SLOVENSKI STANDARD
oSIST prEN IEC 62631-2-3:2023

01-april-2023

Dielektrične in uporovne lastnosti trdnih izolacijskih materialov - 2-3. del: Določanje relativne permitivnosti in faktorja dielektričnih izgub (metode AC) - Metoda kontaktne elektrode za izolacijske folije

Dielectric and resistive properties of solid insulating materials - Part 2-3: Determination of relative permittivity and dielectric dissipation factor (AC methods) - Contact electrode method for insulating films

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COMMITTEE DRAFT FOR VOTE (CDV)

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IEC TC 112 : EVALUATION AND QUALIFICATION OF ELECTRICAL INSULATING MATERIALS AND SYSTEMS	
SECRETARIAT: Germany	SECRETARY: Mr Bernd Komanschek
OF INTEREST TO THE FOLLOWING COMMITTEES: TC 15	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.

FUNCTIONS CONCERNED:

☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY

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TITLE:

Dielectric and resistive properties of solid insulating materials - Part 2-3: Determination of relative permittivity and dielectric dissipation factor (AC methods) - Contact electrode method for insulating films

PROPOSED STABILITY DATE: 2027

NOTE FROM TC/SC OFFICERS:

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

DIELECTRIC AND RESISTIVE PROPERTIES OF SOLID INSULATING MATERIALS -

Part 2-3: Determination of relative permittivity and dielectric dissipation factor (AC methods) - Contact electrode method for insulating films

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

FDIS	Report on voting
112/XX/FDIS	112/XX/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://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- withdrawn,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.

The National Committees are requested to note that for this document the stability date is 2027.

THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED AT THE PUBLICATION STAGE.

INTRODUCTION

Measuring the relative permittivity and the dielectric dissipation factor (tan *δ*) of insulating polymer film with very thin thickness (about 10-100 μm) without any additional layer is important for insulation applications. Now, there is lack of suitable technology and standard for a single layer polymer film with very thin thickness. Using multilayer polymer films with 20-50 layers it can be feasible to get the average value of the relative permittivity and dielectric dissipation factor of insulating polymer film, but the effect of airgap inside may not be ignored. With metalized electrodes on the surface of polymer film, it is possible to get acceptable results of the relative permittivity and dielectric dissipation factor of insulating polymer film in research laboratory. In this standard, the measuring technology and the test method are provided for relative permittivity and dielectric dissipation factor of insulating polymer film with very thin thickness without any additional layer or metallization on the sample, under technical frequency.

DIELECTRIC AND RESISTIVE PROPERTIES OF SOLID INSULATING MATERIALS –

Part 2-3: Determination of relative permittivity and dielectric dissipation factor (AC methods) - Contact electrode method for insulating films

1 Scope

This International Standard of IEC 62631-2-3 specifies the measuring technology and the test method for relative permittivity and dielectric dissipation factor of insulating polymer film with very thin thickness without any additional layer and metallization on the sample surface. The adaptive thickness range is about from 10 to 100 μm. The proposed frequency is the power frequency (50 or 60 Hz), and it is also suitable in the technical frequency range from 1 Hz to 1 MHz.

2 Normative references

IEC 60050-212:2010, International Electrotechnical Vocabulary — Part 212: Electrical insulating solids, liquids, and gases

IEC 62631-2-1:2018, Dielectric and resistive properties of solid insulating materials - Part 2-1: Relative permittivity and dissipation factor-Technical frequency （0.1 Hz to 10 MHz) – AC methods

ISO 4593:1993, Plastics — Film and sheeting — Determination of thickness by mechanical scanning

IEC 60674-2:2019, Specification for plastic films for electrical purposes — Part 2: Methods of test

ISO 14644-1:2015, Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration

ISO 21920-2:2021, Geometrical product specifications (GPS) — Surface texture: Profile — Part 2: Terms, definitions and surface texture parameters

ISO 25178-2:2012, Geometrical product specifications (GPS) — Surface texture: Areal — Part 2: Terms, definitions and surface texture parameters

ISO 3534-1:2006, Statistics — Vocabulary and symbols —Part 1: General statistical terms and terms used in probability

ISO 3434-2:2006, Statistics — Vocabulary and symbols —Part 2: Applied statistics

ISO 3534-3:2013, Statistics — Vocabulary and symbols —Part 3: Design of experiments

3 Terms definitions and abbreviated terms

3.1 Terms and definitions

3.1.1 thin insulating film

an insulating polymer film without any additional layer, with 10 to 100 μm uniform thickness, planar, even and smooth.

3.1.2 AC bridge

an instrument to use balance method to measure the capacitance and loss of capacitor sample under AC voltage, for example, a capacitor bridge.

Note 1 to entry: Usually, it works under power frequency with very high accuracy and with low applied voltage.

Note 2 to entry: In some special case, it is also possible to work under technical frequency.

