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The first international standards for IEC/TC119 printed electronics materials substrate and conductive ink

Masaaki Oda,[1] Satoshi Maeda,[2] Tadanobu Sato[3] and Chizu Sekine,[4]

[1] Japan Advanced Printed Electronics Technology Research Association, Ibaraki-pref. 305-8565, Japan

[2] Toyobo Co., Ltd., Shiga-pref. 520-0290, Japan

[3] Fujifilm Co. Ltd., Minato-ku Tokyo, 107-0052, Japan

[4] Sumitomo Chemical Co., Ltd., Tsukuba Ibaraki-pref. 300-3294, Japan

Abstract

The first international standards for IEC/TC119 printed electronics materials substrates and conductive ink were published on Feb. 25th 2016. Printed electronics is one of the growing technology fields and expected to have a large market in the future. Standardization of materials has been discussed in WG2 of IEC/TC119 (Technical committee of printed electronics). One of the authors of this paper, Ms. Sekine is the convener of WG2 and has been leading the activities in WG2. Thus first of all, two new proposals of generic standards including measurement methods concerning material substrate and conductive ink were proposed to lead standardization in printed electronics materials and accelerate developments in printed electronics from Japan. I was selected as the project leader of standardization of conductive ink. Contents of the both IS will be introduced.

Introduction

Due to the trend towards a globalized, technical and connected society, there is a rising demand for a new breed of technologies enabling low-priced, flexible and new-concept products. Some conventional technologies (including silicon based microelectronics) have reached their limits due to their high fabrication costs and environmental issues. Armed with new printing technologies (including screen, gravure, reverse gravure, flexo, offset, ink jet, etc.) and innovative materials, printed electronics has recently emerged as a promising environmentally friendly alternative route to produce electronic/display/energy products at a low cost and with new possibilities of such creative technologies as flexible electronics.

Currently this technology is ready to be applied to the manufacture of items such as photovoltaic devices, signage, RFID, batteries, lighting devices, etc., where cost, flexibility and recycling are very critical issues. Recently printing technologies in combination with other technologies form hybrid systems which showed promising market potential in areas such as flexible and wearable electronics. Standardization is important in these growing technical field because researchers or engineers must use same vocabularies or same evaluation methods to develop the technologies, otherwise development speed become slower down by miscommunications among the peoples involved. For successful industrialization of this technology, reliability and repeatability in equipment and processes should be provided under global standardization. Standardization needs in printed electronics had been discussed world-widely in academic societies and industrial societies since 2008. However, a practical movement was initiated by Korean proposal to form a new TC under the IEC (International Electrical Commission) in June 2011. The SMB in IEC decided to establish a new technical committee for the field of printed electronics, TC119, and appointed the Republic of Korea as the secretariat country in October 2011. The chairperson is Mr. Alan Hodgson from England. The scope is to standardize terminology, materials, processes, equipment, printed products, quality assurance which are related to the printing technology for manufacturing electronic and electrical devices. The first plenary conference was held in May 2012 and then the plenary conferences have been held once a year shown in Figure 1. P-member and O-member countries are listed in Figure 2.

The structure and the history of TC119 are going to be introduced and then it is going to present about the first international standards for printed electronics of substrate materials and conductive ink.

2011.6 IEC New TC "printed electronics" Proposal（Korea）

2011.10 Start

2012.5 The 1st Plenary Conference (Seoul Korea)

2013.2 The 2nd Plenary Conference (San Diego USA)

2014.3 The 3rd Plenary Conference (Cambridge England)

2014.11 The 4th Plenary Conference (Tokyo Japan)

2015.11 The 5th Plenary Conference (Santa Clara USA)

Figure 1. *History of plenary conferences held so far*

13 P-member countries
China, Finland, Germany, Japan, Korea, Nederland, Russian Federation, Spain, Sweden, Switzerland, Cyprus United Kingdom, United States of America

7 O-member countries
Brazil, Canada, Czech Republic, France, Italy, Malaysia, Poland

Around 100 individual members.

