
**Nanotechnologies — Polymeric
nanocomposite films for food
packaging with barrier properties —
Specification of characteristics and
measurement methods**

*Nanotechnologies — Films de polymères nanocomposites pour
emballages alimentaires avec les propriétés barrières — Spécification
des caractéristiques et méthodes de mesure*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 229, *Nanotechnologies*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The rapid market growth of emerging packaging containing nano-objects is due to the effects this packaging has on improving food shelf life and decreasing food waste. In addition, the increasing export and import of food and food products is creating a growing future demand for nano-enhanced packaging.

Typical plastics used for packaging are polyethylene, polypropylene, polyamide and polyester. The presence of nano-objects in packaging can enhance various characteristics of the polymeric films such as gas/water vapour barrier properties, UV-Vis light transparency, thermal properties and mechanical strength. One of the key purposes of such packaging is to deliver longer shelf life by improving the barrier properties of food packaging to reduce gas diffusion, water vapour exchange and UV-Vis light exposure^[1]. The effect of gas, water vapour and UV-Vis light permeability of food packaging on the shelf life is described in [Annex A](#). Various types of nano-objects, such as clay nanoplates, zinc oxide nanoparticles/nanorods, titanium oxide nanoparticles, have been incorporated into the polymeric matrix to improve the above-mentioned barrier properties.

In contrast to glass or metal packaging materials, polymeric materials are permeable to small molecules of gas(es) and water vapour as well as UV-Vis light. The possibility to improve the barrier properties of polymer packaging by the application of nanocomposites is a very attractive field. The principal factors affecting the permeability of the original polymer matrix and the nanocomposite are the crystallinity and crystal phases of the polymer, the state of dispersion and orientation of nano-objects in the nanocomposite, etc. (see [Annexes B](#) and [C](#)).

In general, for a successful application of nano-enhanced barrier food packaging, it is required:

- to define the relationship among composition, structure and properties;
- to identify characteristics and their measurement methods.

This document specifies the characteristics including barrier properties to be measured of polymeric nanocomposite films. It also recommends the relevant measurement methods for the characteristics. This document is expected to promote communication and mutual understanding of polymeric nanocomposites for food packaging application between buyers and sellers.

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Nanotechnologies — Polymeric nanocomposite films for food packaging with barrier properties — Specification of characteristics and measurement methods

1 Scope

This document specifies characteristics including barrier properties to be measured of polymeric nanocomposite films used for improving food packaging. The barrier properties cover gas (oxygen), water vapour transmission and UV-Vis light transparency. This document also describes the relevant measurement methods.

This document addresses neither safety and health issues related to the food packaging nor environmental aspects.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

3.1.1

glass transition temperature

characteristic value of the temperature range over which the glass transition takes place

Note 1 to entry: Glass transition is a reversible change in an amorphous polymer or in amorphous region of partially crystalline polymer between a viscous or rubbery condition and a hard and relatively brittle one.

[SOURCE: ISO 11357-2:2020, 3.1, modified — Note 1 to entry has been replaced.]

3.1.2

melting temperature

temperature range over which crystalline or *semi-crystalline polymers* (3.1.7) lose their crystalline characteristics or particulate shape to produce a liquid, when heated

[SOURCE: ISO 472:2013, 2.584, modified — The definition has been reworded.]

3.1.3

nanocomposite

solid comprising a mixture of two or more phase-separated materials, one or more being nanophase

Note 1 to entry: Polymer matrix nanocomposite is referred to nanocomposite with at least one major polymeric phase.

[SOURCE: ISO/TS 80004-4:2011, 3.2, modified — Note 1 to entry has replaced the original Notes 1 and 2 to entry.]

3.1.4

nano-enhanced

exhibiting function or performance of materials intensified or improved by nanotechnology

[SOURCE: ISO/TS 80004-1:2015, 2.16, modified — “of materials” has been added.]