3.1.3 impendence material analyzer

an instrument to use AC current method to measure the capacitance and dielectric loss of a capacitor.

Note 1 to entry: It works under a relatively low voltage and with large band range, but its accuracy is usually relatively low.

Note 2 to entry: It uses five terminals to measure the device parameters so that it needs a suitable adaptor for the three electrodes sample.

3.1.4 power frequency

the frequency used for power system, is usually at 50 Hz or 60 Hz.

3.1.5 technical frequency

the frequency for technical application, is usually from 1 Hz to 1 MHz.

3.1.6 measuring voltage

the voltage applied on the measuring sample during the measurement, should be lower than the voltage induced by partial discharge.

3.1.7 apparent thickness (mechanical thickness)

the thickness of sample measured by a mechanical apparatus, which is equivalent to “bulking thickness” in IEC 60674-2.

3.1.8 density thickness

the thickness of sample measured from the density of sample, which is equivalent to “gravimetric thickness” in IEC 60674-2.

3.1.9 void ratio α

the percentage increase between the apparent thickness and the density thickness, which is dependent on the surface roughness.

Note 1 to entry: For the sample with scabrous surface, the apparent thickness and the density thickness are different.

Note 2 to entry: The void ratio α (%) is defined by the following formula:

$$\alpha = \frac{d_x - d_d}{d_x} \cdot 100(\%) \qquad (1)$$

where,

d_x is the apparent thickness of sample in μm;

d_d is the density thickness of sample in μm.

Note 3 to entry: The apparent thickness and the density thickness should be measured by using the same sample in accordance with ISO 4593.

3.1.10 contact ratio η

the percentage ratio of contact area over the total area.

Note 1 to entry: For the sample with scabrous surface, it cannot make perfect contact with the high flatness and low roughness surface of electrode.

Note 2 to entry: It is dependent on the sample surface roughness and is defined by the following formula:

$$\eta = \frac{contact\ \ area}{total\ \ area} \cdot 100\,(\%) \tag{2}$$

where, η is the contact ratio in %.

3.1.11 surface roughness of sample R$_a$

is defined by the following formula according to ISO 21920-2:

$$R_a = \frac{1}{l_e}\int_0^{l_e} \left|z\left(x\right)\right| \mathrm{d}x \tag{3}$$

where

l_e is the evaluation length of the sample profile,

z(x) is the function that described the height of the assessed scale-limited profile,

R_a is the arithmetic mean height in μm of the sample profile, also called the surface roughness of sample in this standard.

3.2 Abbreviated terms

AC - Alternating Current

α – void ratio

η - contact ratio

R_a - surface roughness of sample in μm

4 Principle of method

4.1 The principle of measurement

The complex capacitance $\dot{C}_x$ of the dielectric sample with electrode can be obtained by using an AC bridge or an impedance/material analyzer. For planar, even and smooth film sample, the relationship between the complex permittivity $\dot{\varepsilon}_x$ and the complex capacitance $\dot{C}_x$ can be shown as follows,

$$\dot{C}_x = \frac{\varepsilon_0 \dot{\varepsilon}_x S}{d_x} \text{ ,} \tag{4}$$

where, d_x is the thickness of planar film sample, S is the area of electrode and ε_0 is the electric constant (also called permittivity of vacuum). Therefore, the complex permittivity of the dielectric materials can be derived as,

$$\dot{\varepsilon}_x = \frac{d_x}{\varepsilon_0 S} \dot{C}_x \text{ .} \tag{5}$$

The relationship of the complex permittivity $\dot{\varepsilon}_x$ with real part ε', imaginary part ε'' and dielectric dissipation factor $\tan\delta$ (also marked *D*$_x$) can be shown as follows,

$$\begin{cases} \dot{\varepsilon}_x = \varepsilon' + j\varepsilon'' \\ \tan\delta = \dfrac{\varepsilon''}{\varepsilon'} \\ \varepsilon_x = \varepsilon' \end{cases} \text{ ,} \tag{6}$$

where, the real part ε' is called relative permittivity ε_x, and the imaginary part ε'' is called dielectric loss index. By using an AC bridge, the dielectric dissipation factor $\tan\delta$ and the real part C_x of complex capacitance $\dot{C}_x$ can be measured directly. The relative permittivity ε_x of dielectric material can be obtained from

$$\varepsilon_x = \frac{d_x}{\varepsilon_0 S} C_x \tag{7}$$

4.2 The edge effect of electrodes

Due to the limitation of mechanical manufacture, the gap between the measuring electrode and the guard ring will be bigger than 0.5 mm. Generally, there is edge effect of electrodes in the dielectric measurement. In the case of sample with thick thickness (the thickness>0,5 mm), the guard ring electrode is effective to reduce the edge effect of electrodes. However, for the sample with thin thickness (the thickness<0,5 mm), the guard ring electrode does not significantly reduce the edge effect because the gap between the measuring electrode and the guard ring is much bigger than the thickness of sample. In this case, due to the limitation of mechanical manufacture, the gap between the measuring electrode and the guard ring will be much bigger than the thickness of sample. See also Clause 5.2.

