

SEMI FH4-0724

TEST METHOD AND GUIDE FOR THE TACTILE CHARACTERISTICS OF FLEXIBLE HYBRID ELECTRONICS MATERIALS AND PRODUCTS

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NOTICE: The section symbol (§) is used to reference a numbered section, paragraph, or header and all subordinate paragraphs, headers, and embedded material (i.e., EXCEPTIONS, lists) therein. The paragraph symbol (§§) is used to reference a particular numbered paragraph and embedded material therein. When duplicated (i.e., §§ and §§§) the symbols are used to reference more than one section or paragraph, respectively.

1 Purpose

1.1 Wearable electronics and e-textile products are typical application fields where flexible hybrid electronics (FHE) technology is applied. Since these products are directly touched by human hands or worn directly on parts of the body, texture is one of the important characteristics of product quality.

1.2 This Standard specifies the methods of evaluating tactile characteristics to FHE materials and products.

1.3 The parameters obtained by this Test Method are physical parameters that reflect the tactile characteristics of the object to be tested. In order to translate the numerical values into sensibility values such as touch, another means, which is the know-how of each supplier, is required. However, some equations for translation in the textile industry are open to the public, and suppliers can refer to them to build their own know-how.

1.4 The measurement and calculation of physical parameters are ‘Test Method’ Standard, and conversion from these physical values to sensibility values (refer to § 11 and § 12) is ‘Guide’ Standard.

2 Scope

2.1 This Standard specifies test method of parameters to express the tactile sensation of FHE materials and products, and provides a guide for calculating physical values to sensitivities values.

2.2 The Test Method is an application of the ‘handling’ evaluation method that has been applied for many years in the field of textile technology.

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3 Referenced Standards and Documents

3.1 ISO® Standards¹

ISO 291 — Plastics – Standard Atmospheres for Conditioning and Testing

ISO 139 — Textiles – Standard Atmospheres for Conditioning and Testing

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 Abbreviations and Acronyms

4.1.1 *B* — bending rigidity

4.1.2 *G* — shear stiffness

¹ International Organization for Standardization, ISO Central Secretariat, Chemin de Blandonnet 8, CP 401-1214 Vernier, Geneva, Switzerland; Telephone: +41.22.749.01.11, Fax: +41.22.733.34.30, <http://www.iso.org>. ISO trademark is owned by International Organization for Standardization.

- 4.1.3 *LC* — linearity of compression property
- 4.1.4 *LT* — linearity of tensile property
- 4.1.5 *MIU* — mean value of the coefficient of friction
- 4.1.6 *MMD* — standard deviation of the coefficient of friction
- 4.1.7 *RC* — resilience of compression property
- 4.1.8 *RT* — resilience of tensile property
- 4.1.9 *SMD* — standard deviation of surface roughness
- 4.1.10 *T* — thickness at 0.5 gf/cm²
- 4.1.11 *W* — weight per unit area
- 4.1.12 *WC* — energy required for the compression
- 4.1.13 *WT* — tensile energy
- 4.1.14 *2HB* — moment of hysteresis
- 4.1.15 *2HG* — hysteresis at shear angle 0.5 degrees
- 4.1.16 *2HG5* — hysteresis at shear angle 5 degrees

4.2 Definitions

4.2.1 Physical Parameters

4.2.1.1 *bending properties* — the bending properties are obtained from the relationship between the curvature and the bending moment when bending deformation is applied to the materials and products up to the maximum curvature $\pm 0.25 \text{ mm}^{-1}$ with the increasing rate of curvature $0.05 \text{ mm}^{-1}/\text{sec}$. The bending properties are B: the gradient of the curve of the deformation process and 2HB: the hysteresis at the curvature 0.1 mm^{-1} .

4.2.1.2 *compression properties* — the compression properties are obtained from the relationship between compression pressure and thickness of materials and products when compressive pressure is applied to the materials and products by a circular plane compression element having area of 200 mm^2 .

4.2.1.3 *surface properties* — surface properties in this Standard are measurement values aimed at quantifying the texture feeling of the materials and products. It is obtained from the response when rubbing the surface with a contact element imitating a human fingerprint.