3.1.5

oxygen transmission rate

volume or amount of oxygen gas passing through a plastic material, per unit area and unit time, under unit partial-pressure difference between the two sides of the material

Note 1 to entry: The oxygen transmission rate in terms of volume is generally expressed in cubic centimetres per square metre, per 24 h and per atmosphere [$\text{cm}^3/(\text{m}^2 \cdot 24 \text{ h} \cdot \text{atm})$], the volume of the gas being converted to standard conditions under a pressure difference of one atmosphere.

Note 2 to entry: The oxygen transmission rate in terms of amount is expressed in moles per square metre, per second and per pascal [$\text{mol}/(\text{m}^2 \cdot \text{s} \cdot \text{Pa})$].

[SOURCE: ISO 15105-1:2007, 3.1, modified — “oxygen” has replaced “gas” in the term and “or amount of oxygen gas” has replaced before “of gas” in the definition. Notes 1 and 2 to entry have replaced the original note.]

3.1.6

packaging

product to be used for the containment, protection, handling, delivery, storage, transport and presentation of goods, from raw materials to processed goods, from the producer to the user or consumer, including processor, assembler or other intermediary

[SOURCE: ISO 21067-1:2016, 2.1.1]

3.1.7

semi-crystalline polymer

polymer containing both crystalline and amorphous phases, which may be present in varying proportions

[SOURCE: ISO 3146:2000, 3.1]

3.1.8

tortuous path

path of the gas passing through a polymeric matrix via passive shielding

3.1.9

UV-Vis transmittance

ratio of the radiant flux of a UV-Vis beam going through a film sample to that of the UV-Vis beam without the film sample

3.1.10

water vapour transmission rate

mass of water vapour transmitted through a unit area in a unit time under specified conditions of temperature and humidity

Note 1 to entry: Water vapour transmission rate is expressed in grams per square metre and per 24 h [$\text{g}/(\text{m}^2 \cdot 24 \text{ h})$].

Note 2 to entry: Adapted from ISO 15105-1:2007, 3.1.

3.2 Abbreviated terms

AFM	atomic force microscopy
DLS	dynamic light scattering
DSC	differential scanning calorimetry
GC	gas chromatography
ICP/AES	inductively coupled plasma atomic emission spectroscopy
ICP/MS	inductively coupled plasma mass spectrometry
OTR	oxygen transmission rate
PTA	particle tracking analysis
SAXS	small angle X-ray spectroscopy
SEM	scanning electron microscopy
TEM	transmission electron microscopy
TGA	thermogravimetric analysis
UV-Vis	ultraviolet-visible
WVTR	water vapour transmission rate
XRD	X-ray diffraction
XRF	X-ray fluorescence

4 Essential and optional characteristics to be measured and their measurement methods

4.1 General

The characteristics to be measured of polymeric nanocomposite film are classified into two groups: essential characteristics and optional ones. The essential characteristics listed in [Table 1](#) shall be measured. The optional characteristics listed in [Table 2](#) are provided for information. These characteristics may be useful to measure depending on specific applications.

Table 1 — Essential characteristics to be measured and their measurement methods

Item	Characteristics	Measurement method	
Nano-object	Size and size distribution	See 4.2.1	
	Chemical composition content	See 4.2.2	
Nanocomposite	Total luminous transmittance	See 4.3.1	
	Ash content	See 4.3.2	
	Barrier properties	OTR	See 4.3.3.2
		WVTR	See 4.3.3.3
UV-Vis transmittance		See 4.3.3.4	

Table 2 — Optional characteristics to be measured and their measurement methods

Item	Characteristics	Measurement method
Nano-object	Colour	See 4.4.1
	Morphology	See 4.4.2
Nanocomposite	Appearance	See 4.5.1
	Mechanical properties	See 4.5.2
	Melting temperature	See 4.5.3.1
	Glass transition temperature	See 4.5.3.2
	Crystalline phase type and crystallinity	See D.1
	Morphology	See D.2

4.2 Nano-object (essential characteristics)

4.2.1 Size and size distribution

4.2.1.1 General

The barrier properties of polymeric nanocomposite film are sensitive to the size of nano-objects incorporated into the polymeric matrix.

