Designation: E 2039 – 99

Standard Practice for Determining and Reporting Dynamic Dielectric Properties[1]

This standard is issued under the fixed designation E 2039; 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 practice is to be used for gathering and reporting dynamic dielectric data. It incorporates laboratory practice 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 practice 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}siemens/cm.

1.3 The practice 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 practice) under which the data were obtained, in full, will enable apparent differences observed in another study to be reconciled.

1.5 Values reported in SI units are to be regarded as 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:*

D 150 Test Method for A-C Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials[2]

E 473 Terminology Relating to Thermal Analysis[3]

E 1142 Terminology Relating to Thermophysical Properties[3]

E 2038 Test Method for Temperature Calibration of Dielectric Analyzers[3]

3. Terminology

3.1 *Definitions:*

3.1.1 The following technical terms are applicable to this document and are defined in Terminologies E 473 and E 1142: 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).

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[1] This practice is under the jurisdiction of ASTM Committee E37 on Thermal Measurements and is the direct responsibility of Subcommittee E37.01 on Test Methods and Recommended Practices.

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[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

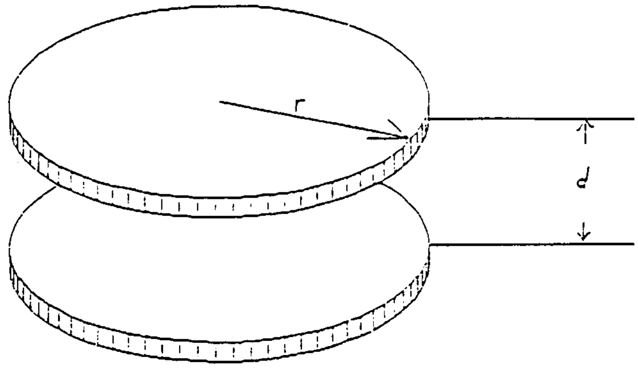

FIG. 1 Parallel Plate Electrode

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.

3.2.3 *electrode spacing* (E_S), *n*—for interdigitated electrodes, the distance between 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 length of the path between the two conductors in the electrode array.

3.2.6.1 *Discussion*—It is the distance a flea situated in the space between the electrodes would have to walk, starting at one end of the array, to get to the other.

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:*

A = plate area (calculated as $2\times \pi \times r^2$) (see Fig. 1)
C_p = parallel capacitance (see Test Method D 150)
R_p = parallel resistance (see Test Method D 150)
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

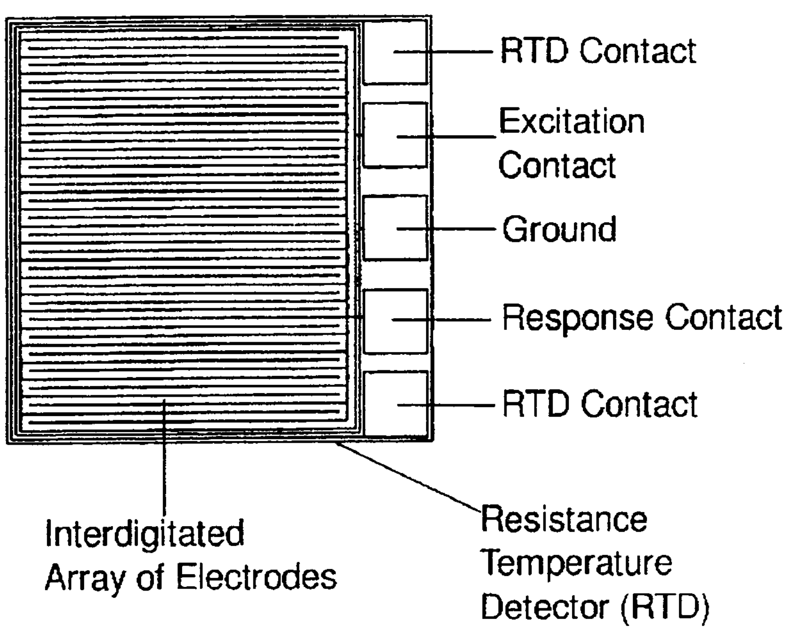

FIG. 2 Interdigitated Electrodes