IEC 62631-2-3

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INTERNATIONAL STANDARD

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Dielectric and resistive properties of solid insulating materials – Part 2-3: Relative permittivity and dissipation factor – Contact electrode method for insulating films – AC methods

Propriétés diélectriques et résistives des matériaux isolants solides – Partie 2-3 : Permittivité relative et facteur de dissipation – Méthode d'électrode de contact pour films isolants – Méthodes en courant alternatif

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DIELECTRIC AND RESISTIVE PROPERTIES OF SOLID INSULATING MATERIALS –

Part 2-3: Relative permittivity and dissipation factor – Contact electrode method for insulating films – AC methods

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

Draft	Report on voting
112/631/FDIS	112/641/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 62631 series, published under the general title *Dielectric and resistive properties of solid insulating materials*, 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

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INTRODUCTION

Measuring the relative permittivity and the dielectric dissipation factor (tan δ) of thin insulating polymer films with a thickness of approximately 10 µm to 100 µm without any additional layer is important for insulation applications. There is currently a lack of suitable technology and standard for the measurement of the relative permittivity and dielectric dissipation factor of very thin single-layer polymer films. By using multilayer polymer films with 20 to 50 layers, it can be feasible to get the average value of the relative permittivity and dielectric dissipation factor of an insulating polymer film, but the effect of air gap inside should not be ignored. With metallized electrodes on the surface of the polymer film, it is possible to get acceptable results of the relative permittivity and dielectric dissipation factor of an insulating polymer film in research laboratory. This document provides the measuring technology and the test method for the relative permittivity and dielectric dissipation factor of thin insulating polymer films without any additional layer or metallization on the sample, under technical frequency.

DIELECTRIC AND RESISTIVE PROPERTIES OF SOLID INSULATING MATERIALS –

Part 2-3: Relative permittivity and dissipation factor – Contact electrode method for insulating films – AC methods

1 Scope

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

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 60674-2, *Specification for plastic films for electrical purposes – Part 2: Methods of test*

ISO 4593, *Plastics – Film and sheeting – Determination of thickness by mechanical scanning*

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

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

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions 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

3.1.1
thin insulating polymer film
insulating polymer film, planar, even and smooth, without any additional layer, with a 10 µm to 100 µm uniform thickness

3.1.2
AC bridge
instrument that uses the balance method to measure the capacitance and loss of a capacitor sample under AC voltage

EXAMPLE Capacitor bridge.

Note 1 to entry: The AC bridge usually works under power frequency with a very high accuracy and with a low applied voltage.

Note 2 to entry: In some special cases, the AC bridge can also work under a technical frequency.

3.1.3
impedance material analyser
instrument that uses the AC current method to measure the capacitance and dielectric loss of a capacitor

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

Note 2 to entry: The impedance material analyser uses five terminals to measure the device parameters and therefore a suitable adaptor for the three-electrode sample is necessary.

3.1.4
power frequency
frequency used for the power system, which is usually of 50 Hz or 60 Hz

3.1.5
apparent thickness
mechanical thickness
thickness of a sample measured by a mechanical apparatus, which is equivalent to the "bulking thickness" specified in IEC 60674-2

3.1.6
density thickness
thickness of a sample measured from the density of the sample, which is equivalent to the "gravimetric thickness" specified in IEC 60674-2

3.1.7
void ratio
α
percentage increase between the apparent thickness and the density thickness, which is dependent on the surface roughness

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

Note 2 to entry: The void ratio α is expressed in per cent (%) and is defined by Formula (1):

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

where

d_x is the apparent thickness of the sample in μm;

d_d is the density thickness of the 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.

3.1.8
contact ratio
η
percentage ratio of the contact area over the total area

Note 1 to entry: Samples with scabrous surfaces cannot have a perfect contact with the high flatness and low roughness surface of the electrode. The contact area is the area between the dielectric material and the electrode that remain in contact. The total area is the apparent area of the sample, usually equal to the area of the electrode.