Nano-objects are three-dimensional objects with different shapes. It is impossible to represent the size of nano-object using a single number. Consequently, in most techniques it is assumed that the shape is spherical because a sphere is the shape that can be represented by a single number, its diameter (see ISO 19430:2016).

A test specimen for measurements of size and size distribution is taken from the nano-object raw material sample and a suspension is prepared.

The average size of a nano-object shall be measured using an appropriate measurement method and, if possible, specifying if the nano-object measured is primary or secondary (agglomerate). The measurement results shall be expressed in the unit of nm.

An appropriate measurement method from among SAXS, electron microscopy (TEM and SEM), DLS, AFM and PTA is recommended to be taken for measuring the average diameter of nano-objects.

NOTE 1 In most cases, the measured size can be of a secondary nano-object because of agglomeration. To inhibit agglomeration, an appropriate sample preparation is necessary.

NOTE 2 Ultra-sonication of the suspension containing a nano-object is an appropriate method before size measurement by the above mentioned methods.

4.2.1.2 Small angle X-ray spectroscopy

The size of nano-objects in liquid medium can be measured via SAXS. The SAXS technique is used to measure the primary and secondary nano-object size distribution, and primary and secondary nano-object average size.

NOTE ISO 17867:2015 specifies a method for the application of SAXS to the estimation of average nano-objects sizes in dilute dispersions where the interaction between the nano-object is negligible. Both number- and volume-based size distribution is measured via the SAXS method.

4.2.1.3 Electron microscopy

The size of nano-objects can also be measured by electron microscopy. TEM and SEM are used for size measurement of nano-objects (see ISO 21363 and ISO 19749, respectively). TEM and SEM methods provide two-dimensional images of the nano-object, which are number-based size distribution.

4.2.1.4 Particle tracking analysis

The size of nano-objects in a liquid can also be measured by PTA where the Brownian motion of nano-objects is traced optically. ISO 19430:2016 describes the evaluation of the number-based nano-object size distribution in liquid dispersions (solid, liquid or gaseous particles suspended in liquids) using the PTA method for diffusion velocity measurements.

4.2.1.5 Dynamic light scattering

The size of nano-objects in a liquid can also be measured by DLS. Particle size analysis is performed using the DLS method, which probes the hydrodynamic mobility of the particles. ISO 22412:2017 provides estimates of the average particle size and size distribution.

4.2.1.6 Atomic force microscopy

The size of nano-objects in dry form on a flat substrate can also be measured by AFM using height measurement (z-displacement). AFM provides a three-dimensional surface profile. While the lateral dimensions are influenced by the shape of the probe, displacement measurements can provide the height of nanoparticles with a high degree of accuracy and precision (see ASTM E2859-11).

4.2.1.7 Laser diffraction

The size of nano-objects and size distribution in many two-phase systems (e.g. powders, sprays, aerosols, suspensions, emulsions and gas bubbles in liquids) can be measured through the analysis of their light-scattering properties. In laser diffraction measurement, a laser beam is passed through a well-dispersed particle sample and particle size is measured by detecting the intensity of the scattered light produced (see ISO 13320).

The laser diffraction method is often applied to nanoplates the lateral size of which is larger than 100 nm.

4.2.2 Chemical composition content

4.2.2.1 General

A test specimen for measurements of chemical composition content is taken from the nano-object raw material sample and a dried powder is prepared. The chemical composition of nano-objects, i.e. elemental and compound compositions, of a nano-object raw material sample is one of the essential characteristics because it can influence the final products properties. The chemical composition includes major composition and minor composition (impurities). The chemical composition content is the ratio of the mass of an element or compound contained in a dried powder sample of nano-object raw material to that of the dried powder sample.

The chemical composition content shall be measured using an appropriate method. XRD, XRF, energy dispersive X-ray analysis, inductively coupled plasma/optical emission spectroscopy (ICP/OES) and mass spectroscopy (ICP/MS) are recommended to be used for chemical composition content measurements.

The results of chemical composition content measurements shall be expressed in the form of element type, element content (kg/kg), chemical compound type and chemical compound content (kg/kg).