4.2.1.4 *shearing properties* — the shear deformation properties of this Standard are not characteristic values obtained from materials and products destruction test but are characteristic values related to the handling properties of the FHE materials and products. The parameters are G: shear stiffness per unit length of materials and products, and 2HG and 2HG5: hysteresis width at shear angles of 0.5 degrees and 5 degrees.

4.2.1.5 *tensile properties* — the tensile properties in this Standard are not characteristic values obtained from destructive testing of materials and products, but are characteristic values related to handling properties of materials and products. They are ‘tensile energy per unit area (WT)’, ‘tensile properties Linearity (LT)’, ‘tensile resilience (RT)’, and ‘elongation percentage (EM) at maximum load 245 N/m (250 gf/cm)’.

Table 1 Physical Parameters to be Measured

<i>Property</i>	<i>Characteristics Value</i>	<i>Description</i>	<i>Condition</i>
Bending	B ($\times 10^4$ Nm ² /m)	Bending rigidity	Curvature K = ± 0.25 mm ⁻¹
			effective size 200 mm $\times$ 10 mm
	2HB ($\times 10^2$ Nm/m)	Hysteresis	speed curvature 0.5 mm ⁻¹ /s
Compression	LC (–)	Linearity	Pmax = 4900 N/m ²
	WC (Nm/m ²)	Compression energy	compression area: 200 mm ²
	RC (%)	Compression resilience	Speed 0.02 mm/s
Shearing	G (N/m $\cdot$ deg)	Shear stiffness	Constant tension= 9.8 N/m
	2HG (N/m)	Hysteresis ($\phi = 0.5^\circ$)	strain speed: 0.00834/s
	2HG5	Hysteresis ($\phi = 5^\circ$)	$\phi = \pm 8^\circ$
Surface	MIU (–)	Coefficient of friction	Strain speed: 1 mm/sec
			Distance: 20 mm
			MIU conductor: 5 mm $\times$ 5 mm
			Pressure: 0.25 N
	MMD (–)	Mean deviation of MIU	SMD conductor: 0.5 mm ϕ piano wire
	SMD (μ m)	Geometrical roughness	Pressure: 0.049 N
Tensile	LT (–)	Linearity	Fmax: 245 N/m
	WT (Nm/m ²)	Tensile energy	Strain speed: 0.4%/sec
	RT (%)	Tensile resilience	effective size: 200 mm $\times$ 50 mm
Thickness & Weight	T (mm)	Thickness at pressure 50 N/m ²	
	W ($\times 10^{-1}$ N/ m ²)	Mass per unit area	

4.2.2 Sensibility Parameters — The criterion of tactile sensation for FHE materials and products is based on the end use of materials and products. Three of primary tactiles expressions, that is KOSHI, NUMERI, and FUKURAMI, are selected and the proportion of the importance of these tactiles in the evaluation of quality of FHE materials and products are estimated. Samples are obtained and labeled by numbers, 0 to 10. This number is named Hand Value (HV), and the higher value corresponds to strong feeling of the tactile.

4.2.2.1 KOSHI (stiffness) — a feeling related with bending stiffness. Springy property promotes this feeling. The fabric having compact weaving density and woven by springy and elastic yarn makes this feeling strong.

4.2.2.2 NUMERI (smoothness) — a mixed feeling comes from smooth, limber, and soft feeling. The fabric woven from cashmere fiber gives this feeling strongly.

4.2.2.3 FUKURAMI (fullness and softness) — a feeling comes from bulky, rich, and well-formed feeling. Springy property in compression and thickness accompanied with warm feeling are closely related with this feeling.

4.2.2.4 total hand value (THV) — the essential quality is expressed by the ‘total hand’. Good tactile is an evaluation of the primary quality of FHE materials and products, the quality is concerned with comfortability and beautiful appearance in the silhouette of garment and is in conformity with function of garment and with human sense. Samples are labeled by numbers, 0 to 5. This number is named Total Hand Value (THV). The degree of good tactile has been expressed THV.

