The Institute for Interconnecting and Packaging Electronic Circuits
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IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.3.2	
Subject	
Flexural Fatigue and Ductility, Flexible Metal-Clad Dielectrics	
Date **3/91**	Revision **C**
Originating Task Group **N/A**	

1 Scope With this test method, the flexural fatigue life for any given bend radius, the flexural fatigue behavior, and the ductility of the metal cladding in percent deformation after tensile failure can be determined.

Note: The indirect determination of cladding ductility by using a fatigue test is made necessary by the geometry and dimensions of foil samples, which make tensile elongation and rupture tests inadequate for ductility determination.

Note: Processing may change the original mechanical properties of the conductor metal.

2 Applicable Documents

IPC-TM-650 Test Methods Manual

2.1.1 Microsectioning

2.4.18 Tensile Strength and Elongation, Copper Foil

IPC-D-330 IPC Design Guide

3 Test Specimen Foil/dielectric laminate of sufficient size to permit cutting of three 3.2 mm wide specimens of at least 50.8 mm in length. Specimens must be clean cut and free of burrs and nicks.

4 Equipment/Apparatus

4.1 Ductility Flex Tester, Universal Mfg., Model FDF or 2FDF or equivalent (see 6.4 and Figure 1)

4.2 Sample cutter, punch or tensile cut router (see 6.4.2)

4.3 Micrometer tool capable of measurement to the nearest 0.0025 mm

4.4 Hewlett-Packard, HP-67, Programmable Calculator or equivalent

4.5 Sample holders, 203.2 mm x 12.7 mm, of very flexible material (e.g., epoxy impregnated glass cloth, paper, etc.)

4.6 Microscope – capable of 200X

5 Procedure

5.1 Preparation of Samples

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Figure 1 Fatigue Ductility Flex Tester

5.1.1 The samples should be smooth and undistorted (wrinkle free).

5.1.2 Use the sample cutter to cut the 3.2 mm-wide test specimen. Examine each specimen for nicks, cuts, or curled edges. Discard any specimen with defects.

5.1.3 Use the micrometer to determine the specimen thickness, t, in the center of each specimen to the nearest 0.0025 mm. In the case of single sided specimens the core thickness, t_M has to be determined also (see Figure 2).

Note: Thickness is a critical parameter in the determination of fatigue ductility. A 10% error in t_M results in a 14% error in D_f.

Note: The second configuration in Figure 2, the core thickness, t_M, is preferably determined as a fraction of the specimen thickness, t, from a microsection prepared per IPC-TM-650, Method 2.1.1, and measured with a metallurgical microscope at 200X minimum with a suitable filar eyepiece or reticle. The measurement is to be made from the valley of the rough surface to the smooth surface or valley to valley where both surfaces are rough. The t_M is to be made once on a

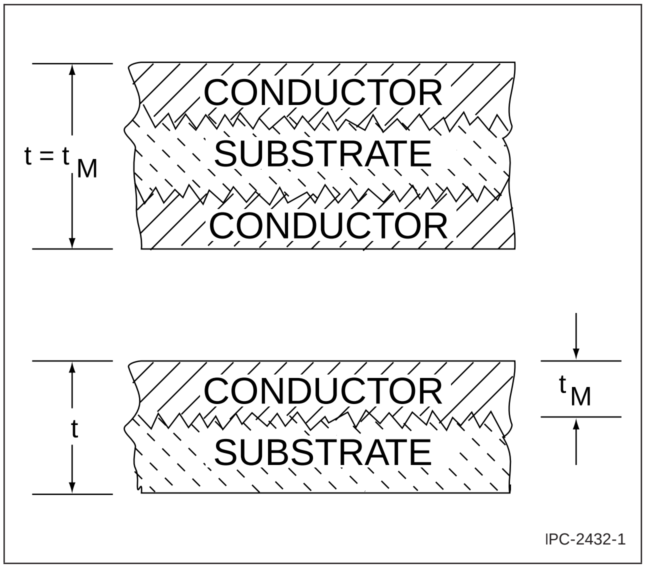

Figure 2 Core Thickness

batch or lot basis, and this fractional value of t_M/t is then multiplied by all other micrometer, t, values to achieve core values for all samples.

