface of the substrate as a drop will move towards a lower energy position.

4.6.5 Surface flooding

If ink is being deposited at a faster rate than can be absorbed by the substrate or otherwise rendered dry then subsequent drops can fall onto a wet surface, directly affecting drop placement.

4.6.6 Thermal conductance

Thermal conductance will affect the dot placement when ink is dropped onto the surface of the substrate and during sintering.

4.6.7 Temperature (of substrate)

Temperature will affect the dot placement when ink is dropped onto the substrate because a drop can be affected by the temperature of the substrate.

It is noted that surface treatment, precoated interlayer and the glass transition temperature also affect the substrate temperature.

4.7 Ink

4.7.1 General

The other major material for inkjet printing for printed electronics that is considered is ink. Significant characteristics are shown in Table 6.

Table 6 – Significant characteristics of ink

Characteristic	Subclause
Density	4.7.2.2
Rheology- viscosity	4.7.2.3
Rheology-bulk elasticity rate	4.7.2.4
Surface tension	4.7.2.5

4.7.2 Characteristics of ink

4.7.2.1 General

The above-mentioned characteristics of ink will directly affect the dot placement in many ways, such as jetting characteristics, or dropped ink on the surface of the substrate, because the droplet dropped onto the surface of the substrate can move because of ink characteristics.

The measurement methods of those characteristics are described in the IEC 62899 documents listed in Table 7.

Table 7 – Ink material measurement methods

Project reference	Title
IEC 62899-202 [7]	Printed electronics – Part 202: Materials – Conductive ink
IEC 62899-203 [8]	Printed electronics – Part 203: Materials – Semiconductor ink
IEC 62899-204 [9]	Printed electronics – Part 204: Materials – Insulator ink – Measurement methods of properties of insulator inks and printed insulating layers
NOTE IEC 62899-203 is currently being revised.	

4.7.2.2 Density

The density of ink will change the behaviour of a droplet from an inkjet head during flying (see IEC 62899-202:2023 [7], 6.3.1).

4.7.2.3 Rheology-viscosity

Viscosity of ink will change the behaviour of a droplet from an inkjet head during flying (see IEC 62899-202:2023 [7], 6.3.2).

4.7.2.4 Rheology-bulk elasticity rate

The bulk elasticity rate of ink will change the behaviour of a droplet from an inkjet head during flying. So far, there is no IEC standard that covers this characteristic for inkjet printing [5].

4.7.2.5 Surface tension

Surface tension will affect the dropped position because of the behaviour of a droplet from an inkjet head when ink hits the substrate (see IEC 62899-202:2023 [7], 6.3.3).

4.7.3 Important considerations of ink

4.7.3.1 Ink constituents

An ink typically comprises of a solvent, particles, and various other materials, including co-solvents, monomers, oligomers, polymers, surfactants, and more. As stated before, a function of the inkjet printing comes from the functional material(s) in the ink. Sometimes, the function of that material comes from a very precise quantity of that material. In other words, some materials are very sensitive to contamination.

For conventional printing, sometimes, an inkjet head vendor uses a certain ink with a certain material, for example ink for testing purposes, to evaluate the inkjet head before releasing it to a customer. For functional printing, especially for printed electronics, in most cases, the customer wants to avoid contamination by using another material than functional ink. Thus, it is important for an inkjet head vendor and a customer to discuss how to evaluate the inkjet head before evaluation.

In order to avoid contamination, when using a different ink from the ink used for actual functional printing, a cleaning procedure is set up to remove that ink for evaluation before shipping a print head after evaluation.

4.7.3.2 Density, viscosity, surface tension or bulk elasticity rate of ink

The parameters of ink, such as density, viscosity, surface tension or bulk elasticity rate are directly related to jetting and to the printed characteristics. Therefore, an ink will be used for evaluation that has the same characteristics as an ink for actual functional printing. If the ink for the evaluation does not have the same characteristics as the ink for actual printing, for the evaluation, an alternative method is used.

4.7.3.3 Transparency of ink

Unlike conventional print, where the ink most likely has some colour, sometimes the functional material in an ink for functional print does not have any colour and is most likely transparent. In such a case, it would be hard to evaluate the material on a substrate since it does not have any colour. At the same time, as stated before, a customer does not want to put any other material other than functional materials to avoid contamination. Under these conditions, the key discussion area is how a droplet can be evaluated, or a dropped ink.

5 Conclusion

The above-mentioned characteristics are important characteristics related to functional inkjet printed qualities. In order to have adequate functions for inkjet printing for printed electronics, these characteristics are the ones considered.