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Materials Testing for Microelectronics

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Like buildings and bridges, electronic circuits are structures in which materials with quite different mechanical properties are joined together. Predictable and reliable behavior depends on understanding their properties and potential failure modes. A wide range of methods exist to help improve this understanding.

The simplest form of bend is known as pure bend and this is what we aim to achieve in a four-point bend test. The strain is constant over a large part of the sample's surface and this is particularly useful for straining board-level interconnect (IPC/JEDEC 9702).

Bend testing is also used for quality control of PC laminates and more general materials testing. Either 4-point (ASTM D 6272, EN ISO 14125) or 3-point (ASTM 790, EN ISO 14125) bending can be used. The well defined sample geometry permits the use of simple beam theory and flexural modulus can be determined from the initial slope of the load-displacement plot. Bend testing is not confined to measuring elastic properties, but can be used to measure both yield and failure strengths of the material. The values obtained are not the same as those measured in a tensile test and are referred to as the flexural yield strength and flexural strength respectively.

Micro bend is ideal for assessing the impact of surface cracks and treatments on the strength of brittle materials, such as silicon. In these materials the high level of stress at the tip of a crack cannot be relieved by plastic flow and even small loads can lead to catastrophic failure. The standard way of assessing the deleterious effects of dicing and grinding is to perform some form of bend test on a statistically significant population of samples, typically >25. Different bend methods result in different stress distributions and methods used include: 3 point (SEMI G86-0303), 4 point, ring-on-ring and ball-on-ring (spherical bend). Bend testing can be applied to other microelectronic components, such as SMT resistors and capacitors made from brittle glass or sintered ceramics (IEC 60068-2-77).

Straining board interconnect using 4-pt. bend.

Fatigue Failure

Fatigue failure is generally attributed to the initiation and subsequent growth of a crack under cyclic load or strain. More often than not cracks start at material defects which act as powerful stress concentrators, and with each cycle the crack gets longer until the material fails. Often the material shows no gross plasticity, the high plastic strains being localized at the tip of the growing crack. Plastic flow plays a key part in the crack growth process and so this mechanism of failure cannot account for failure in brittle materials, such as silicon.

Glass fiber composite undergoing a 3-pt. bend test to assess rigidity and flexural strength.

Low Cycle Fatigue is generally characterized by a fatigue life <104 cycles. Crack initiation is rapid and growth dominates the lifetime. The cyclic load-displacement plot can be used to highlight energy loss in the sample due to inelastic deformation and change in compliance due to crack growth.

Cycles Until Failure

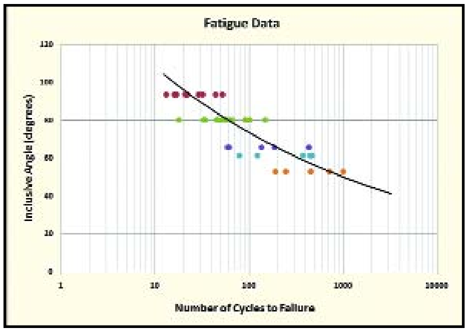
For a given set of conditions, the number of cycles until failure will exhibit some variation and statistical models such as the two-parameter Weibull distribution are employed. This is to be expected as material defects and microstructure have a big influence on crack initiation and propagation.

The simplest way of straining a solder joint is to bend a test board on which the component has been attached. Bond failure can be monitored by measuring the resistance of the connection. However, care must to be taken in interpreting such data to predict thermal cycling performance.

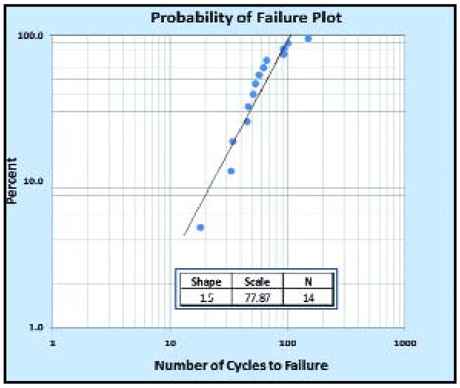
Mechanical tests performed isothermally are different from thermal cycling and, at the moment, there is no proven correlation between them. Fatigue of solder is a complex subject.

The adhesion of tapes, PCB tracks and solar cell ribbon bonds can be assessed using a peel test. The peel test measures the force per unit width (peel strength) to tear the flexible adherent from a rigid substrate. This is not a direct measure of adhesion strength as work is done in plastically deforming the flexible component, but if the sample and test conditions are standardized, the peel test becomes a convenient quality control tool.

Adhesive joints between rigid adherents can be assessed using a lap shear test but in many cases, such as die adhesion a simple shear test suffices (MIL-STD-883H). Shear testing can also be used to test underfill adhesion and to measure the adhesive strength between leadframes and molding compounds (SEMI G69-0996).