Note 2 to entry: The contact ratio is dependent on the sample surface roughness and is defined by Formula (2):

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

where

S_{contact} is the contact area;

S_{total} is the total area;

η is the contact ratio in %.

3.1.9
surface roughness of sample
R_{a}
arithmetic mean height in µm of the sample profile expressed by Formula (3) in accordance with ISO 21920-2

$$R_{\mathrm{a}} = \frac{1}{l_{\mathrm{e}}} \int_{0}^{l_{\mathrm{e}}} \left| z(x) \right| \mathrm{d}x \tag{3}$$

where

l_{e} is the evaluation length of the sample profile;

$z(x)$ is the function that describes the height of the assessed scale-limited profile.

3.2 Abbreviated terms and symbols

AC	alternating current
HRC	hardness Rockwell C scale
RH	relative humidity
α	void ratio
d_{x}	apparent thickness of the sample in µm
d_{d}	density thickness of the sample in µm
η	contact ratio
R_{a}	surface roughness of sample in µm
S	area of the electrode
S_{contact}	contact area
S_{total}	total area
l_{e}	evaluation length of the sample profile
$z(x)$	function that describes the height of the assessed scale-limited profile

$\dot{C}_x$ complex capacitance

C_x real part of the complex capacitance

ε_0 electric constant

$\dot{\varepsilon}_x$ complex permittivity

ε_x relative permittivity

ε' real part of the complex permittivity

ε'' imaginary part of the complex permittivity

d_x thickness of the planar film sample

$\tan\delta$ dielectric dissipation factor

k ratio between the measured dielectric dissipation factor and the real dielectric dissipation factor

g gap between the guarded electrode and the measuring electrode

4 Principle of method

4.1 Principle of measurement

The complex capacitance $\dot{C}_x$ of the dielectric sample with the electrode can be obtained by using an AC bridge or an impedance material analyser. For a planar, even and smooth film sample, the relationship between the complex permittivity $\dot{\varepsilon}_x$ and the complex capacitance $\dot{C}_x$ is expressed by Equation (4).

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

where d_x is the thickness of the planar film sample, S is the area of the 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 shown in Equation (5).

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

The relationship of the complex permittivity $\dot{\varepsilon}_x$ with the real part ε', imaginary part ε'' and dielectric dissipation factor $\tan\delta$ is expressed as shown in Equation (6).

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

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 δ and the real part C_{x} of the complex capacitance $\dot{C}_{\mathrm{x}}$ can be measured directly. The relative permittivity ε_{x} of the dielectric material can be obtained by Equation (7).

$$\varepsilon_{\mathrm{x}} = \frac{d_{\mathrm{x}}}{\varepsilon_0 S} C_{\mathrm{x}} \tag{7}$$