Figure 2. *P-member and O-member countries*

Organization of TC119

Scope of TC119 is "Standardization of terminology, materials, processes, equipment, products and health/safety/environment in the field of printed electronics." The organization of TC119 is shown in Figure 3. It consist of 7 groups such as Adv1 (Advisory), WG1 (Terminology), WG2 (Materials), WG3 (Equipment), WG4 (Printability), WG5 (Quality assessment) and AHG8 (Roadmap).
I have been working for WG2 as the project leader of (NP) New Proposal of material conductive ink which now became one of the first two ISs. A convenor of each WGs has been leading the activities in WGs. A convenor country is written in Figure 3 respectively. WG meetings are held 2 or 3 times a year to discuss about proposals from P-member countries.

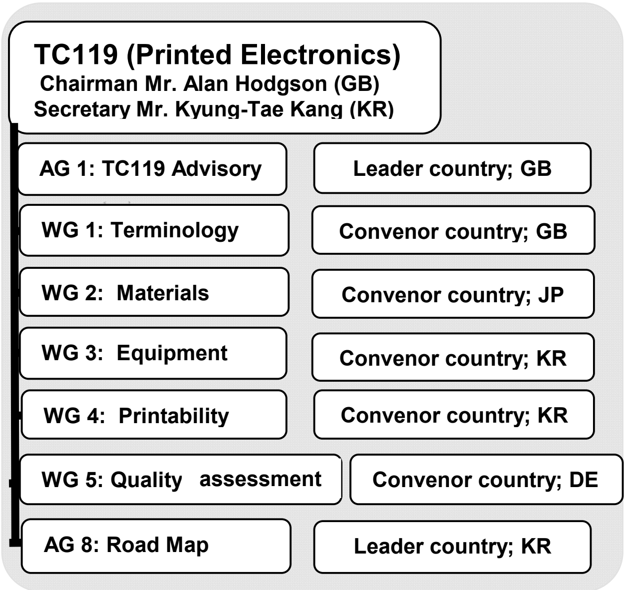

Figure 3. Organization of TC119 (Printed Electronics)

Process of NP becoming IS

The process of NP becoming IS is shown in Figure 4. PWI (preliminary working item) is usually introduced first in WG for collecting opinions from experts in the WG. A NP which reflects those opinions is proposed formally through the IEC central office. The NP is circulated among the national committees of P-member countries for 3 months to get an approval. The NP is approved by approval ballot of more than half of voting P-members and 4 experts participation to the WG in the case of all P-member numbers are less than 16 or 5 experts participation to the WG in the case that all P member numbers are more than 17.

WG meeting is usually held 2 or 3 times for 1 year and the expert members discuss about the content of the approved NP in the WG meetings and then the working draft (WD) is completed. The WD is circulated as a committee draft (CD) among P-member and O-member countries for 3 months to get comments and then the committee draft (CD) is completed. The CD is circulated as CDV among the P-member and O-member countries for 3 months. CDV is approved by approval ballot of more than 2/3 of voting P-members and the opposition ballot numbers are less than 1/4 of the total voting numbers. If the CDV does not have any against votes, it is approved as IS. The revised final draft for IS (FDIS) is circulated among the P-member and O-member countries for 2 months.

FDIS is approved by approval ballot of more than 2/3 of voting P-members and the opposition ballot numbers are less than 1/4 of the total voting numbers. It usually takes 36 months from NP step to the approval of IS.

