



# National Institute of Standards & Technology

## Certificate

### Standard Reference Material<sup>®</sup> 2870

#### Relative Permittivity and Loss Tangent 1422 Cross-Linked Polystyrene

Specimen No. SAMPLE

This Standard Reference Material (SRM) is intended for the evaluation of measurement systems used to characterize the relative permittivity and loss tangent of dielectric materials. A unit of SRM 2870 consists of a cross-linked polystyrene cylindrical disk, nominally 60 mm in diameter and 10 mm thick. This specimen can be machined to the necessary geometry required by various measurement systems.

Measurements for certifying SRM 2870 were obtained using the cylindrical cavity method described in reference 1. The particular cavity used was a mode-filtered, circular-cylindrical cavity, nominally 60 mm in diameter and 450 mm in length. Additional details concerning the resonator theory, measurement procedure, and uncertainty analysis can be found in reference 1.

**Certified Values:** A NIST certified value is a value for which NIST has the highest confidence in its accuracy in that all known or suspected sources of bias have been investigated or accounted [2]. Certified relative permittivity and loss tangent values for SRM 2870, measured at 10 GHz, are listed in Table 1. The measurements were performed at  $23\text{ °C} \pm 1\text{ °C}$  and  $40\% \pm 5\%$  relative humidity. The certified values are valid under these environmental conditions. Relative permittivity and loss tangent measurements performed on cross-linked polystyrene that are outside of this temperature range can be found in reference 3.

**Information Values:** Supplemental values of relative permittivity and loss tangent are given in Table 2. Although these values are not certified, they provide additional information about the behavior of the relative permittivity and loss tangent of SRM 2870 over a frequency range of 2 GHz to 25 GHz. All supplemental measurements were performed at  $23\text{ °C} \pm 2\text{ °C}$  and  $40\% \pm 5\%$  relative humidity.

**Expiration of Certification:** The certification of **SRM 2870** is valid, within the measurement uncertainty specified, until **01 January 2024**, provided the SRM is handled and stored in accordance with the instructions given in this certificate (see "Instructions for Storage and Use"). However, the certification is invalid if the SRM is damaged, contaminated, or otherwise modified.

**Maintenance of SRM Certification:** NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification before the expiration of this certificate, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

The coordination of the technical measurements leading to the certification of SRM 2870 was under the leadership of M.D. Janezic of the NIST Electromagnetics Division.

Statistical consultation was provided by J.D. Splett and K.J. Coakley of the NIST Statistical Engineering Division.

Support aspects involved in the issuance of this SRM were coordinated through the Office of Reference Materials.

Perry F. Wilson, Acting Chief  
Electromagnetics Division

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Office of Reference Materials

Gaithersburg, MD 20899  
Certificate Issue Date: 06 February 2013  
*Certificate Revision History on Last Page*

## INSTRUCTION FOR STORAGE AND USE

**Storage:** When not in use, SRM 2870 should be stored at room temperature, below 50 % relative humidity, in the provided container.

**Instruction for Use and Handling:** Contaminants on the surfaces of the specimen can be a source of measurement error; therefore, prior to measurement, contaminants on the surfaces should be removed. To remove the contaminants, clean each sample with 99 % pure isopropyl alcohol and a lint-free cloth, making sure that the alcohol has completely evaporated. In addition, use lint-free gloves to avoid contact with the specimen.

## PREPARATION AND ANALYSIS<sup>(1)</sup>

**Source and Fabrication of Material:** The cross-linked polystyrene (Rexolite 1422) sheet was manufactured by C-Lee Plastics (Philadelphia, PA) and fabricated into individual samples by Colorado Precision Optics (Longmont, CO).

Table 1. Certified Values for SRM 2870<sup>(a)</sup>

Frequency (GHz)	Relative Permittivity	Loss Tangent
10	SAMPLE ± 0.004	SAMPLE ± 0.00002

<sup>(a)</sup> Certified values of relative permittivity and loss tangent are based on equally weighted means of three repeat measurements completed on different days. The uncertainty in each certified value is an expanded uncertainty,  $U = ku_c$ , calculated in accordance with the GUM and NIST Guides [4]. The quantity  $u_c$ , represents the combined standard uncertainty [4] and  $k$  is the coverage factor used to obtain an expanded uncertainty with an approximate confidence level of 95 %. The coverage factors for permittivity ( $k = 2$ ) and loss tangent ( $k = 2.093$ ) are derived from the Student's  $t$ -distribution with > 30 degrees and 19 degrees of freedom, respectively.