4.2.2.2 X-ray diffraction

XRD can identify the chemical compound type for a nano-object raw material sample.

The XRD technique, by way of the study of the crystal structure, can be used to identify the crystalline phases present in a material and chemical composition. Identification of phases is carried out by comparison of the achieved data to that in reference databases. The chemical compound content is measured via the ratio of the intended chemical compound's peak intensity to the base material chemical compound's peak intensity.

4.2.2.3 X-ray fluorescence analysis

XRF analysis can identify the type and content of elements in a nano-object raw material sample.

XRF analysis can be used for a quantitative determination of major and trace element concentrations in homogeneous powder using a calibration with standard sample of same matrix (see ISO 18227:2014).

4.2.2.4 Energy dispersive X-ray analysis

Energy dispersive X-ray analysis can make quantitative measurement and identify the type of the elements in a nano-object raw material sample in terms of mass fraction fitted to a scanning electron microscope or an electron probe microanalyser (see ISO 22309:2011).

4.2.2.5 Inductively coupled plasma

ICP/AES and ICP/MS (see ISO 17294-1:2004) can measure the type and content of elements in a nano-object raw material sample.

NOTE A solution test specimen is prepared using an appropriate solvent for the ICP technique.

4.3 Nanocomposite (essential characteristics)

4.3.1 Total luminous transmittance

The luminous transparency of polymeric materials for food packaging is usually desirable since it increases the aesthetic value of the packaging for identification and display of the packaged products. The transparency, commonly known as “see-through”, refers to the transparency in the visible wavelength range.

The total luminous transmittance of a film test specimen is defined as the ratio of the radiant flux of a standard visible light that is transmitted through the film test specimen to that of the standard visible light when removing the film test specimen.

The total luminous transmittance shall be measured for a nanocomposite film and a polymer matrix film. The thickness of the polymer matrix film test specimen shall be the same as that of the nanocomposite film test specimen. The measurement results of the total luminous transmittance are usually expressed in per cent (%).

The equipment necessary for measurements includes a light source, photodetector, optical filter and integrating sphere. See ISO 13468-1:2019 and ISO 13468-2:1999 for the total luminous transmittance measurements.

The measurement results of total luminous transmittance shall be reported for nanocomposite film test specimens and polymer matrix film test specimens. Also, the change in the total luminous transmittance from the polymer matrix film to the nanocomposite film shall be reported so that the effect of nano-object incorporation into the polymer matrix is readily seen. The test specimen thickness shall also be reported.

4.3.2 Ash content

Nano-object content in the nanocomposite is an important factor that affects the barrier properties. The nanocomposite sample is predominantly composed of base polymer and incorporated nano-objects. Incineration of the nanocomposite sample at an appropriate temperature can remove the polymeric constituent from the sample. The ash remaining in a nanocomposite sample after incineration may be the added nano-objects if the ash content of the original polymeric matrix is negligible. It can be an indication of nano-object content in the sample.

The ash content of a polymeric nanocomposite sample is the ratio of the mass of the residue of the sample after removal of polymeric constituents by incineration to that of the dried sample before incineration.

The ash content of a polymeric nanocomposite sample shall be measured by an appropriate measurement method. The measurement results of ash content shall be expressed in the unit of kg/kg or as % mass fraction.

There are two options for the measurement method: the ash weighing method and TGA. The ash weighing method is much simpler and uses less expensive instrumentation. It consists of weighing a sample, then placing it in a crucible that goes into a furnace, where it is heated until all the polymer is decomposed. The remaining ash is then weighed and the filler content is calculated. ISO 3451-1 for general applications may be useful to the ash content measurement of a polymeric nanocomposite sample.

NOTE XRD analysis of the residual ash can be utilized for the identification of the crystalline structure of a nano-object incorporated inside a polymer matrix.

In the case of small sample size, TGA can be employed (see ISO 11358-1:2014). A thermogravimetric analyser consists of a very sensitive analytical balance, a furnace that can be heated in a programmed manner, and software that continuously monitors the mass of the sample and graphs this as a function of temperature.