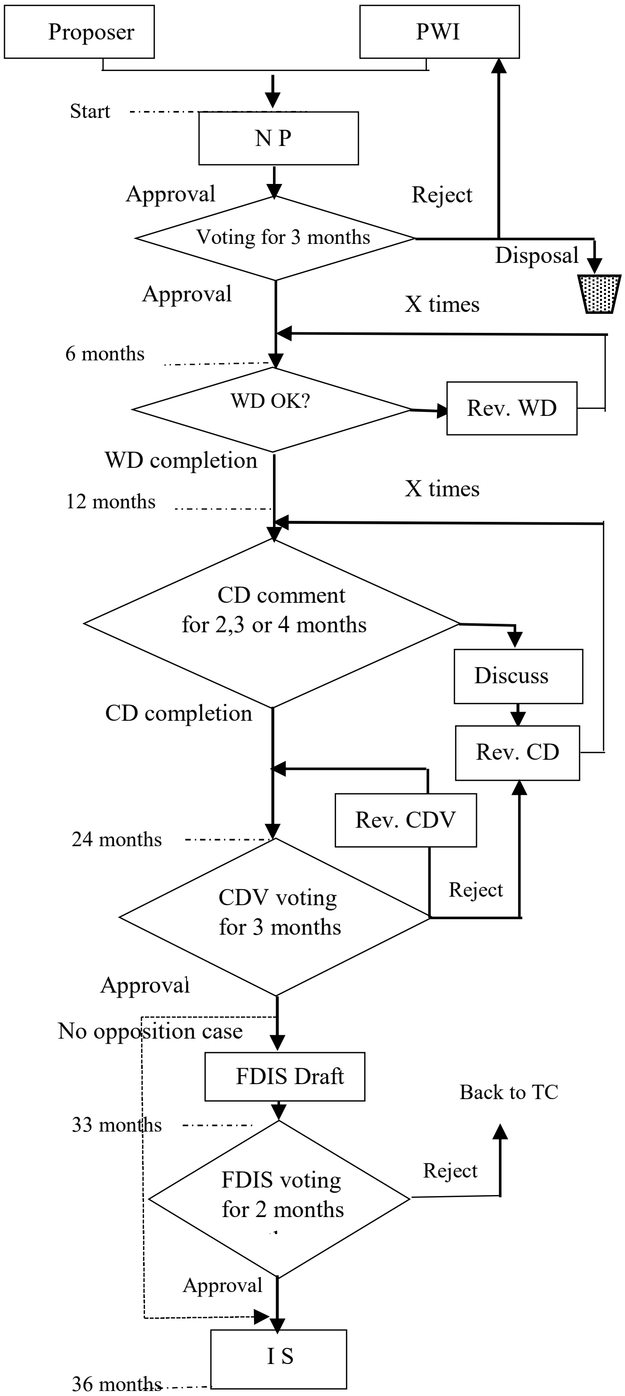

Figure 4. The process of NP becoming IS

Grand Map of WG2

The grand map of WG2 is shown in Table 1. In early stage of PE industry, the common evaluation methods in the generic specifications is effective to any kinds of PE materials and effective to expand PE technology rapidly.
In the advanced stage, the sectional standard will be proposed according to the demands of users and/or suppliers of PE industry. The generic standard is listed on the left side of the map. Our ISs are located on the top of the left side. Other standards of sectional specifications are going to be proposed under those generic specifications. The generic specifications are the standards showing items which should be decided for the materials and a document format. Once the format is decided, other proposals are going to use it and it is easy to propose.

Table1. Grand map of printed electronics materials standardization

Grand Map of Printed Electronics Materials Standardization IEC62899-20X-Y

Generic Specifications		Sectional Specifications		Blank Detail Specifications	
Part No.	Title & Contents	Part No.	Title & Contents	Part No.	Title & Contents
Substrates for PE					
Part 201	Substrates [JP] IS Common evaluation methods for substrates (polymer, glass, others)	Part 201-1	Evaluation method(s) of paper substrate [JP]		Speci-fications of the substrates
		Part 201-2	Evaluation method(s) of stretchable substrate [JP]		
Functional material inks for PE					
Part 202	Conductive material ink [JP] IS Common evaluation methods for inks and unpattered films	Part 202-1	Measurement method of dispersion property in silver ink [KR]		[**]
		Part 202-2	Evaluation method of stretchable functional ink [JP]		
		Part 202-3	Measurement of sheet resistance of conductive films (non-contact style) [KR]		
		Part 202-5	Mechanical bending test of a printed conductive layer on substrate [KR]		
Part 203	Semiconductor ink [GB] CD	Part 203-1	… [**]		[**]
Part 204	Insulator ink [JP/GB] NP	Part 204-1	… [**]		[**]
Part 205	Other functional material ink [**]				