5 The electrodes

5.1 Design and manufacture of electrodes

It is the most important requirement in the standard to design and manufacture the measuring electrodes. It is a system with three electrodes, including a measuring electrode (M), a guarded electrode (G) and a high voltage electrode (H). For example, the possible dimension of three electrodes is shown in Table 1, and key requirements of three electrodes for manufacture are noted in Figure 1. As the thickness of sample is relatively thin, the diameter of the measuring electrode should not be too large to avoid a large measured capacitance that would make the choice of measuring instrument difficult. The most important requirements on the manufacture are the situation of the surface of the measuring electrode and the surface of high voltage electrode. They must satisfy the following conditions: the roughness <0.012 μm and the flatness

<0.5 µm. The surface condition is very important for keeping good contact between the electrode and the measured dielectric film.

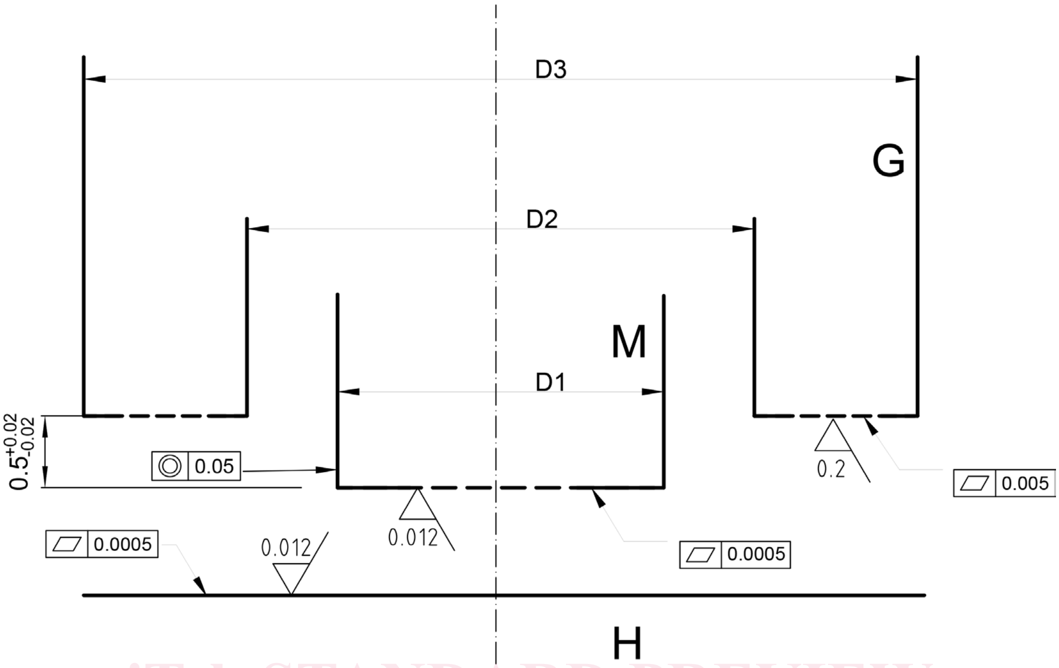

Figure 1 – The diagram of the system with three electrodes
D1: the diameter of the measuring electrode M
D2: the inner diameter of the guarded electrode G
D3: the outer diameter of the guarded electrode G
D4: the diameter of the high voltage electrode H.

With Figure 1, g is the gap between the guarded electrode and the measuring electrode the gap g=(D2-D1)/2 is kept to about 1 mm.

The material of electrode M and electrode H must satisfy the following condition: good conductivity, non-ferromagnetic, anti-rust, and enough rigidity and hardness. The suggested hardness is within HRC 58 to 62. The possible optional material is the alloy 7Mn15Cr2Al3V2WMo (C 0.65-0.75, Si≤0.80, Mn14.50-16.00, Cr 2.00-2.50, Mo 0.50-0.80, W 0.50-0.80, V 1.50-2.00, Al 2.70-3.30, P≤0.040, S≤0.0.030), which is an Austenitic non-magnetic tool steel. More information about the manufacture of electrodes can be found in Annex B

The material of electrode G can be a metal material with good conductivity, non-ferromagnetic, anti-rust, like stainless or brass with surface plating protection, etc.

Table 1 – The diameter parameters of the three electrodes system and the relationship of measured ε_x for the thickness of sample and the measured capacitance

D1 (mm)	D2 (mm)	D3 (mm)	D4 (mm)	ε_x
35.68±0.05	37.68±0.1	58	70	$C_x(pF)\cdot d_x(mm)/8.85$ $=C_x(nF)\cdot d_x(\mu m)/8.85$