Table 2 Evaluation of THV

<i>THV</i>	<i>Evaluation</i>
5	excellent
4	good
3	average
2	below average
1	poor
0	out of use

5 Summary of Test Method

5.1 Preparing Test Specimens

5.1.1 Cut test specimens from materials and products into specified sizes.

5.1.2 Stored test specimens under ISO 291 (temperature: $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$, relative humidity: $50\% \pm 10\%$) condition or ISO 139 (temperature: $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$, relative humidity: $65\% \pm 4\%$) condition for 24 hours.

5.2 Tests for Physical Parameters

5.2.1 If each individual specimen is tested, the order of test is not specified.

5.2.2 When multiple tests are performed on the same specimen, test in the order specified.

1. Bending test or Compression test
2. Bending test or Compression test (Test item not tested first)
3. Surface test
4. Shearing test
5. Tensile test

5.3 Calculation for Physical Parameters — Calculate physical parameters from test results.

5.4 Calculations for Sensibility Parameters — Calculate sensibility parameters from physical parameters.

6 Apparatus

6.1 *Apparatus for Bending Test* — Pure bending is applied to a material 10 mm in length with a constant rate of curvature.

6.1.1 Clipping the test piece with effective length of 10 mm. In order to reduce the influence of gravity, the width direction of the test piece is oriented in the vertical direction.

6.1.2 Bending the test piece at a deformation rate of $0.05 \text{ mm}^{-1}/\text{sec}$ in the range of curvature $K = -0.25 \text{ mm}^{-1}$ to $+0.25 \text{ mm}^{-1}$.

6.1.3 Plotting the relation between curvature K and M bending moment per unit length of the test piece.

6.2 *Apparatus for Compression Test* — A specimen is compressed in the direction of thickness to a maximum pressure (4900 N/m^2) at a constant velocity, $20 \text{ } \mu\text{m/s}$.

6.2.1 It has a circular compression element with a flat plane of 200 mm^2 area.

6.2.2 The compression pressure of 0 to P_m is 4900 N/m^2 can be applied to the test piece.

6.3 *Apparatus for Surface Property Test* — Surface frictional smoothness and geometrical smoothness are measured.

6.3.1 It has a contact element for surface friction characteristics. The contact element has ten 0.5 mm diameter piano wire aligned in parallel to simulate a human fingerprint.

6.3.2 It has a contact element for measuring surface roughness (unevenness of fabric surface). The contact element has one 0.5 mm diameter piano wire.

6.3.3 The contact element rubs the fabric surface that fixed on the flat plane by tension with specific load and records the response of the contact element.

6.4 *Apparatus for Shearing Test* — A rate of shear strain of $8.34 \times 10^{-3}/s$ (shear deformation 1.46×10^{-4} degrees/s) is applied under a constant tension (9.8 N/m [10 gf/cm]) up to a maximum shear angle.

6.4.1 Clipping a test piece with a width of 200 mm and an effective length of 50 mm.

6.4.2 Applying a load of 9.8 N/m (10 gf/cm) to the test piece and apply shear deformation to plus or minus 8 degrees.

6.4.3 Plotting the relationship between shear angle ϕ and shear load F_s .

6.5 *Apparatus for Tensile Test* — Tensile deformation is applied along the length direction. And the strain in the width direction becomes approximately zero because of long sideways of the specimen. This deformation is called 'strip biaxial deformation' in mechanics.

6.5.1 Clipping a test piece with width of 200 mm, and effective length of 50 mm.

6.5.2 Tensile load is applied to the test piece to maximum load of 245 N/m (250 gf/cm) with the strain rate constant at $4.00 \times 10^{-3}/sec$, and then the load is returned to zero at the same strain rate.

6.5.3 Plotting out the relationship between tensile load per unit width and elongation.

7 Test Specimens

7.1 *The Size of the Test Piece* — When multiple tests are performed on the same specimen, the size of the test piece shall be 200 mm long and 200 mm wide.

