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Practice for use of a radiochromic optical waveguide dosimetry system

Pratique de l'utilisation d'un système dosimétrique à guide d'ondes optiques radiochromiques

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Foreword

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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. International Standards are drafted in accordance with the editorial rules of ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by ASTM Committee E61 Radiation Processing and by Technical Committee ISO/TC 85, nuclear energy, nuclear technologies and radiological protection.

This third edition cancels and replaces the second edition (ISO/ASTM 51310:2004), which has been technically revised.

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This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Standard Practice for Use of a Radiochromic Optical Waveguide Dosimetry System[1]

This standard is issued under the fixed designation ISO/ASTM 51310; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision.

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1. Scope

1.1 This is a practice for using a radiochromic optical waveguide dosimetry system to measure absorbed dose in materials irradiated by photons and high energy electrons in terms of absorbed dose to water. The radiochromic optical waveguide dosimetry system is generally used as a routine dosimetry system.

1.2 The optical waveguide dosimeter is classified as a Type II dosimeter on the basis of the complex effect of influence quantities (see ISO/ASTM Practice 52628).

1.3 This document is one of a set of standards that provides recommendations for properly implementing dosimetry in radiation processing, and describes a means of achieving compliance with the requirements of ISO/ASTM 52628 for an optical waveguide dosimetry system. It is intended to be read in conjunction with ISO/ASTM Practice 52628.

1.4 This practice applies to radiochromic optical waveguide dosimeters that can be used within part or all of the specified ranges as follows:

1.4.1 The absorbed dose range is from 1 Gy to 20 000 Gy.

1.4.2 The absorbed dose rate is from 0.001 Gy/s to 1000 Gy/s.

1.4.3 The radiation photon energy range is from 1 MeV to 10 MeV.

1.4.4 The radiation electron energy range is from 3 MeV to 25 MeV.

1.4.5 The irradiation temperature range is from –78 °C to +60 °C.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced documents

2.1 *ASTM Standards:*[2]

E275 Practice for Describing and Measuring Performance of Ultraviolet and Visible Spectrophotometers

E925 Practice for Monitoring the Calibration of Ultraviolet-Visible Spectrophotometers whose Spectral Bandwidth does not Exceed 2 nm

E958 Practice for Estimation of the Spectral Bandwidth of Ultraviolet-Visible Spectrophotometers

E3083 Terminology Relating to Radiation Processing: Dosimetry and Applications

2.2 *ISO/ASTM Standards:*[2]

51261 Practice for Calibration of Routine Dosimetry Systems for Radiation Processing

51707 Guide for Estimation of Measurement Uncertainty in Dosimetry for Radiation Processing

52628 Practice for Dosimetry in Radiation Processing

52701 Guide for Performance Characterization of Dosimeters and Dosimetry Systems for Use in Radiation Processing

2.3 *International Commission on Radiation Units and Measurements (ICRU) Reports:*[3]

ICRU Report 80 Dosimetry Systems for Use in Radiation Processing

ICRU Report 85a Fundamental Quantities and Units for Ionizing Radiation

[1] This practice is under the jurisdiction of ASTM Committee E61 on Radiation Processing and is the direct responsibility of Subcommittee E61.02 on Dosimetry Systems, and is also under the jurisdiction of ISO/TC 85/WG 3.

Current edition approved December 2021. Published February 2022. Originally published as ASTM E 1310–89. Last previous ASTM edition E 1310–98$^{\varepsilon 1}$. ASTM E 1310–94 was adopted by ISO in 1998 with the intermediate designation ISO 15559:1998(E). The present International Standard ISO/ASTM 51310:2022(E) is a revision of the last previous edition ISO/ASTM 51310:04(2012)(E).

[2] For referenced ASTM and ISO/ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from the International Commission on Radiation Units and Measurements, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814, U.S.A.

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2.4 *ISO Standard:*[4]

12749-4 Nuclear energy – Vocabulary - Part 4: Dosimetry for radiation processing

2.5 *Joint Committee for Guides in Metrology (JCGM) Reports:*

JCGM 100:2008, GUM 1995 , with minor corrections Evaluation of measurement data – Guide to the Expression of Uncertainty in Measurement[5]

JCGM 200:2012, VIM , International Vocabulary of Metrology — Basis and General Concepts and Associated Terms[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *analysis wavelength*—wavelength used in a spectrophotometric instrument for the measurement of optical absorbance or reflectance.