IS IEC 62899-201 Printed electronics-Part 201: Materials-Substrate [1]

Scope and Terminology

First of all, the scope of this IS is defined such as “This part of IEC 62899 defines the terms and specifies the evaluation method for substrates used in the printing process to form electronic components/devices. This international standard is also applied to the substrates which make surface treatment in order to improve their performance.” The scope defines the area where this IS can be applied. If the standard does not define some area, this IS can’t be applied to the area. Thus a scope better to be wider as much as possible.

Then the definitions of terminology are listed. Terminology is important to communicate with each other among people involved. For examples, the word “printed electronics” is used to mean “printed products” or “a technology which produce products by printing methods” or “a field where printing methods are used to produce electric appliances”. Thus it is important to define the vocabulary which is used in IS.

The main body of this IS is about evaluation methods of several properties such as surface properties, mechanical properties, chemical properties, thermal properties, optical properties and flammability for polymer substrate and glass substrate. Finally, it is defined about storage, packaging and transportation.

Materials, structures and dimensions

Base materials are used in the printing process to form electronic components/devices that are polymer, glass and other materials such as ceramics, metal, paper, etc.

The substrate shall have a monolithic structure, a composite structure of several of those materials, or a reinforced composite structure strengthened with fibres or particles. The surface of the substrate may be treated to enhance wettability, adhesive property, gas transmission, smoothness, and electric insulation.

Substrates made of the material(s) shall be supplied in the form of (rigid or flexible) sheets or rolls. The recommended standard area dimensions (width and length) of a sheet are shown and the tolerance of width and length is shown for polymer substrates and glass substrates. The recommended substrate thickness are shown for polymer substrates and glass substrates. The standard dimensions of width, length and thickness are defined, otherwise so many kinds of dimensions of substrate are supplied and customers are confused.

General descriptions of evaluation tests

The substrate shall be in its original form, or cut into the appropriate size for testing. Care should be taken not to touch the test specimens with fingers, etc. The specimens shall not be cleaned unless otherwise specified.

The temperature and humidity conditions for evaluation tests shall be at a temperature of 23 °C ± 1 °C and relative humidity of (50 ±5) %. Polymer substrates need conditioning. The test specimens to be evaluated shall be stored at a temperature of 23 °C ± 1 °C and relative humidity of (50 ± 5) % for 48 h or more. Since glass substrates have no hygroscopicity, conditioning is generally not necessary.

Characteristics and evaluation method of polymer substrates

This section is composed of surface properties, mechanical properties, chemical properties, electrical properties, thermal properties, optical properties and flammability of polymer substrates.

First of all, the surface of a substrate shall not have the following defects such as pinholes, hollows, blisters, pimples, fish-eyes, speckles, cracks, fractures, wrinkles, detachment and creep. However, since the maximum permissible size of defects depends on the purpose, the defect condition shall be agreed upon between user and supplier. The permissible bow ratio and twist ratio shall be agreed upon between user and supplier as required. This agreement should consider the actual use on products as well as the manufacturing process.

Secondly, it is explained about the items of mechanical properties such as elongation at break, tensile strength, tensile modulus, minimum bending radius, tear strength, tear propagation resistance, edge strength and hardness. And then, it is explained about the items of chemical properties such as resistance to chemicals, halide contents, volatile content, gas transmission and moisture absorption. And then, it is explained about the items of electrical properties at ambient temperature and high temperature. And then, it is explained about the items of thermal properties such as glass transition temperature, coefficient of linear thermal expansion, dimensional stability and relative temperature index. And then, it is explained about the items of optical properties such as colour, refractive index, retardation, luminous reflectance and haze. Finally, it is explained about the items of flammability.

