Applications Note

A NORDSON COMPANY

Using energy as the main metric for High Strain Rate pull and shear testing of solder balls

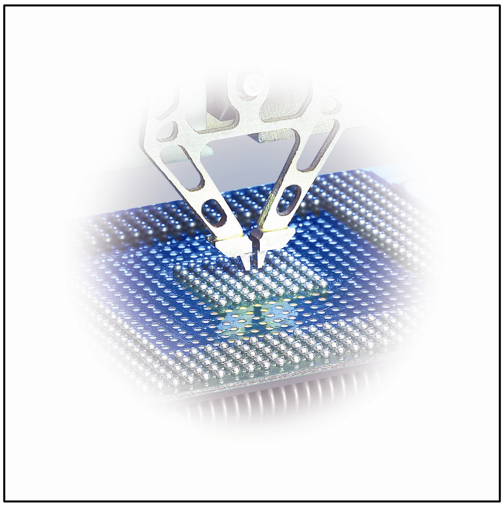
Why high strain rate?

High strain rate testing methods have become particularly important with the legislated introduction of lead-free solder, particularly for portable electronics using BGAs, micro-BGAs and flip chips which use solder balls as the interconnects

- Board level drop testing is a standard method for investigating solder joint reliability, but is very time consuming, expensive and cumbersome to perform. The only quantitative measure is the number of drops to failure. Results are often noisy and ambiguous
- Charpy and IZOD are pendulum based impact testers widely used in materials evaluations and latterly adapted to test solder joints. Although these devices do yield an energy value for bond failure, only total energy is measured and there are no force versus displacement curves. The test does not occur at constant velocity and there is no means (XY table, adjustable Z axis, microscope) of quickly and reproducibly aligning the sample with respect to shear height etc

Dage high strain rate bond testing

The DAGE 4000HS bond tester addresses all these shortcomings. Developed in response to the electronics industries' need to swiftly evaluate new alloys and bond materials introduced to meet the lead-free legislation, the instrument provides a credible alternative to the methods cited above



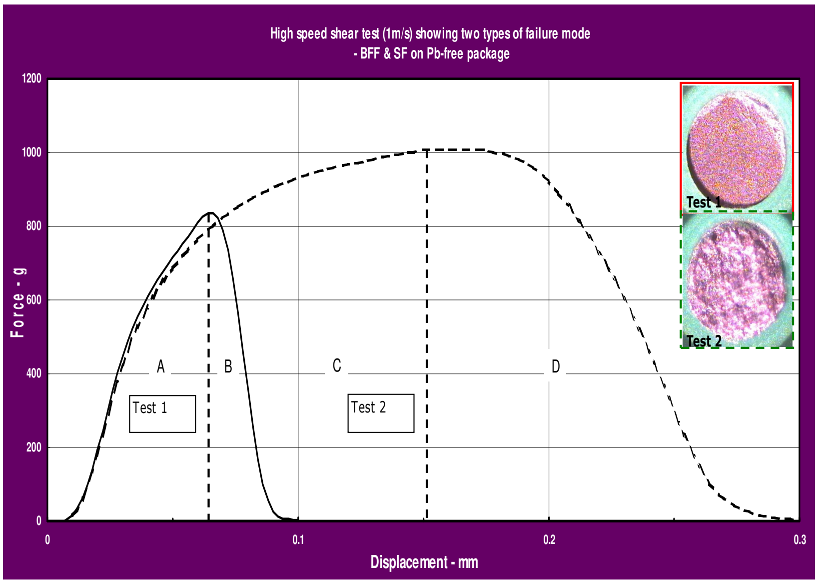
- Traditional bond testing at low test speeds (<5mm/s for pull, <1mm/s shear) uses accurate force measurement as the principal quality control tool for interconnect strength
- But in high strain rate testing on the DAGE 4000HS, peak force measurements on any particular solder ball give similar values even for very different failure modes
- Detection of brittle fracture failures, especially in lead-free solder materials, is a vital capability in material selection, process refinement and quality control. Force measurement in either conventional or high strain rate bond testing cannot discriminate between different failure modes. Compare the force and energy measurements (total or post-peak) in Table 1 below
- High strain rate bond testing on the DAGE 4000HS generates brittle fracture failures as the test speed is increased. All tests are accompanied by force-displacement curves, the shape of which are characteristic of the failure mode
- Graph 1 below shows two curves, one for a brittle failure (Test 1) and the other for a ductile failure (Test 2). Note their distinctive shapes and different areas representing distinct bond energies associated with the different failure modes

Energy is the main metric

Indeed, the measurement of energy on the DAGE 4000HS is the principal metric for all applications of the tool

- Energy can be used for rapid screening of new bond materials – solder alloys and surface finishes
- Energy can be used to refine and monitor production processes for BGA and flip chip manufacture
- Increases in energy values show an improved bond strength

