

Die and Package Testing Protocol/Best Practices

1 Introduction

In order to achieve comparable testing results from site to site, a fully defined test protocol is required. The goal of this test protocol is to specify important test parameters that, when set up similarly in different machines, will allow those machines to capture similar results. While the following recommendations are a good starting point, different samples will require different setups to optimize the captured data. Where different, users should communicate exact test conditions.

2 Hardware

An Akrometrix TherMoiré AXP or PS400 w/ Studio Upgrade is recommended for optimal surface characterization. A 100 line per inch (LPI) grating along with a zoom lens is also recommended. Special attention should be paid to what field of view is chosen for each test. Because zoom lenses have no detents, it is especially important to use the same size ROI between systems. The users should set an ROI size in pixels and match the edges of the ROI to the part edges using the lens zoom. Certain applications benefit from different fields of view and gratings. When differing from the standard hardware, all parties should coordinate such that they are using the same setup.

For smaller BGA sizes (<15 x 15 mm), a 300 LPI grating may be used to allow increased data density on the part. Again, communication of grating type used, as well as zoom level is critical for data reproducibility.

3 Calibration (Fringe Value / Fringe Height)

Before measurement, each machine should be calibrated to ensure system accuracy. Calibration should be performed according to each equipment manual and use a recently calibrated standard. It is recommended that calibration blocks be recertified yearly by Akrometrix. The calibration procedure calculates a unique constant, the **Fringe Value**, which ensures that the system accuracy will be the greater of 2.5 μm or 3% of the measured value.

If there are periodic ripples visible in each room-temperature 3D result, which have double the frequency as that in the phase image (see **Figure 1**), make sure the sample is not touching the grating during phase shifting. If the sample has not touched the grating and this problem remains, another constant, the **Fringe Height**, may need to be calibrated. Contact Akrometrix for a detailed procedure. If no ripples are visible, the fringe height is properly calibrated.

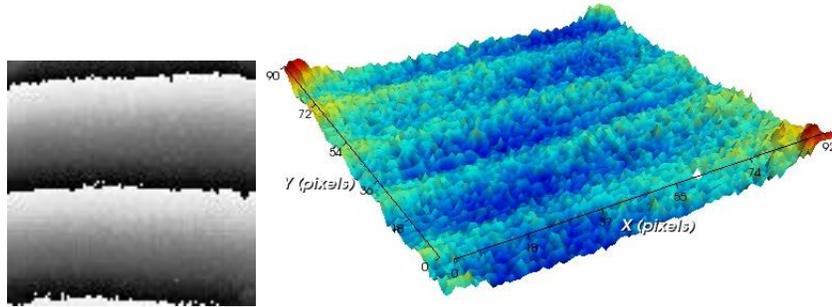


Figure 1 Phase Image with resulting 3D Surface showing periodic ripples

4 Sample Characteristics

There are several sample and sample prep characteristics that are recommended for use with Akrometrix TherMoiré systems. Firstly, the measurement technique used in all TherMoiré systems is ideally suited to measuring surfaces that are continuous in nature. That is, they do not have areas of interest that contain step heights. An example of this ideal type of surface is a typical bare BGA substrate with no solder balls. If that BGA has solder balls, then it is an example of a surface that cannot be measured. In this case, the solder balls either need to be removed or an alternative sample chosen which does not have solder balls.

In addition to the continuous criteria, the ideal surface finish and color for use with the shadow moiré technique is one that is diffuse and white. Such a sample surface will result in the least amount of noise and highest contrast for the moiré fringe pattern. In order to achieve this surface type, a thin layer of high-heat white paint should be applied on top of the sample. This coating should be scattered uniformly across the whole sample but still be semi-transparent so that surface features are not completely covered. Akrometrix uses and recommends Rust-Oleum™ Specialty High Heat white enamel spray paint.

Finally, in addition to the above characteristics, it is important to take moisture sensitivity into consideration. JEDEC standard J-STD-020D.1 regarding moisture sensitivity levels is widely adhered to in the electronics industry. This same standard should be followed while testing samples with Akrometrix equipment. Typically, the main consideration is that samples are baked prior to exposure to reflow cycles. This baking should occur after any paint has been applied to the sample. Typical bake times are 12 hours at 125°C.

