Designation: E2039 – 04

Standard Test Method for Determining and Reporting Dynamic Dielectric Properties[1]

This standard is issued under the fixed designation E2039; 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 gathering and reporting of dynamic dielectric data. It incorporates laboratory test method for determining dynamic dielectric properties of specimens subjected to an oscillatory electric field using a variety of dielectric sensor/cell configurations on a variety of instruments called dielectric, microdielectric, DETA (DiElectric Thermal Analysis), or DEA (DiElectric Analysis) analyzers.

1.2 This test method determines permittivity, loss factor, ionic conductivity (or resistivity), dipole relaxation times, and transition temperatures, and is intended for materials that have a relative permittivity in the range of 1 to 10^5; loss factors in the range of 0 to 10^8; and, conductivities in the range $10^{16}$to 10^{10}S/cm.

1.3 The test method is primarily useful when conducted over a range of temperatures for nonreactive systems (−160°C to degradation) and over time (and temperature) for reactive systems and is valid for frequencies ranging from 1 mHz to 100 kHz.

1.4 Apparent discrepancies may arise in results obtained under differing experimental conditions. Without changing the observed data, completely reporting the conditions (as described in this test method) under which the data were obtained, in full, will enable apparent differences observed in another study to be reconciled.

1.5 SI units are the 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 and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 10.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation

E473 Terminology Relating to Thermal Analysis and Rheology

E1142 Terminology Relating to Thermophysical Properties

E2038 Test Method for Temperature Calibration of Dielectric Analyzers

3. Terminology

3.1 *Definitions:*

3.1.1 The following technical terms are applicable to this document and are defined in Terminologies E473 and E1142:E1142 dielectric thermal analysis, angular frequency, capacitance, conductivity, dielectric constant, dielectric dissipation factor, dielectric loss angle, dipole relaxation time, dissipation factor, frequency, loss factor, permittivity, phase angle, and tangent delta.

3.1.2 *Relative permittivity* and *loss factor* are dimensionless quantities and are relative to the permittivity of free space (ε_0= 8.854 pF/m). Relative permittivity also is known as the dielectric constant.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *dielectric (or microdielectric) sensor*, *n*—a set of at least two (perhaps three) contacting electrodes for measuring the dielectric response of materials.

3.2.1.1 *Discussion*—The sensor generally consists of parallel, circular, conducting (metallic) plates or discs, between which the sample is placed. The sensor also may be a set of interdigitated conductors on an insulating substrate. In some cases, the sensor may incorporate amplifying electronics or a temperature sensing device (see Fig. 1), or both.

3.2.2 *interdigitated electrode*, *n*—an electrode configuration consisting of two nonconnected, interpenetrating conductors firmly attached to an insulating substrate and exposed to the specimen on top.

3.2.2.1 *Discussion*—Interdigitated electrodes of different geometry are available, such as, interpenetrating "fingers" or "combs," interpenetrating circular spirals, or interpenetrating square spirals (see Fig. 1).

Whereas parallel plate electrodes contact a specimen on a "top" and "bottom" surface, the interdigitated electrodes make contact on only one side (single-sided contact) of the specimen.

[1] This test method is under the jurisdiction of ASTM Committee E37 on Thermal Measurements and is the direct responsibility of Subcommittee E37.10 on Fundamental, Statistical and Mechanical Properties.

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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.

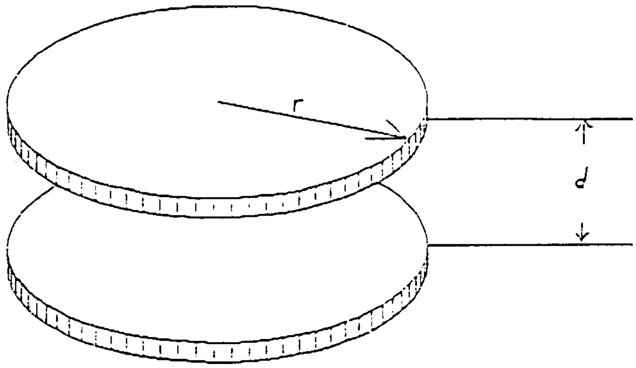

FIG. 1 Parallel Plate Electrodes

3.2.3 *electrode spacing* (E_S), *n*—for interdigitated electrodes, the width of the insulator strip between adjacent electrodes in the electrode array (see Fig. 1).