The ash weighing method gives sample masses before and after incineration, but TGA gives continuous change of sample mass during incineration. The disadvantage of TGA is that it can only work with small samples (10 mg to 50 mg), while the ash weighing method uses 2 g to 3 g and therefore provides a more representative sample.

4.3.3 Barrier properties

4.3.3.1 General

In order to adequately preserve the quality of the food, the packaging materials have to provide efficient barriers against oxygen, water vapour and light (UV-Vis), preventing food degradation and oxidation and preserving flavours. The absorption and transmission of light by polymers is especially important in the food packaging industry where the packaged goods are UV-light sensitive.

Oxygen, water vapour and UV-Vis light barrier properties are examined in [4.3.3.2](#), [4.3.3.3](#) and [4.3.3.4](#), respectively.

4.3.3.2 Oxygen transmission rate

The OTR change is the difference between the OTR of a nanocomposite film sample and that of the original polymeric matrix film sample measured under the same conditions as the nanocomposite film sample.

The OTR of a nanocomposite film sample and an original polymeric matrix film sample shall be measured by an appropriate measurement method. The thickness of the original polymer matrix film test specimen shall be the same as that of the nanocomposite film test specimen. The measurement results shall be expressed in the unit of $\text{mol}/(\text{m}^2 \cdot \text{s} \cdot \text{Pa})$ or $\text{cm}^3/(\text{m}^2 \cdot 24 \text{ h})$. Calculate the OTR change from the measured OTR data of nanocomposite film test specimen and of original polymer matrix film test specimen.

There are two different measurement methods: differential-pressure method (see ISO 15105-1:2007) and equal-pressure method (see ISO 15105-2:2003). The ISO 15105 series specifies methods for the determination of the gas transmission rate of any plastic material in the form of film, sheeting, laminate, co-extruded material or flexible plastic-coated material.

In ISO 15105-1:2007, two methods are proposed for determining the gas transmission rate of single-layer plastic film or sheet and multi-layer structures under a differential pressure. One method uses a pressure sensor and the other uses a gas chromatograph to measure the amount of gas that permeates through a test specimen.

In ISO 15105-2:2003, the volume of oxygen passing through a plastic material, per unit area and unit time, under unit partial-pressure difference between the two sides of the material is measured.

4.3.3.3 Water vapour transmission rate

The WVTR change is the difference between the WVTR of a nanocomposite film sample and that of the original polymeric matrix film sample measured under the same conditions as the nanocomposite film sample. The WVTR of a nanocomposite film sample and the original polymeric matrix film, having the same thickness, shall be measured by an appropriate measurement method. The measurement results shall be expressed as $[g/(m^2 \cdot d)]$. Calculate the WVTR change from the measurement data of the nanocomposite film sample and the original polymeric matrix film sample.

There are five different measurement methods: humidity detection sensor method (see ISO 15106-1:2003), infrared detection sensor method (see ISO 15106-2:2003), electrolytic detection sensor method (see ISO 15106-3:2003), gas-chromatographic detection sensor method (see ISO 15106-4:2008) and gravimetric (dish) method (see ISO 2528:2017).

In ISO 15106-1:2003, a dry chamber, at a specified relative humidity, is separated by a sheet test specimen from a wet chamber, in which the atmosphere is saturated with water vapour controlled at a known temperature. The change in humidity brought about by water vapour transmitted through the sheet test specimen is detected by a humidity sensor capable of providing an electrical output signal, which is a measure of the relative humidity in the dry chamber. The time taken for the humidity to increase by a given amount is measured and converted into a WVTR.

In ISO 15106-2:2003, a dry chamber, at a specified relative humidity, is separated from a wet chamber, in which the atmosphere is saturated with water vapour at a known temperature, by a sheet of the material to be tested. The change in humidity brought about by water vapour transmitted through the specimen is detected by an infrared sensor capable of providing an electrical output signal, which is a measure of the relative humidity in the dry chamber. The time taken to reach a steady state is measured and converted into a WVTR.