Table 2. Supplemental Values for SRM 2870

Method	Frequency (GHz)	Relative Permittivity	Loss Tangent
Split-Post Resonator [5]	1.44	2.55	0.00036
Split-Post Resonator	2.06	2.55	0.00037
Split-Post Resonator	5.53	2.54	0.00044
Split-Cylinder Resonator [6]	8.53	2.55	0.00046
Split-Post Resonator	9.92	2.53	0.00048
Dielectric-Post Resonator [7]	10.02	2.54	0.00047
Split-Cylinder Resonator	12.67	2.54	0.00052
Split-Cylinder Resonator	17.17	2.55	0.00059
Split-Cylinder Resonator	19.19	2.53	0.00060
Split-Cylinder Resonator	22.03	2.55	0.00062

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<sup>(1)</sup> Certain commercial equipment, instrumentation, or materials are identified in this certificate to adequately specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

## REFERENCES

- [1] Janezic, M.D.; Splett, J.D.; Coakley, K.J.; Kaiser, R.F.; Grosvenor, J.H.; *Relative Permittivity and Loss Tangent Measurement with the NIST 60 mm Cylindrical Cavity*; NIST Special Publication 260-159, U.S. Government Printing Office: Washington, DC (2004).
- [2] May, W.; Parris, R.; Beck II, C.; Fassett, J.; Greenberg, R.; Guenther, F.; Kramer, G.; Wise, S.; Gills, T.; Colbert, J.; Gettings, R.; MacDonald, B.; *Definition of Terms and Modes Used at NIST for Value-Assignment of Reference Materials for Chemical Measurements*; NIST Special Publication 260-136 (2000); available at <http://www.nist.gov/srm/publications.cfm> (accessed Feb 2013).
- [3] Riddle, B.; Baker-Jarvis, J.; *Complex Permittivity Measurements of Common Plastics Over Variable Temperatures*; IEEE Trans. Microwave Theory Tech., Vol. 51, No. 3 (2003).
- [4] JCGM 100:2008; *Evaluation of Measurement Data — Guide to the Expression of Uncertainty in Measurement* (GUM 1995 with Minor Corrections); Joint Committee for Guides in Metrology (2008); available at [http://www.bipm.org/utils/common/documents/jcgm/JCGM\\_100\\_2008\\_E.pdf](http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf) (accessed Feb 2013); see also Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297; U.S. Government Printing Office: Washington, DC (1994); available at <http://www.nist.gov/pml/pubs/index.cfm> (accessed Feb 2013).
- [5] Krupka, J.; Geyer, R.G.; Baker-Jarvis, J.; Ceremuga, J.; *Measurements of the Complex Permittivity of Microwave Circuit Board Substrates Using Split Dielectric Resonator and Reentrant Cavity Techniques*; DMMA Conference, Bath, United Kingdom, pp. 21–24 (1996).
- [6] Janezic, M.D.; Kuester E.F.; Baker-Jarvis, J.; *Broadband Complex Permittivity Measurements of Dielectric Substrates Using a Split-Cylinder Resonator*; 2004 IEEE MTT-S Digest, pp. 1817–1820 (2004).
- [7] Kobayashi, Y.; Katoh, M.; *Microwave Measurement of Dielectric Properties of Low-Loss Materials by the Dielectric Rod Resonator Method*; IEEE Trans. Microwave Theory Tech., Vol. 33, pp. 586–592 (1985).

<b>Certificate Revision History:</b> 06 February 2013 (Extension of certification period, editorial changes); 25 October 2006 (Original certificate date).
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*Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail [srminfo@nist.gov](mailto:srminfo@nist.gov); or via the Internet at <http://www.nist.gov/srm>.*