3.2.4 *electrode width* (E_W), *n*—for interdigitated electrodes, the width of a single electrode in the electrode array (see Fig. 1).

3.2.5 *electrode height* (E_h), *n*—for interdigitated electrodes, the thickness of an electrode normal to the surface of the substrate upon which it is situated (see Fig. 1).

3.2.6 *meander length* (M_L), *n*—for interdigitated electrodes, the total length of the zig-zag path between the two sets of conductors in the electrode array.

3.2.7 *substrate capacitance* (C_{sub}), *n*—for interdigitated electrodes, the capacitance of the sensor due to the insulating substrate.

3.2.7.1 *Discussion*—This value depends only on the geometry of the sensor and the material of the substrate, and not on the specimen under test on top of the interdigitated electrodes.

3.3 *Abbreviations:Abbreviations:*

A = plate area (calculated as $2\times \pi \times r^2$) (see Fig. 1)
C_p = parallel capacitance (see Test Method D150)
R_p = parallel resistance (see Test Method D150)
r = radius of circular plate (see Fig. 1).

4. Summary of Practice

4.1 An oscillatory electric potential (voltage) is applied to a test specimen by means of an electrode of known geometry. An electric current is measured at a sensing electrode separated from the transmitting electrode by the specimen under test. From the amplitude and phase shift of the measured current relative to the applied voltage and from known geometrical constants, such as electrode spacing and electrode arrangement, desired dielectric properties of the specimen under test may be obtained. Such properties include conductivity, dielectric constant, dielectric dissipation factor, dielectric loss angle, dipole relaxation time, dissipation factor, relative permittivity, loss factor, and tangent delta. The desired dielectric properties may be obtained as a function of frequency, temperature, or time by varying and measuring these independent parameters during the course of the experiment.

NOTE 1—The particular method for measurement of amplitude and phase shift depends upon the operating principle of the instrument used.

5. Significance and Use

5.1 Dielectric measurement and testing provide a method for determining the permittivity and loss factors as a function of temperature, frequency, time, or a combination of these variables. Plots of the dielectric properties against these variables yield important information and characteristics about the specimen under test.

5.2 This procedure can be used to do the following:

5.2.1 Locate transition temperatures of polymers and other organic materials, that is, changes in molecular motion (or

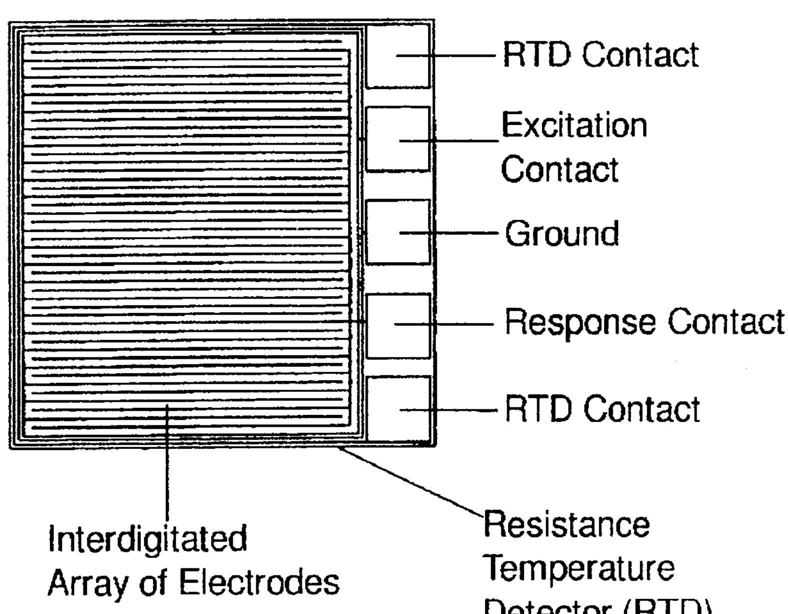

FIG. 2 Interdigitated Electrodes