5.1.4 Connect all conductors to be tested and monitored in series and attach thin relay leads to the two free ends.

5.1.5 Attach test specimen to the ends of two sample holders with adhesive tape and clamp 224 grams circuit weight to the free ends of the sample holders to form a loop (see Figure 1).

Note: For flexural fatigue test lasting in excess of 1000 cycles, the adhesive tape attachment needs to be substantial enough to prevent relative sliding of the specimen and sample holder as a result of cyclic flexure movements.

5.2 Test Procedure

5.2.1 Mount mandrels to flex tester and adjust the support roller positions for a clearance of 1.27 mm (shim provided) between rollers and mandrels.

Note: For the ductility test, it is important that the specimens fail between 30 cycles and 500 cycles. Suggested mandrel diameters are 19.05 mm for double-sided laminate and 6.35 mm for single-sided laminate, but for some samples, mandrel diameters different from the above suggested may be necessary. Larger mandrel diameters result in longer cyclic life and smaller diameters in shorter life.

5.2.2 Mount the test specimen between mandrels, plug the relay leads into the relay jacks, set the counter to zero, and start the flex tester.

5.2.3 Electrical discontinuity constitutes failure; the flex tester stops automatically.

5.2.4 Record cycles-to-failure indicated on counter.

5.3 Evaluation

5.3.1 Ductility Test

5.3.1.1 Calculate the ductility for each specimen by iteratively solving the formula below:

$$N_f^{-0.6} D_f^{0.75} + 0.9\,\frac{S_u}{E}\left[\frac{\exp(D_f)}{0.36}\right]^{(0.1785\,\log\frac{10^5}{N_f})} - \frac{2t_M}{2_e + t} = 0$$

where:

D_f = fatigue ductility, inch/inch (x100,%)

N_f = cycles-to-failure

S_u = ultimate tensile strength, psi

E = modulus of elasticity, psi

t_M = core thickness, inch

t = specimen micrometer thickness, inch

ρ = mandrel radius of curvature, within 0.005 mm

Note: This formula is exact only for symmetric cross sections. In the case of non-symmetrical single-sided laminate, the uncertainty of the location of the neutral axis introduces some error. The error in D_f is kept below 20% if

$$\left[\frac{t}{t_M} - 1\right]^2 \frac{E_{substrate}}{E} \leq 0.1$$

IPC-D-330 gives more detailed information for the accurate determination of the location of the neutral axis and the cyclic strains.

Note: Determine S_u as per IPC-TM-650, Method 2.4.18. Determine E during the test for S_u by unloading and reloading after about 2% elongation and measuring the slope of the reloading curve.

5.3.1.2 Report the average product ductility from at least three specimens.

5.3.2 Fatigue Test The number of cycles to failure is the flexural fatigue life in fully reversed bending for the bend radius corresponding to the radius (1/2 diameter) of the test mandrel used. An average flexural life from at least three specimens should be reported.

5.3.3 Fatigue Behavior The fatigue behavior of a sample can be obtained by determining the flexural fatigue life with a number of different diameter mandrels. Plotting the results in a strain range versus fatigue life Manon-Coffin plot log $\Delta\varepsilon = [2t_M/(2t\rho + t)]$ versus log N allows intrapolation and extrapolation to other bend radii or fatigue lives.

6 *Notes* For further technical details, reference the material given in 6.1 through 6.3.

6.1 IPC-TP-204 Engelmaier, W., *A New Ductility and Flexural Fatigue Test Method for Copper Foil and Flexible Printed Wiring,* April, 1978

6.2 Engelmaier, W., *Fatigue Ductility for Foils and Flexible Printed Wiring,* Program No. 1883D HP-67/97 User's Library, Hewlett Packard Co., Corvallis, Oregon, 1978.

6.3 Engelmaier, W., *Fatigue Ductility Flex Tester*, Drawing L520163, Bell Telephone Laboratories, Inc., Whippany, New Jersey, 1978.

6.4 Test Equipment Sources The equipment sources given in 6.4.1 and 6.4.2 represent those currently known to the industry. Users of this test method are urged to submit additional source names as they become available, so this list can be kept as current as possible.

6.4.1 Fatigue Ductility Flex Tester, Universal Mfg. Co., Inc., (201) 374-9800, 1168 Grove St., Irvington, NJ 07111.

6.4.2 JDC Precision Sample Cutter, Model JDC 125-N or equivalent.