3.1.2 *dosimeter batch*—quantity of dosimeters made from a specific mass of material with uniform composition, fabricated in a single production run under controlled, consistent conditions and having a unique identification code.

3.1.3 *dosimeter response (indication)*—reproducible, quantifiable change produced in the dosimeter by ionizing radiation.

3.1.3.1 *Discussion*—The dosimeter response value (indication), obtained from one or more measurements, is used in the estimation of absorbed dose.

3.1.3.2 *Discussion*—For optical waveguide dosimeters, the dosimeter response value (indication) is the net response obtained from measurements of the optical absorbance.

3.1.4 *net response, ΔR*—radiation–induced change in the relationship of measured absorbance at a specific wavelength determined by subtracting the pre-irradiation response, R_0, from the post–irradiation response, R:

$$\Delta R = R - R_0 \quad (1)$$

with:

$$R = A_\lambda / A_{\lambda ref}$$
$$R_0 = [A\lambda / A_{\lambda ref}]_0 \quad (2)$$

where:

A_λ = optical absorbance at the analysis wavelength, λ, and
$A_{\lambda ref}$ = optical absorbance at a reference wavelength, λ_{ref}.

3.1.5 *optical waveguide*—device that contains an optical material at a high index of refraction relative to the material enclosing the optical material.

3.1.6 *radiochromic optical waveguide dosimeter*—specially prepared optical waveguide containing ingredients that undergo an ionizing radiation–induced change in photometric absorbance which can be related to absorbed dose to water (**1, 2**).[7]

3.1.7 *reference wavelength, λ_{ref}*—wavelength selected for comparison with the analysis wavelength. This wavelength is chosen to minimize effects associated with optical coupling and other geometric variations in the dosimeter.

3.2 Definitions or other terms used in this standard that pertain to radiation measurement and dosimetry may be found in ISO/ASTM Practice 52628. Other terms that pertain to radiation measurement and dosimetry may be found in ASTM Terminology E3083 and ISO 12749-4. Where appropriate, definitions in these standards have been derived from, and are consistent with definitions in ICRU 85a, and general metrological definitions given in the VIM.

4. Significance and use

4.1 The radiochromic optical waveguide dosimetry system provides a means of measuring absorbed dose in materials. Under the influence of ionizing radiation such as photons, chemical reactions take place in the radiochromic optical waveguide creating and/or modifying optical absorbance bands in the visible region of the spectrum. Optical response is determined at selected wavelengths using the equations in 3.1.4. Examples of appropriate wavelengths for the analysis for specific dosimetry systems are provided by their manufacturers and in Refs (**1-5**).

4.2 These dosimetry systems commonly are applied in the industrial radiation processing of a variety of products, for example, the sterilization of medical devices and radiation processing of foods (**4-6**).

NOTE 1—For additional information on dosimetry systems used in radiation processing, see ICRU Report 80.

5. Overview

5.1 Radiochromic optical waveguide dosimeters may be manufactured by various methods. For example, consisting of a solution held in a fluorinated ethylenepropylene (FEP) tube by means of glass beads inserted in the ends of the tube. In addition to sealing the solution in the tube the beads act as lenses for light during the analysis of the dosimeter's response.

5.2 The FEP tube has a lower index of refraction than the radiation-sensitive solution, creating an optical waveguide. Light entering through one end will tend to move through the solution to the other end, reflecting off the wall of the tube.

5.3 The response is measured as a ratio of the absorbance at the wavelength of interest to the absorbance at a reference wavelength that is minimally affected by the radiation-induced changes of the solution inside the tube.

6. Influence quantities

6.1 Factors other than absorbed dose which influence the dosimeter response are referred to as influence quantities and are discussed in the following sections. Examples of such

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

[5] Document produced by Working Group 1 of the Joint Committee for Guides in Metrology (JCGM WG1). Available free of charge at the BIPM website (http://www.bipm.org).

[6] Document produced by Working Group 2 of the Joint Committee for Guides in Metrology (JCGM WG2). Available free of charge at the BIPM website (http://www.bipm.org).

[7] The boldface numbers in parentheses refer to the bibliography at the end of this practice.

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