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Standard Test Method for Evaluating Trans-Vinylene Yield in Irradiated Ultra-High-Molecular-Weight Polyethylene Fabricated Forms Intended for Surgical Implants by Infrared Spectroscopy¹

This standard is issued under the fixed designation F2381; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes the measurement of the number of trans-vinylene groups in ultra-high molecular weight polyethylene (UHMWPE) intended for use in medical implants. The material is analyzed by infrared spectroscopy.

1.2 This test method is based on Guide F2102.

1.3 The applicability of the infrared method has been demonstrated in other literature reports. This particular method, using the intensity (area) of the C-H absorption centered at 1370 cm^{-1} to normalize for the sample's thickness, will be validated by an Interlaboratory Study (ILS) conducted according to Practice E691.

1.4

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

1.5 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 and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:²

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E1421 Practice for Describing and Measuring Performance of Fourier Transform Mid-Infrared (FT-MIR) Spectrometers: Level Zero and Level One Tests

F2102 Guide for Evaluating the Extent of Oxidation in Ultra-High-Molecular-Weight Polyethylene Fabricated Forms Intended for Surgical Implants

3. Terminology

3.1 Definitions: <https://www.astm.org/standards/sist/60b8a080-e53c-448d-95e5-6e97024ba2b3/astm-f2381-10>

3.1.1 *trans-vinylene index (TVI)*—a trans-vinylene index is defined as the ratio of the absorption peak area between 950 and 980 cm^{-1} to the area of the absorption peak centered near 965 cm^{-1} to the absorption peak area between 1330 and 1396 cm^{-1} .

3.1.2 *depth locator (DL)*—a measurement of the distance from the articular surface, or surface of interest, that a spectrum was collected and a corresponding TVI calculated.

3.1.3 *trans-vinylene index profile*—a trans-vinylene index profile is defined as the graphical representation of variation of the sample's trans-vinylene index with distance from its articular surface or the surface of interest. This is a plot of TVI versus DL. Typically, the graph will show the profile through the entire thickness of the sample.

4. Significance and Use

4.1 Published literature shows that the yield of radiolytic reactions that occur during radiation treatment increases with radiation dose level. Measurement of the products of these reactions can be used as an internal dosimeter.

4.2 Trans-vinylene unsaturations are formed during ionization treatment by abstraction of a hydrogen molecule, and to a lesser

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² For referenced 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.

extent by the recombination of two adjacent alkyl free radicals that reside on the same chain.

4.3 Previous work generated calibration curves of trans-vinylene absorption area as a function of absorbed radiation dose, yielding a linear relationship for both gamma- and electron beam-irradiated polyethylene.

4.4 This data can be used to determine received dose as a function of position, assuming a calibration curve (TVI versus radiation dose level) is known for the particular material and radiation conditions used, and can be used to determine uniformity of dose level in irradiated polyethylene.

5. Apparatus

5.1 Infrared Spectrometer:

5.1.1 A calibrated infrared spectrometer capable of recording a transmission absorption spectrum over a minimum range of 900 to about 2000 cm^{-1} using about 200 μm -thick films at a resolution of 4 cm^{-1} and an aperture of approximately 200 by 200 μm for a rectangular aperture, or 200 μm diameter for a circular aperture.

5.1.1.1 Other modes of collection (that is, reflection, attenuated total reflection (ATR), and so forth) and aperture and sampling step sizes may be used to generate the sample's absorption spectrum provided they can be demonstrated to produce equivalent results. Too large an aperture can result in a loss of profile accuracy.

5.1.1.2 When a Fourier Transform Infrared (FTIR) spectrometer is used, a minimum of 32 scans shall be collected per spectrum.

5.1.1.3 The FTIR instrument and sample compartment should be purged with a moisture- and carbon-dioxide-free inert gas (for example, nitrogen, helium, or argon) to minimize spectral interference from these components.

5.2 *Specimen Holder*—Equipment, such as an x - y table, capable of accurately positioning the sample under the FTIR aperture with a minimum resolution at the scale of the aperture dimensions.

5.3 *Microtome*—Equipment capable of producing films of thickness 200 μm or less of a sample perpendicular to the articular surface or the surface of interest.

6. Sampling, Test Specimens, and Test Units

6.1 Using a microtome, or other appropriate device, prepare a thin slice of the sample about 200 μm thick. If the detected signal from the FTIR is too weak with this thickness, a thicker sample may be used.

6.2 The slice shall typically be taken near the center of the sample's articular surface or the surface of interest.

6.3 The orientation of the slice shall typically be perpendicular to the articular surface or the surface of interest.

6.4 Waviness in the infrared spectrum caused by Fourier rippling on the lower wavelengths can interfere with the trans-vinylene absorbance at 965 cm^{-1} . This rippling is caused by internal reflection of the infrared beam, and can be avoided by lightly rubbing the sample film against 400 grit sandpaper until the film becomes translucent. This roughening procedure should be done slowly to avoid heating the film, and should be performed until the area under a single peak due to Fourier rippling is less than 10 % of the area under the trans-vinylene peak.

7. Preparation of Apparatus

7.1 Prepare the infrared spectrometer for collection of a transmission absorption spectrum from a thin film of the UHMWPE sample according to the manufacturer's recommendations, Practice E1421, and the conditions described in 5.1.

8. Procedure

8.1 The test film (slice) shall be first configured in the spectrometer (after an appropriate background spectrum has been collected) such that the aperture is positioned over the first 200 μm of the film starting at the surface of interest.

8.2 Subsequent spectra shall be collected sequentially at increments matching the aperture size (that is, about 200 μm) from the articular surface, or surface of interest, across the width of the film to the opposite surface.

8.3 Larger increments may be used; however, too large an increment size may result in a loss of profile accuracy.

9. Calculation of Results

9.1 Trans-vinylene Peak Area:

9.1.1 For each absorbance spectrum, calculate the total area of the absorption peak absorptions between 950 and 980 centered near 965 cm^{-1} (see Fig. 1).

9.1.2 This area is the area below the ~~sample's~~ sample's absorbance curve and above the straight baseline drawn between the same starting and ending ~~points, namely 950 and 980 cm^{-1}~~ points used in 3.1.1.

9.2 Normalization of Peak Area:

9.2.1 For each absorbance spectrum, calculate the total area of the absorption peak absorptions between 1330 and 1396 centered near 1370 cm^{-1} (see Fig. 2).

9.2.2 This area is the area below the sample's absorbance curve and above the straight baseline drawn between the same starting and ending ~~points, namely 1330 and 1396 cm^{-1}~~ points used in 3.1.1.

9.3 *Trans-vinylene Index (TVI)*—For each absorbance spectrum, calculate its TVI by dividing the area of its trans-vinylene peak (see 9.1) by the area of its normalization peak (see 9.2).

9.4 *Depth Locator (DL)*—Calculate the distance from the articular surface, or surface of interest, termed the depth locator (DL), for each spectrum and its corresponding TVI from the following equation: