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**Plastics — Methodology for assessing  
polymer photoageing by FTIR and  
UV/visible spectroscopy**

*Plastiques — Méthodologie d'évaluation du photovieillissement des  
polymères par spectroscopie IRTF et UV/visible*

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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.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10640 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 6, *Ageing, chemical and environmental resistance*.

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## Introduction

One of the main interests in the use of artificial accelerated weathering tests is to provide an estimate of the lifetime of polymeric materials exposed in outdoor conditions. This is a very difficult task, and ISO 4892-1<sup>[1]</sup> describes some of the reasons why it is difficult and why the use of simple “acceleration factors” relating time in an accelerated test versus time in an outdoor exposure is not recommended without special care.

One way to evaluate whether an artificial accelerated test can predict the relative performance of materials used in outdoor applications is to compare the chemical changes caused by the artificial accelerated test with the chemical changes that occur in outdoor exposure.

Changes in visual appearance (gloss, discoloration, yellowing, bleaching, micro-cracks, etc.) and deterioration in physical (or functional) properties are consequences of chemical changes, even if there is not always a direct relationship between the chemical changes and the mechanical changes. The use of Fourier transform infrared (FTIR) spectroscopy to follow the chemical changes can facilitate the research of correlations between different ageing tests (natural or any kinds of accelerated devices).

This International Standard describes the methodology and a procedure for using FTIR spectroscopy and UV/visible spectroscopy.

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# Plastics — Methodology for assessing polymer photoageing by FTIR and UV/visible spectroscopy

## 1 Scope

This International Standard provides a methodology to assess the ageing of polymeric systems during exposure to laboratory accelerated weathering as well as in outdoor exposures.

**NOTE** This methodology applies mainly to photoageing, but it can also be applied to thermal ageing.

This methodology identifies analyses that follow the chemical changes which control the deterioration of physical properties of materials during photoageing. The main procedure is based on infrared (IR) spectroscopy analysis and is described in this International Standard. In addition, UV spectroscopy is used for monitoring the behaviour of some additives and to identify the origin of discoloration in polymeric materials (degradation of pigments and colorants, or polymer yellowing).

Examples of applications of this methodology are given in Annex A as guidance for the interpretation of the results.

## 2 Terms and definitions and abbreviated terms

### 2.1 Terms and definitions

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

#### 2.1.1 photoageing

entirety of the irreversible chemical and physical processes occurring in a material over the course of time that are initiated by radiation and that can be affected by heat, oxygen and moisture

#### 2.1.2 artificial accelerated weathering

exposure of a material in a laboratory weathering device to conditions which can be cyclic and intensified over those encountered in outdoor or in-service exposure

**NOTE 1** This involves a laboratory radiation source, heat and moisture (in the form of relative humidity and/or water spray, condensation or immersion) in an attempt to produce more rapidly the same changes that occur in long-term outdoor exposure.

**NOTE 2** The device can include means for controlling and/or monitoring the light source and other weathering variables. It can also include exposure to special conditions, such as acid spray to simulate the effect of industrial gases.

#### 2.1.3 natural outdoor weathering

exposure of a material to global solar radiation under outdoor climatic conditions

**2.1.4**

**absorption spectrum**

fraction of the incident electromagnetic radiation absorbed by a material or a molecular entity over a range of frequencies

**2.1.5**

**transmission spectrum**

fraction of the incident electromagnetic radiation that is not absorbed but passes through a material or a molecular entity over a range of frequencies

**2.1.6**

**reflection spectrum**  
**reflectance spectrum**

fraction of the incident electromagnetic radiation reflected or scattered by a material or a molecular entity over a range of frequencies

NOTE The re-emitted radiation can be composed of two kinds of radiation referred to as specular reflection (when the angle of reflection is equal to the angle of incidence) and diffuse reflection (at all other angles).

**2.2 Abbreviated terms**

ABS acrylonitrile-butadiene-styrene

ATR attenuated total (internal) reflection

EVAC ethylene-(vinyl acetate) plastic

FTIR Fourier transform infrared

PA polyamide

PAS photoacoustic spectroscopy

PBT poly(butylene terephthalate)

PC polycarbonate

PE polyethylene

PEBA polyether block amide

PEEK polyetheretherketone

PE-LD polyethylene, low density

PET poly(ethylene terephthalate)

PMMA poly(methyl methacrylate)

POM poly(oxymethylene); polyacetal; polyformaldehyde

PP polypropylene

PPE poly(phenylene ether)

PS polystyrene

PUR polyurethane

PVC-P plasticized poly(vinyl chloride)

PVC-U unplasticized poly(vinyl chloride)

SAN	styrene-acrylonitrile plastic
TPU	thermoplastic polyurethane
UP	unsaturated polyester resin
UV/VIS	ultraviolet/visible

### 3 Principle

When a polymeric material is exposed to UV radiation and other moderate environmental stresses, the change in most physical properties is attributable to chemical ageing, and the extent of the chemical changes can be related to the duration of the exposure under natural outdoor weathering or artificial weathering exposure.

Chemical changes control the degradation of mechanical properties and contribute to changes in the visual appearance of polymer materials during photoageing. These chemical changes are analysed primarily by IR spectroscopy, with additional analyses using UV/visible spectroscopy during the photoageing of polymers. The analysis at this earliest stage of degradation allows the identification of the critical oxidation products, allows the stoichiometry of reactions to be checked and, in some cases, indicates weak points in the polymer material (e.g. a weakness in the specific structure of the polymer, such as a double bond, an ether group or a urethane group, unstable colorant, lack of UV stabilizers, or migration of low-molecular-mass components of formulations to the surface and their accumulation there).

The relevance of artificial ageing can be determined by comparing the chemical changes that occur in the accelerated test to those that occur in natural weathering. It should be pointed out that, in some cases, oxidation products can be partially eliminated by hydrolysis, or erosion caused by water under humid climates (e.g. southern Florida) or by wind under very dry climates (e.g. Arizona). Kinetic analysis is recommended to determine the rate of degradation under different conditions of ageing in order to rank different formulations or to determine the range of acceleration possible for an artificial ageing test compared to a given natural outdoor weathering exposure (without distortion of the photodegradation mechanism of the polymer). In addition, these analyses can be used as a tool for developing improvements in polymers and polymeric products.

## 4 Methodology

### 4.1 General

Since the mechanism of degradation of polymers is a function of the polymer composition, it might be necessary to identify the chemical composition of the exposed plastics to allow comparison of results from laboratory experiments with those from actual use conditions. This will help in the design of better accelerated tests in those cases when existing accelerated tests have not given useful results for comparison with actual use conditions.

The specific chemical changes which control a given physical deterioration should be identified. For example, mechanical failures are generally controlled by the extent of oxidation, which makes their prediction possible.

In many cases, the extent of oxidation and the extent of changes in mechanical properties are often closely linked via main-chain scissions. A specific correlation study could be carried out for a given material in order to predict mechanical-property changes from the measurement of the concentration of oxidation products.

Except in the case of yellowing due to direct phototransformation, e.g. in the case of aromatic polymers, the change in visual appearance is generally controlled by several chemical processes (loss of gloss, discoloration, bleaching, micro-cracks, etc.). Therefore, an accelerated photoageing test is only predictive if one single process prevails over the others.