In ISO 15106-3:2003, the gas transmission cell is designed in such a way that, with the test specimen inserted, it is divided into a dry chamber and a controlled-humidity chamber. The dry side of the specimen is swept by a flow of dry carrier gas, and water vapour permeating through the specimen from the controlled-humidity chamber is carried by the carrier gas into an electrolytic cell. This cell contains two spiral wire electrodes, coated with a thin layer of phosphorous pentoxide, mounted on the inside wall of a glass capillary. The carrier gas is passed through the capillary where the moisture it holds is quantitatively absorbed by the phosphorous pentoxide and decomposed electrolytically into hydrogen and oxygen by the application of a DC voltage to the electrodes. The mass of the water vapour that permeates through the test specimen and is decomposed per unit time is calculated from the electrolytic current required.

In ISO 15106-4:2008, a dry chamber, evacuated by a vacuum pump, is separated by a test specimen from a wet chamber, in which the relative humidity of a gas flow is controlled at a specified level. The water vapour transmitted through the test specimen is collected in a sampling loop for a certain period of time. The absolute mass of the water collected is measured using a gas chromatograph. The WVTR is then calculated from the mass of water vapour transmitted, the period of time and the transmission area of the test specimen.

In ISO 2528:2017, dishes containing a desiccant and closed by the material to be tested are placed in a controlled atmosphere. These dishes are weighed at suitable intervals of time and the WVTR is determined from the increase in mass when this increase has become proportional to the time interval.

NOTE WVTR is not a linear function of temperature nor, generally, of relative humidity difference. A determination of WVTR obtained under certain conditions is not, therefore, necessarily comparable with one carried out under other conditions.

The gravimetric (dish) method is not generally recommended for use if the transmission rate is expected to be less than $1 g/m^2$ per day or for a test specimen thicker than 3 mm.

4.3.3.4 UV-Vis transmittance

The UV-Vis transmittance of a nanocomposite film test specimen and an original polymer matrix film test specimen shall be measured by an appropriate measurement method in the spectral range from 320 nm to 750 nm. The test specimen thickness shall be the same between the nanocomposite film and the original polymer matrix film. The measurement results of UV-Vis transmittance are usually expressed in per cent (%).

UV-Vis spectrophotometry should be employed for the measurements. ASTM D1746-03 is useful for the measurement procedures.

The measurement results of UV-Vis transmittance for the nano-composite film test specimen and the original polymer matrix film test specimen shall be displayed together on a spectral chart ranging from 320 nm to 750 nm so that the transmittance change between the two data is clearly seen. The thickness of the test specimens shall be reported.

4.4 Nano-object (optional characteristic)

4.4.1 Colour of nano-object raw material

The colour of the nano-object raw material can affect the colour of the nanocomposite product. Visual observation is carried out for colour assessment and also qualitative evaluation.

NOTE The colour of the final product can be induced by colour of a master batch/compound granule, which is incorporated during the production process.

4.4.2 Morphology

The nano-object can be in form of nanofiber, nanoplate and nanoparticle. The morphology of nano-objects may affect the barrier properties of the nanocomposite. The morphology of nano-objects in a raw material is observed using SEM, TEM and AFM techniques. Microscopic images should have the scale bars. The number of images to be taken can be decided between interested parties.

4.5 Nanocomposite (optional characteristic)

4.5.1 Appearance of nanocomposite

4.5.1.1 General

Visual observation is carried out for colour assessment and also qualitative transparency evaluation of a nanocomposite film.

4.5.1.2 Colour

The colour of a nanocomposite film can be induced by colour of a master batch granule, which is incorporated during the production process.

4.5.1.3 Haze of a nanocomposite film

Haze is the percentage of transmitted light, passing through the film, that deviates from the incident light by more than 0,044 rad (2,5°) by forward scattering. The haze can be measured in accordance with International Standards for haze (see ISO 14782). The haze depends on various factors such as polymer(s) type, processing condition, surface texture and also any additive inside the polymeric matrix as well as exposure to the environment, e.g. sun and moisture.