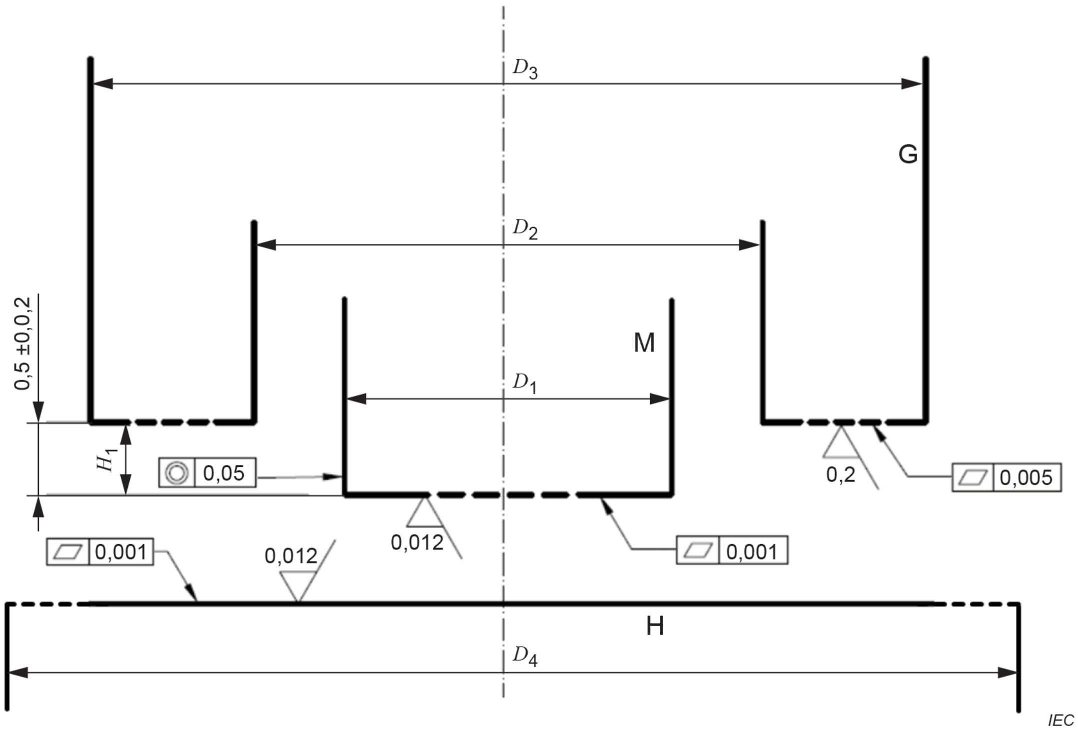
4.2 Edge effect of electrodes

Owing to manufacturing limitations, the gap between the measuring electrode and the guard ring will be more than 0,5 mm. Dielectric measurements are subject to the edge effect of electrodes. In the case of samples having a thickness equal to or greater than 0,5 mm, the guard ring electrode has been found effective to reduce the edge effect of electrodes. However, for samples having a thickness less than 0,5 mm, the guard ring electrode does not significantly reduce the edge effect since the gap between the measuring electrode and the guard ring is much bigger than the thickness of the sample. In this case, owing to the limitation of mechanical manufacture, the gap between the measuring electrode and the guard ring will be much bigger than the thickness of the sample. See also 5.2.

5 Electrodes

5.1 Design and manufacture of electrodes

The design and manufacture of the measuring electrodes is the most critical parameter of this test method. The measuring system is composed of three electrodes, a measuring electrode (M), a guard electrode (G) and a high-voltage electrode (H). The allowed dimensions of the electrodes are provided in Figure 1 and Table 1. The measuring electrode (M) and the high-voltage electrode (H) shall have a surface roughness of less than 0,012 µm and a relative flatness less than 0,5 µm. It shall be noted that the provided surface conditions are very important to ensure adequate contact between the electrodes and the sample. Since the thickness of the sample is relatively thin, the diameter of the measuring electrode should not be too big to avoid a large, measured capacitance that would make the selection of the measuring instrument difficult.



Key

D_1 diameter of the measuring electrode M

D_2 inner diameter of the guarded electrode G

D_3 outer diameter of the guarded electrode G

D_4 diameter of the high-voltage electrode H

Figure 1 – Diagram of the three-electrode system

In Figure 1, the gap between the guarded electrode and the measuring electrode, which can be calculated by $g = (D_2 - D_1)/2$, is kept to about 1 mm.

Table 1 – Dimensional parameters of the three-electrode system and the relationship between the measured ε_x for the thickness of sample and the measured capacitance

D_1 mm	D_2 mm	D_3 mm	D_4 mm	H_1 mm	ε_x
37,93 ± 0,05	39,93 ± 0,1 or 40,0 ± 0,1	60	70	0,5 ± 0,02	$C_x(\text{pF}) \cdot d_x(\text{mm})/10$ or $C_x(\text{nF}) \cdot d_x(\mu\text{m})/10$

The material of electrode M and electrode H shall satisfy the following conditions: good conductivity, non-ferromagnetic, anti-rust, and enough rigidity and hardness. More information about the manufacture of electrodes can be found in Annex B.

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