7.2 Bending Test

7.2.1 The length of the test piece shall be $200 + 0, -5$ mm. The length of the test piece includes a clipping margin, and the pure bending is applied to a material 10 mm in length with a constant rate of curvature (its effective length is 10 mm).

7.2.2 The width of the test piece shall be $200 + 0, -5$ mm, unless the bending rigidity of the test piece is too strong.

7.2.3 If the bending stiffness of the test piece is strong, the width should be selected between 20 mm and 200 mm.

7.2.4 When test samples with directional differences in mechanical properties, such as not homogeneous materials, specimens shall be cut out of the original material in different orientations.

7.3 Compression Test and Surface Property Test

7.3.1 The area to be tested is less than 20 mm long and 20 mm wide.

7.3.2 The test piece size shall be $200 + 0, -5$ mm long and $200 + 0, -5$ mm wide.

7.3.3 When test samples with directional differences in mechanical properties, such as not homogeneous materials, specimens shall be cut out of the original material in different orientations.

7.3.4 Only one type of compression test piece is sufficient because the directional differences in mechanical properties of the test piece do not affect compression test result.

7.4 Tensile Test and Shearing Test

7.4.1 The size of the test piece shall be $200 + 0, -5$ mm in width and not less than $90 + 0, -5$ mm in length. The length of the test piece contains 20 mm each of the clipping margins, so its effective length is 50 mm. 200 mm $\times$ 50 mm sample is cramped and extension is applied along the 50 mm direction up to a maximum load.

7.4.2 When test samples with directional differences in mechanical properties, such as not homogeneous materials, specimens shall be cut out of the original material in different orientations.

8 Test Condition

8.1 The atmosphere for test shall be a temperature of $(23 \pm 2)^{\circ}\text{C}$ and relative humidity of $(50 \pm 10)\%$, conforming to standard atmosphere class 2 specified in ISO 291 or ISO 139 of $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and $65\% \pm 4\%$.

8.2 Test Specimens and apparatuses shall be stored in the atmosphere of test conditions for 24 hours.

9 Procedure and Calculations for Physical Parameter

9.1 If each individual specimen is tested, the order of test is not specified.

9.2 When multiple tests are performed on the same specimen, test in the order specified.

1. Bending test or Compression test
2. Bending test or Compression test (Test item not tested first)
3. Surface test
4. Shearing test
5. Tensile test

9.3 Bending Test

9.3.1 An image of the bending test is shown in Figure 1.

9.3.2 For test pieces with directional differences in mechanical properties, test each test piece individually.

9.3.3 Clip the test piece with effective length of 10 mm.

9.3.4 Pure bend the test piece in the range of curvature $K = -0.25 \text{ mm}^{-1}$ to $+0.25 \text{ mm}^{-1}$ at a deformation rate of $0.05 \text{ mm}^{-1}/\text{sec}$.

9.3.5 The relationship between the curvature K and the bending moment M per unit length of the test piece is plotted as shown in Figure 2.

9.3.6 B: gradient between from $K = 0.5$ to $K = 1.5$ when bent.

9.3.7 Read 2HB from the graph as Figure 2.

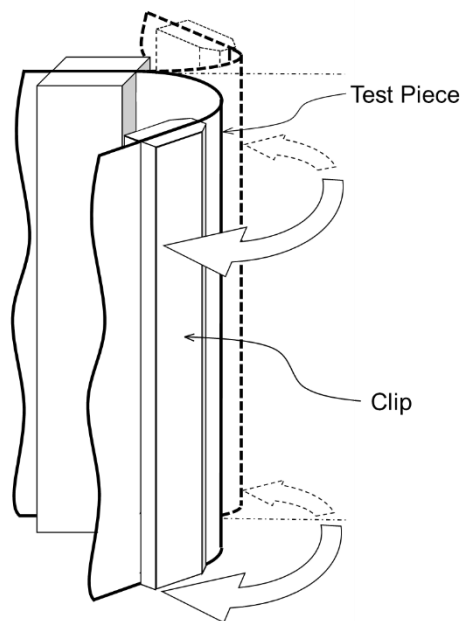


Figure 1
An Image of the Bending Test