Creep of Tin Based Alloys

Application Note

THE CHALLENGE

The dimensional changes that occur with time when materials are statically loaded, is referred to as creep. Creep measurements are important for solders, polymers and adhesives where large strains can develop over time and strain rates are very temperature sensitive.

Creep in metals is governed by the thermally activated movement of dislocations. Dislocations blocked at low temperatures are able to move by climbing to new guide planes and so the material continues to deform.

The low melting point of tin based solders means they are prone to this deformation mechanism even at room temperature.

THE SOLUTION

Creep measurements are usually made under a constant load often produced by hanging a weight directly or via a lever. This method is still the best way of conducting very long term tests. However, for performing short term tests on small samples, it is generally more convenient to carry out some form of simple shear test.

As a comparative measurement testing individual solder balls is attractive, although it is not possible to extract the creep parameters directly from the displacement-time profile. Initially, the solder flattens at the point of contact with the tool and deformation is highly inhomogeneous. If a test structure can be manufactured, then additional information can be obtained.

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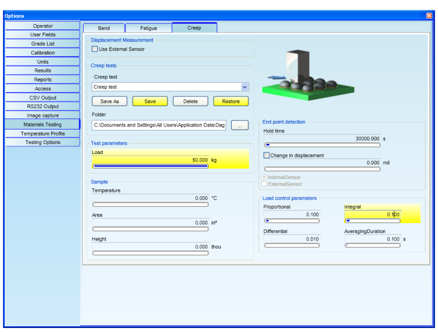
THE METHOD

Shear tests are normally conducted at a constant displacement rate, with the force being recorded as a function of time and position. Generally, only the peak force is saved. Displacement rates are typically in the range microns to millimetres per second.

Shear creep testing on the 4000*Plus* is conducted at a fixed load, Paragon™ test software continuously adjusting the stage position to maintain the set load. Position is recorded as a function of time, typically over time intervals that last thousands to tens of thousands of seconds.

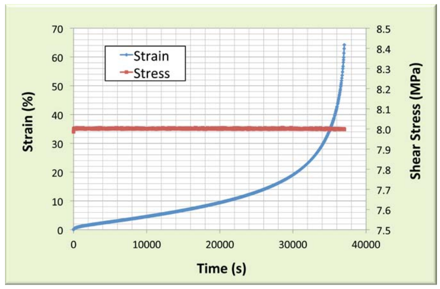
At the start of test, the shear height is automatically set and the load applied. The test stops when the sample fails, deformation exceeds a set amount or after a set period of time.



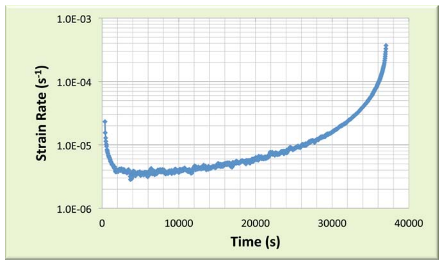
Paragon™ simplifies the entry of test parameters

THE RESULT

At moderate to long lifetimes, the initial primary creep phase soon gives way to a steady state (secondary) deformation rate. Secondary creep rates exhibit a strong dependence on the test load and temperature. Before failure, the rate of deformation is observed to increase as it enters the final stage of the process.



Creep data for a 60/40 SnPb solder



Strain rate vs. time for a 60/40 SnPb solder

Equations of steady state Creep

$$\frac{d\gamma}{dt} \propto \tau^n \qquad \text{Stress dependence}$$

Where γ is the shear strain, τ the applied shear stress and η is the stress exponent.

$$\frac{d\gamma}{dt} \propto e^{-Q/RT} \qquad \text{Temperature dependence}$$

Where Q is the activation energy, R is the universal gas constant and T is the temperature.

Combining these equations gives –

$$\frac{d\gamma}{dt} = C\tau^n e^{-Q/RT}$$

For more information, please contact your Nordson DAGE regional office or speak with your Nordson DAGE representative, all of which are listed on www.nordsondage.com.

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