Fatigue data for a repeated bend test. Multiple measurements are made at each angle, with the plot representing the average value.

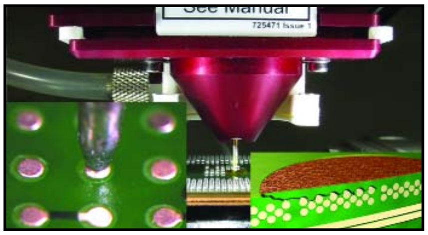


Weibull plot for number of cycles to failure at a bend angle of 80°.

Stud/Hot Pin Pull

Stud pull and Hot Pin pull provide a simple way of applying tensile loads to difficult-to-grip, low geometry samples.

In stud pull an adhesive is used to attach a metal stud. Hot Pin pull uses a small heated pin to make a solder joint between the part being pulled and the force measurement system. Pin geometries can be very small and with care, a bond can be made to features that are <100µ in diameter. One application is pad cratering (IPC 9708). Latent damage introduced during processing of the PC board can cause a pad to fail by crack propagation through the composite.



HBP with magnified view.

Impact Failure Modes

Quite often impact produces failure modes not observed in routine low strain rate tests. At high strain rates, solders yield at significantly higher stresses and as a result other parts of the bond become more highly loaded and can fail first. High-speed testing is widely used for assessing the brittleness of solder joints or the susceptibility of a PC board to pad cratering under impact conditions (JESD22-B115A, JESD22-B117A).

Connector Testing

Connector failures are generally associated with abrasion of the contact materials. Repeated insertion and retraction of connectors wears away coatings and can lead to corrosion of the base metal. Ongoing wear, in general, has a detrimental effect on the insertion force and electrical resistance of the connections. Cyclic loading of connectors not only provides useful information for determining the number of times connectors can be plugged and unplugged, but is also a means of testing design changes, such as pin shape, spring force and coatings.

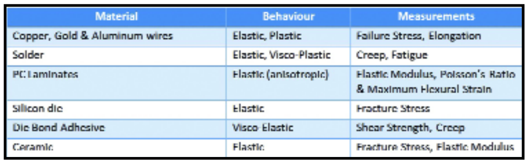
Creep Measurements

Creep measurements are important for solders, polymers and adhesives where large strains can develop over time, and strain rates are very temperature-sensitive. Although creep is essentially a shearing process, it can be assessed using tensile, compressive and bend tests.

There are three types of creep test: The stress rupture test, measures the long term load bearing characteristics of the component. Stress or load relaxation methods, measure the slow replacement of elastic strain by plastic strain at constant total strain. The constant stress/load test measures sample strain rate under conditions of constant load or stress.

As a rule of thumb, for metals, creep is important for temperatures above half the materials' absolute melting point. The behavior of plastics depends on their glass transition temperature, Tg. At temperatures well below Tg, they are elastic and brittle. Above Tg, their behavior depends on whether or not the polymer chains are cross linked. Linear (unlinked) polymers tend to be viscous or visco-elastic, depending on temperature. In cross linked polymers, the individual molecules are restrained and these polymers generally exhibit some form of visco-elastic beaver.

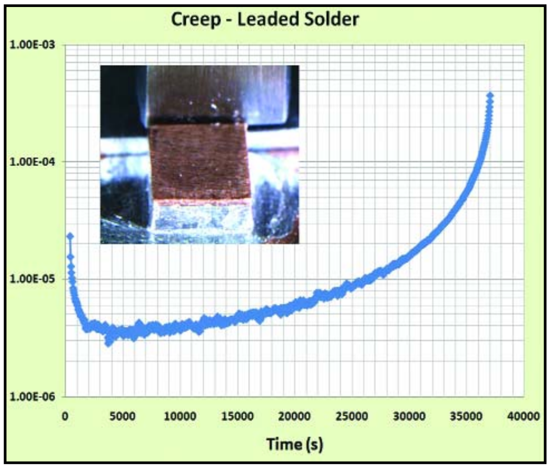
Adhesives are really a subset of plastics. Much of what has been said about plastics applies to adhesives as well, but care must be exercised in understanding the rather special stress condition that exists in the narrow joint between the bonded plates.



Material	Behaviour	Measurements
Copper, Gold & Aluminum wires	Elastic, Plastic	Failure Stress, Elongation
Solder	Elastic, Visco-Plastic	Creep, Fatigue
PC Laminates	Elastic (anisotropic)	Elastic Modulus, Poisson's Ratio & Maximum Flexural Strain
Silicon die	Elastic	Fracture Stress
Die Bond Adhesive	Visco-Elastic	Shear Strength, Creep
Ceramic	Elastic	Fracture Stress, Elastic Modulus

Materials testing table.

Peel test.



Creep for leaded solder.

Contact: Nordson DAGE, 48065 Fremont Blvd., Fremont, CA 94538-6541 ☎ 510-683-3930
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See at IPC/APEX Booth #2915.