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IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.18.3	
Subject	
Tensile Strength, Elongation, and Modulus	
Date **7/95**	Revision
Originating Task Group	
Deposited Dielectric Task Group (C-13a)	

1.0 Scope This test method establishes a procedure for determining the tensile strength, elongation and Young's modulus of organic free films.

2.0 Applicable Documents

ASTM D 618 Standard Practice for Conditioning Plastics and Electrical Insulating Materials for Testing

ASTM D 882 Standard Test Methods for Tensile Properties of Thin Plastic Sheeting

ASTM D 1005 Standard Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers

ASTM D 2370 Standard Test Method for Tensile Properties of Organic Coatings

3.0 Test Specimen The test specimen shall consist of a strip 12.70 mm wide by 76.20 mm in length and at least 10 µm in thickness. The width of the specimen should not deviate by more than 2% over the length of the specimen between the grips. The thickness of the films shall not vary by more than 10% over the entire film. A minimum of ten specimens are required.

4.0 Apparatus or Material

4.1 Thickness Measurement Device Mitutoyo 519-605 Mini-Checker with a 519-891 probe with vacuum assist connected to a MUX-10 multiplexer or equivalent thickness measurement device accurate and precise to 0.1 µm.

4.2 Width Measurement Device Micrometer or equivalent width measurement device capable of measuring to 0.25 mm.

4.3 Specimen Cutter Thwing-Albert JDC Precision Cutter or equivalent. The specimen cutting device must be capable of cutting a film strip 12.70 ± 0.25 mm wide over the length of the specimen. It is imperative that the cutting edges be kept sharp and free from visible scratches or nicks. The use of striking dies is not recommended because of poor and inconsistent specimen edges.

4.4 Tensile Tester Instron Model 4501 Tensile Tester with a 0.2 kN load cell or equivalent. The testing machine must be equipped with a load cell whose compliance is a maximum of 2% of the specimen extension within the range being measured. Digital (as opposed to analog) self-calibrating load cells are preferred since they eliminate the need for and potential error associated with calibrating analog load cells using external weights. The testing machine must be equipped with a device for recording the tensile load and the amount of separation of the grips; both of these measuring systems should be accurate to ± 2%. The rate of separation of the grips shall be accurate to ± 0.1% and capable of adjustment from approximately 0 to 50 mm/min.

4.5 Gripping Devices A gripping system that minimizes both slippage and uneven stress distribution must be used. The grips must be self-aligning, i.e. they must be attached in such a manner that they will move freely into alignment as soon as any load is applied so that the long axis of the specimen will coincide with the direction of the applied pull through the center line of the grip assembly.

4.6 Grip Faces Specimen slippage and necking of the specimen up into the grips are two of the most common problems with this test method. Slippage can be checked by drawing a series of parallel lines across the part of the specimen in the grips. After pulling the specimen, if the lines are not parallel, the specimen may be slipping on one side. On specimens with high elongations, necking of the specimen into the grips is a problem. As the specimen elongates, the reduction of area (necking) results in a loosening of the specimen at the inside edges of the grips. This loosening propagates further back into the grips with continued elongation of the specimen. This can lead to erroneous results for the elongation. Air-actuated grips lined with rubber faces (e.g., neoprene) that have been machined flat were found to be effective against both of these problems and still allowed the specimen to be easily removed from the grips after the test. Another approach is to use line grips, i.e. grips having faces designed to concentrate the entire gripping force along a single line the width of the specimen perpendicular to the direction of the testing stress. This is usually done by combining one standard flat grip face and an opposing grip face that has been cut down. In cases where specimens frequently fail at the edge of the grips, it may be advantageous to round the edges of the grip faces where they meet the test area of the specimen.

4.7 Extension Indicators (optional) Extension indicators (e.g., extensometers) must be designed as to minimize stress on the specimen at the contact points of the specimen and the indicator. Clip type extensometers are not recommended for this reason. Laser extensometers can be used if the method of marking the specimen does not induce any stress or strain into the specimen (e.g., scratching the specimen) or change the specimen in any fashion (e.g., heating the specimen).

4.8 Calibration The thickness gauge should be calibrated every six months using standard gauge blocks. The blades on the film cutter should be resharpened or replaced at least once a year. The load cell on the tensile tester should be calibrated at least once a week following the manufacturer s recommended procedure. Also, the stops which control the initial grip separation should be checked once a week.

5.0 Procedure

5.1 Operating Conditions The tests should be conducted at 23 ± 2°C and 50 ± 5% relative humidity.

5.2 Preparation of Test Specimens

5.2.1 The test specimens should be conditioned at 23 ± 2°C and 50 ± 5% relative humidity for not less than 24 hours prior to testing. Refer to ASTM D 618.

5.2.2 The free films are placed between two cover sheets of clear film (Mylar®* or equivalent) to facilitate handling of the specimens.

5.2.3 Cut at least 10 specimens 76.20 mm long and 12.70 mm wide. No specimen shall vary by more than 2% in width along its entire length. The utmost care must be exercised in cutting specimens to prevent nicks and tears along the edges of the specimen that are likely to cause premature failure. If the properties in the plane of the film are not isotropic (e.g., the films were not prepared by spin coating), then ten films must be cut in both the machine direction (MD) and transverse direction (TD).

5.4 Testing

5.4.1 Measure and record the thickness of the test specimen to an accuracy of 0.1 µm at no fewer than five different places within the gauge length area. Refer to ASTM D 1005 and AST D 2370.