Characteristics and evaluation method of glass substrates

This section is composed of surface properties, mechanical properties, chemical properties, thermal properties and optical properties of glass substrates.

First of all, it is explained about the items of surface properties such as surface roughness, chips, cracks, foreign inclusions, foreign substances on surface and scratches.

Secondly, it is explained about the items of mechanical properties such as Young's modulus, Poisson's ratio, density and hardness. And then, it is explained about the items of chemical properties such as resistance to chemicals and gas transmission. And then, it is explained about the items of thermal properties such as the coefficient of linear thermal expansion and strain point. Finally, it is explained about the items of optical properties such as refractive index and luminous transmittance.

Storage

It is preferable to store substrate materials at a temperature of 20 °C to 25 °C and humidity of 30 % to 60 %. Even if it is impossible to keep substrate materials at a constant temperature, they shall be stored at a temperature of 0 °C to 30 °C and humidity of 30 % to 60 %, without dew condensation, before use. In addition, substrate materials shall be stored out of direct sunlight. The storage conditions for chemically active substances and mechanically active substances are specially determined.

If the specimens are stored unopened in an environment at a temperature of 20 °C to 25 °C and at relative humidity of 30 % to 60 %, the storage period is 3 months after reaching the client. However, if there are special circumstances, the storage period may be determined by agreement between user and supplier.

Packaging

Substrate materials shall be packaged so that no breakage or degradation occurs due to climatic and mechanical conditions during transportation, and climatic conditions during storage.

Transportation

It is preferable to transport substance materials in an environment at a temperature of 0 °C to 30 °C and relative humidity of 30 % to 60 %. Dew concentration shall be prevented even during transportation between the inside and outside of a building. The transportation conditions for chemically active substances and mechanically active substances are specially determined.

IS IEC 62899-201 Printed electronics-Part 202: Materials-Conductive ink [2]

Scope and Terminology

First of all, the scope of this IS is defined such as "This part of IEC62899 defines the terms and specifies the evaluation method for characterization and evaluation. This international standard is applicable to conductive ink and conductive layer that are made from conductive inks." The scope defines the area where this IS can be applied. If the standard does not define some area, this IS can't be applied to the area. Thus a scope better to be wider as much as possible.

Then the definitions of terminology are listed as same as in the substrate case. The main body of this IS is about the evaluation method of physical properties of conductive ink and electrical properties and optical properties of conductive layers. Finally, it is defined about storage.

Atmospheric conditions for evaluation and conditioning

The standard atmosphere for evaluation (test and measurement) and storage of the specimen shall be at a temperature of 23 °C ± 2 °C and relative humidity of (50 ± 10) %. In the case that a polymer substrate is used for a test piece coated with a conductive layer, a temperature of 23 °C ± 1 °C and relative humidity of (50 ± 5) %.

Evaluation of properties of conductive ink

Content

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

Physical properties

The measuring method of density shall be the pyknometer method or the method using oscillation-type density meters or the immersed body (plummet) method. The detailed product specifications shall specify the measuring method to be used.

Viscosity shall be measured using a Brookfield type rotational viscometer or cone-and-plate viscometer or rotational viscometer. The detailed product specifications shall specify the measuring method and measuring temperature to be used.

Surface tension shall be measured using the drawing up liquid film (Wilhelm) method.

The measuring methods of size of conductive materials are determined according to the shape. Shape of conductive materials includes sphere, rod, wire, tube and others.

Flashpoint shall be measured according to the open system. The method of "the open system" is preferable for safety, however, "the closed systems" are also widely used. The measurement method based on the closed systems may be applied if closed system is required.

The evaporation rate is a property which is necessary for the PE ink, but the details of the evaluation condition and the measuring method are significantly different for the ink. In this standard, a common framework of the method is specified as a guideline. The detailed conditions and measurements may be determined between trading partners depending on the properties of the ink. The evaporation rate of solvent from an ink formulation can be determined by measuring the time taken to evaporate up to 90 % of the mass of the solvent content of the ink formulation.

Evaluation of the properties of a conductive layer

Test piece

The substrate for the test piece shall be a clean and smooth-surface non-alkali glass which will not affect the ink. Other substrate materials may be used if agreed between the trading partners (supplier and purchaser). The dimensions of the test piece shall be as specified in each test method. If evaluation is possible, a test piece with smaller and/or thinner dimensions than specified may be used.

Electrical properties

The volume resistivity of a conductive layer made of conductive ink is measured using the four-point probe method. This method, as shown in Figure 5, arranges four electrodes linearly on the test piece, passes current I between two electrodes such as probe A and probe D, measures the potential difference V between the other two electrode, and calculates resistance V/I. The four-point probe head which does not damage the conductive layer should be used.

The test equipment consists of a constant-current source, a voltmeter and probes. Test procedure, resistance measurement and calculating resistivity are explained.

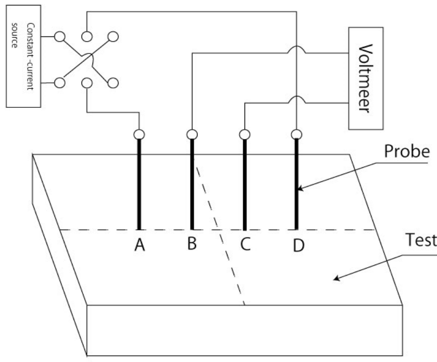

Figure 5. *Example of four-probe measurement equipment*

The Surface resistivity shall be obtained by dividing the volume resistivity measured by the thickness of the conductive layer. If thickness is measured at several points, the average shall be used.

Optical properties

Luminous transmittance shall be measured using beam method or the double-beam method. If agreed between the trading partners (supplier and purchaser), another method which is considered equivalent may be used.

The measuring method of chromaticity shall be the reflected light method or the transmitted light method, depending on the application and the purpose. If the reflected light method is used, a reflecting diffuser shall be placed on both the surface to be measured and the other surface, with the specimen in between. The reflecting diffuser shall be a perfect reflecting diffuser or a reference diffuser used for calibrating measuring equipment.

Uniformity of colour is measured by obtaining colour differences on 10 points on the specimen, and their average is evaluated by the difference from the standard chromaticity and standard deviation.

Haze shall be measured using the method specified in ISO 14782. A similar method may be used as agreed between the trading partners (supplier and purchaser).

The refractive index shall be measured using method A (for measuring the refractive index of films using a refractometer) or a similar method. A contacting liquid with a refractive index higher than that of the measured object and with a substrate which does not swell or dissolve shall be used. When using a plastic film for the substrate, choose the contact liquid in consideration of the refractive index, swelling and melting of the substrate.

Storage

Conductive ink shall be stored in a sealed container, at a temperature of 6 °C ± 4 °C unless otherwise specified. The degradation due to storage is expressed by the change in viscosity. The viscosity just before storage and the viscosity just after storage for 30 days under the conditions shall be measured according to the method specified.

References

[1] International standard, IEC 62899-201 Edition 1.0 Printed electronics-Part 201: Materials-Substrates, published by International Electrical Commission at 2016.02.

[2] International standard, IEC 62899-202 Edition 1.0 Printed electronics-Part 202: Materials-Conductive ink, published by International Electrical Commission at 2016.02.

Author Biography

Masaaki Oda received his BS in applied physics from Nagoya University (1971) and his PhD in applied physics from Nagoya University (1986). Since then he has worked in the Research and Technology Division at Vacuum Metallurgical Co. Ltd. of ULVAC group in Japan. His work has focused on the development of individually dispersed metal nano-particles by the gas evaporation method. He is now working for JAPERA (Japan Advanced Printed Electronics Technology Research Association) as the manager of international standardization of printed electronics.