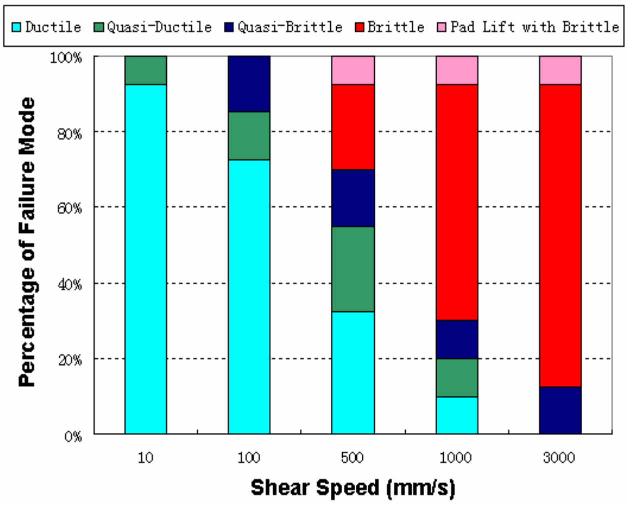
Document No. AN-BT002



Graph 1

How to use energy

Find the optimum or transition speed for pull or shear – transition speed finding is described in a separate Applications Note (AN003). The method is used to generate a histogram such as that below, for shear testing



Graph 2

- In this example the transition speed is between 500 and 1000mm/s and further testing at a range of other speeds would be needed to determine it more accurately
- Next, carry out multiple tests at the transition speed – obtain energy values for failure mode and mean values across all tests

	Force - g	Total energy - mJ	Pre-peak - mJ	Post peak - mJ
Ductile	1091	1.82	0.53	1.29
Brittle	995	0.71	0.30	0.41
Quasi-brittle	1054	1.17	0.41	0.77
Quasi-ductile	1045	1.59	0.47	1.12
All failures	**1063**	**1.57**	**0.47**	**1.10**

Table 1

- Once again, note that force provides poor discrimination across the various failure modes. In sharp contrast there is excellent correlation between failure mode and total or post-peak energy values
- If materials screening, use the transition speed obtained from testing of the control or reference sample for all experimental sample tests – shifts in the mean energy (total or post-peak) will show improvements or deteriorations in bond reliability – checking failure mode is unnecessary

- The following example shows the process for production monitoring – we will use the mean values in Table 1 as the baseline for batch testing – 10 balls on each of five batches are tested and the mean energy values shown in the table below

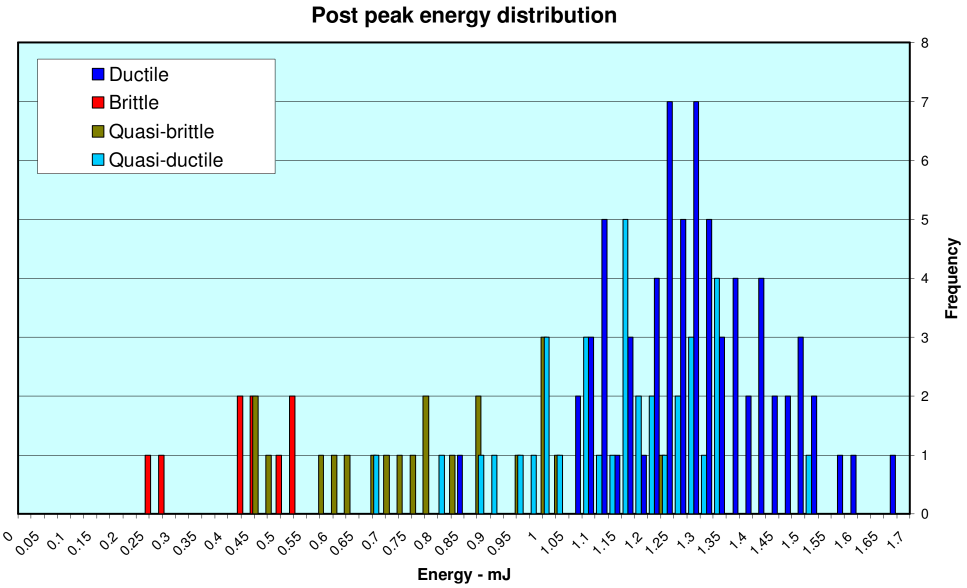
.

	Total E	Pre E	Post E
Baseline Mean	**1.57**	**0.47**	**1.10**
Batch1	1.36	0.39	0.97
Batch2	1.56	0.56	1.00
Batch3	1.59	0.46	1.13
Batch4	1.50	0.46	1.04
Batch5	1.49	0.41	1.08
All batches	1.50	0.46	1.05

Table 2 – values in mJ

- It can clearly be seen that batches 2 to 5 are not significantly different from the baseline values (looking at total energy or post-peak energy). Depending on the tolerances set beforehand, batch 1 should be retested

- Another way to use energy is to look at thresholds: for this the data needs to be plotted in a different way. In the graph below a frequency distribution for post-peak energy has been plotted with the various failure modes colour coded
- Choosing a pass threshold of 1.1mJ and above would reject product with a possibility of brittle or quasi-brittle failures



Graph 3

Summary

It is now conclusive that energy is the principal metric for reliable, repeatable High Strain Rate bond testing, analogous to the use of force in conventional bond testing

- Energy can be used in material selection, process set up and production monitoring
- Using energy on the DAGE4000HS is an accurate, economic, time saving and simple alternative to other high strain rate methods for solder joint evaluation

Further information on high strain rate bond testing can be obtained by contacting your local DAGE office or agent.

www.dage-group.com

A NORDSON COMPANY