4.5.2 Mechanical properties

Incorporation of a nano-object into the polymeric matrix can change the mechanical properties of the nanocomposite. The changes to mechanical properties can be due to the existence of the nano-objects as well as the structural changes induced by the incorporation of nano-objects. Yield stress, modulus of elasticity/stiffness (see ISO 527-1, ISO 527-2 and ISO 527-3), tear strength (see ASTM D1922-15 and ASTM D1004-13) and impact strength (see ISO 180) are the most important mechanical properties for polymeric nanocomposite food packaging. Dynamic mechanical analysis can be also employed for mechanical properties measurement (see ISO 6721-11).

4.5.3 Physical properties

4.5.3.1 Melting temperature

Semi-crystalline polymers show a melting temperature at which a solid to liquid transition takes place in polymer. This property is important for the packaging in which the food or beverage is hot filled during the packaging. The melting temperature is measured by DSC in accordance with ISO 11357-1:2016. Melting temperature of the polymers may be affected by incorporation of nano-objects into the polymeric matrix. Therefore, the melting temperature of nanocomposites should be considered.

4.5.3.2 Glass transition temperature

The glass transition temperature is one of the most important properties of any polymer and is the temperature region at which the amorphous part polymer transitions from a hard, glassy material to a soft, rubbery material take place. Similar to melting temperature, glass transition temperature is important for cases of hot filling of food in the polymeric packaging. The hot filling temperature should not exceed the glass transition temperature of the polymers. The glass transition temperature of the polymer is affected by the incorporation of the nano-objects. In most cases, the addition of nano-objects into the polymer matrix increases the glass transition temperature. The glass transition temperature can be measured in accordance with ISO 11357-2 by DSC. The method of modulated DSC is another method for glass transition temperature determination (see ISO 19935-1).

Dynamic mechanical analysis is also employed for the glass transition temperature measurement (see ISO 6721-11). For dynamic mechanical analysis, a specimen of known geometry is placed or held in a suitable mechanical loading system in an enclosed temperature chamber, or an oven that can be heated at a controlled rate. The specimen is mechanically oscillated at a fixed frequency, and changes in the viscoelastic response of the material are monitored and recorded as a function of the test temperature. The dynamic properties (storage modulus, loss modulus and tan delta) are determined from the load and displacement data recorded throughout the test (see ISO 6721-1). The glass transition temperature is determined as the point of inflection in the storage modulus versus the temperature plot (see ISO 6721-11).

5 Preparation of test specimens

Nanocomposite film test specimens and polymeric matrix film test specimens should be prepared in accordance with ISO 2818 and ISO 3167.

6 Reporting

6.1 General

The manufacturer or provider shall report the general information (see 6.2) and measurement results (see 6.3) of the essential characteristics of a polymer nanocomposite film listed in Table 1. The optional characteristics could also be reported in a similar manner.

6.2 General information

- Manufacturer's name.
- Product name.
- Batch and lot number.
- Type of barrier: oxygen, water vapour and/or UV-Vis.
- Polymer name of matrix: e.g. polyethylene.
- Type and name of nano-objects: e.g. nanoparticle, nanofiber or nanoplate and clay, silica or carbon nanotube.
- Manufacturing method of the nanocomposite.

6.3 Measurement results

6.3.1 Essential characteristics

- Size and size distribution of nano-objects.
- Chemical composition content of nano-objects.
- Total luminous transmittance of nanocomposite film, polymer matrix film and its change as well as the thickness of test specimens.
- Ash content of nanocomposite film.
- Oxygen transmittance rate of nanocomposite film, polymer matrix film and its change as well as the thickness of test specimens.
- WVTR of nanocomposite film, polymer matrix film and its change as well as the thickness of test specimens.
- UV-Vis transmittance of nanocomposite film and polymer matrix film on a spectral chart as well as the thickness of test specimens.

6.3.2 Additional information

- Measuring organization: laboratory name and address.
- Measurement date.

6.4 Example of table format

[Table 3](#) is an example format for reporting. The optional characteristics may be added to the reporting items and [Table 3](#).