5.4.2 Set the initial gauge length (grip separation) at 25.4 mm and the rate of grip separation at 5.08 mm/min.

5.4.3 Place the specimen in the grips of the testing machine, taking care to align the long axis of the specimen with an imaginary line joining the points of attachment of the grips to the machine. The specimen should be aligned as perfectly as possible with the direction of pull so that no rotary motion that may induce slippage will occur in the grips. Tighten the grips evenly and firmly to the degree necessary to minimize slipping of the specimen during testing. The use of air activated grips facilitates the mounting of the specimen in the grips.

5.4.4 Start the test and record the load versus extension.

5.4.5 Repeat steps 5.4.1 - 5.4.4 for each series of ten specimens.

5.5 Calculations

5.5.1 For each series of ten specimens, the arithmetic mean and standard deviation of each property for the specimens with the five highest tensile strengths shall be calculated to the proper number of significant figures. This is done on the basis that the expected errors (nicks or flaws in the specimen, breaks within the grips, specimen slippage, etc.) would all tend to produce lower results. The standard deviation is calculated as follows and reported to two significant figures:

$$S_x = \sqrt{\frac{N\sum_{i=1}^{N} X_i^2 - \left(\sum_{i=1}^{N} X_i\right)^2}{N(N-1)}}$$

where Xi is the value of a single observation (i = 1 through N), N is the number of observations, and s_x is the estimated standard deviation.

5.5.2 Tensile Strength Tensile strength is calculated by dividing the load at break by the original minimum cross-sectional area. The result is expressed in megapascals (MPa) and reported to three significant figures.

$$\text{tensile strength} = \frac{\text{(load at break)}}{\text{(original width) (original thickness}}$$

5.5.3 Percent Elongation Percent elongation is calculated by dividing the elongation at the moment of rupture by the initial gauge length and multiplying by 100. When gauge marks or extensometers are used to define a specific test section, only this length is used in the calculation, otherwise the distance between the grips is used as the initial gauge length. The result is expressed in percent and reported to two significant figures.

$$\text{percent elongation} = \frac{\text{(elongation at rupture) x 100}}{\text{(initial gage length)}}$$

5.5.4 Young's Modulus Young's modulus is calculated by drawing a tangent to the initial linear portion of the stress-strain curve, selecting any point on this tangent, and dividing the tensile stress by the corresponding strain. For purposes of this calculation, the tensile stress shall be calculated by dividing the load by the average original cross section of the test specimen. The result is expressed in gigapascals (GPa) and reported to three significant figures.

$$\text{Young's modululus} = \frac{\dfrac{\text{(load at point on tangent)}}{\text{(original width) (original thickness)}}}{\dfrac{\text{(elongation at point on tangent)}}{\text{(initial gage length}}}$$

5.5.5 Toe Compensation (from ASTM D 882) In a typical stress-strain curve (see below), there is a toe region, AC, which does not represent a property of the material. It is an artifact caused by a take-up of slack, and alignment or seating of the specimen. In order to obtain correct values of such parameters as modulus, strain, and yield point, this artifact must be compensated for to give the corrected zero point on the strain or extension axis. In the case of a material exhibiting a region of Hookean (linear) behavior as shown below, a continuation of the linear (CD) region of the curve is constructed through the zero-stress axis. The intersection (B) is the corrected zero-strain point from which all extensions or strains must be measured, including the yield point, if applicable. The elastic modulus can be determined by dividing the stress at any point along line CD (or its extension) by the strain at the same point (measured from point B, defined as zero-strain).

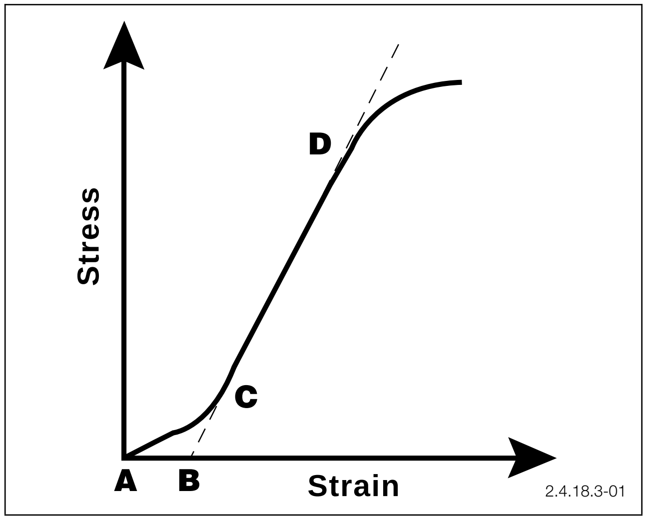

Figure 1

6.0 Notes The tensile properties determined using this test method will vary with method of specimen preparation, specimen thickness, specimen width, rate of grip separation, initial gauge length, type of grips used, and method of measuring extension. The tensile strength and elongation are sensitive to the specimen dimensions and any flaws in the specimen. Young's modulus is an index of the stiffness of the specimen and is sensitive to the rate of grip separation. Note that materials that fail by tearing give anomalous data that cannot be compared with those from normal failure (rupture). A tear failure is a tensile failure characterized by fracture initiating at one edge of the specimen and progressing across the specimen at a rate slow enough to produce an anomalous stress-strain curve. Results obtained using different specimen dimensions or at different rates of grip separation are not comparable; consequently, when trying to make quantitative comparisons between specimens or between laboratories, these factors must be carefully controlled.