Table 3 — Example table format for reporting

General				
Manufacturer's name				
Product name:				
Batch no.:				
Lot no.:				
Manufacturing method of nanocomposite:				
Type of barrier	<input type="checkbox"/> Oxygen			
	<input type="checkbox"/> Water vapour			
	<input type="checkbox"/> UV-Vis			
Polymer matrix				
Polymer type/ composition:				
Nano-object				Measurement date
Type and name:				
Size and size distribution:				
Chemical composition content:				
Nanocomposite				Measurement date
Ash content:		% mass fraction		
Total luminous transmittance	Nanocomposite			
	Polymer matrix			
	change			
	Thickness of test specimens			
Barrier properties	OTR	Nanocomposite		
		Polymer matrix		
		change		
		thickness of test specimens		
	WVTR	Nanocomposite		
		Polymer matrix		
		change		
		thickness of test specimens		
	UV-Vis transmittance	Nanocomposite	(show on a spectral chart)	
		Polymer matrix	(show on a spectral chart)	
thickness of test specimens				
List of laboratory names and addresses				

Annex A (informative)

Shelf life extension of food

A.1 General

Shelf life of the food depends on various parameters including gas and water vapour permeation and UV-Vis light exposure. Among gases, oxygen has the most impact on the food shelf life. In fact, food should be protected from oxygen and UV-Vis light exposure in addition to humidity control inside the packaging. Any kind of spoilage or quality loss can be reduced or even stopped by the right regulation of oxygen, water vapour and UV-Vis light during the expected shelf life of the packaged products.

A.2 Protection from oxygen

Oxygen causes oxidation and promotes the enzymatic and non-enzymatic phenolic browning of fresh fruit and the growth of microorganisms. Packaging without or with less oxygen (e.g. vacuum or modified-atmosphere packaging) extends shelf life and inhibits deterioration.

A.3 Protection from ethylene

Fresh produce generally emits ethylene gas during respiration, filling the inside packaging atmosphere with this gas. The ethylene gas leads to an acceleration of respiration of the agricultural products and consequently spoilage of them. The ethylene gas should be taken out of the packaging atmosphere by absorption (active packaging) or by transmission of gas molecules through the packaging wall.

A.4 Control of CO₂ level

CO₂ gas is a by-product during the respiration of fresh produce. This gas provides a condition for the growth of anaerobic microorganisms inside the packaging. The CO₂ gas should be taken out of packaging through the packaging wall. However, in some cases, a high level of CO₂ gas inside the packaging can extend the shelf life of packaged food. Depending on the application, the presence of a controlled level of CO₂ gas inside the packaging could be desirable.

A.5 Moisture level

Depending on the food product, a high or even a low level of moisture can stabilize the product quality and enhance the shelf life. An adequate choice of packaging material and barrier properties regulates the moisture level and supports the end product quality. The WVTR of the packaging materials, i.e. polymeric materials, is one of the most important factors and has to fit with the moisture requirements of the food. The critical moisture content is a useful parameter to ensure product quality. However, once a certain critical amount of moisture is present, changes to the taste or smell can be detected that could make the product unsaleable (but not unhygienic). For example, some biscuits can absorb 2 % more moisture than that present when they are freshly baked and the consumer would not be able to detect a difference. However, above this moisture level, a distinct lowering of quality and a loss of crispness would be noticed.

A.6 Light protection

Sunlight contains ultraviolet and visible (UV-Vis) rays that cause rapid deterioration of some foods (especially oils and fatty foods) or specific components of a food such as certain vitamins. Flavours and colourings can also be destroyed by strong UV-Vis light. UV-Vis rays can also cause packaging materials to fade or to become brittle and lose their properties (e.g. polythene). In general, all food should be stored in the shade away from direct sunlight. If the organic food product is light-sensitive, a suitable packaging material has to be chosen.

It is expected that the polymers to be used for food packaging act as a good barrier to light incidence in the UV-Vis range. Polymers with a high UV-Vis barrier are desirable to protect especially unsaturated lipid components in food from the formation of radicals that would otherwise accelerate their spoilage.

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