5 Sample Placement

Unlike PCB warpage, component warpage does not tend to vary much with respect to sample placement. However, for consistency sake, components should still be fixtured identically between sites. For BGA's that are approximately 30 x 30 mm and larger, the standard rail supports present in any Akrometrix TherMoiré system will provide adequate sample support while allowing maximal heating and cooling rates.

If testing smaller samples (< 15 x 15 mm) with a 300 LPI grating, another important consideration is vertical movement of the standard sample support due to thermal expansion. This movement can cause the sample to touch the grating at elevated

temperatures resulting in lost data. To alleviate this concern, Akrometrix recommends a spider frame fixture (see **Figure 2**). This fixture is designed to minimally expand under heating such that the samples under test can't touch the grating.



Figure 2 Spider Frame

A third option, for use with intermediate sized samples, is a thin piece of quartz glass (~1mm thin) supported by the standard support rails. This type of support allows the user to spread the support rails further apart to increase heating rates, but is only recommended for use with a 100 LPI grating.

6 Thermocouple Placement

In general, it is best to place the driving thermocouple on the bottom center of the sample. This area will receive the most IR energy and highest heating rates. All other points will typically be at the same temperature or lower during heating. However, this case will only be possible when using edge support on components. Often components will be resting on top of glass for warpage testing. In this case a “dummy” sample is recommended for thermal testing. The thermocouple can be placed on the top of the dummy sample for temperature reading while the other part or parts are measured for warpage. The dummy sample should always be the same form factor as the tested sample and should be in a location where similar heating rates would be expected.

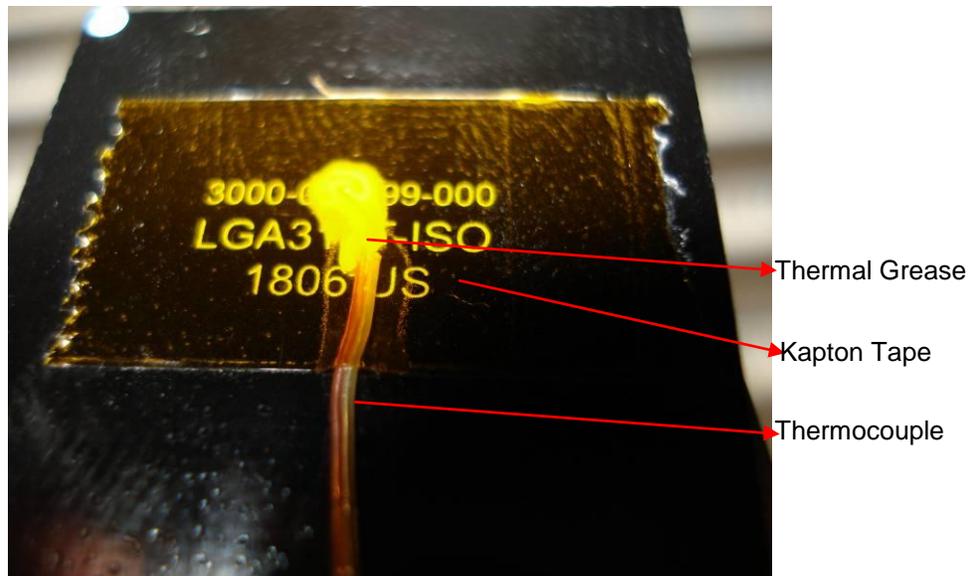


Figure 3 Thermocouple Placement

Thermocouples should be attached to the sample surface using thermal grease and Kapton tape® as described in JEDEC standard JESD22B112. Alternatively, thermocouples can be more permanently attached using some sort of high temperature thermally conductive epoxy. **Figure 3** presents an example of thermocouple attachment on the sample surface.

7 Data Acquisition

- **Grating Cleanliness:** Because many FR-4 type materials tend to outgas at elevated temperatures, it is important that the grating be cleaned between thermal runs. Lint-free paper towels or cloths can be used along with any commercially available glass cleaner or IPA to remove these residues. The user should only wipe with the direction of the grating in order to minimize potential for grating damage. In addition, it is advised to clean any out-gassing residues as soon after the thermal cycle, during which they were deposited, as possible, so as to make their removal easier. These residues become more difficult to remove as they are “baked” on during subsequent thermal cycles.
- **Light Levels:** Set both light sources to approximately 90 percent (Akrometrix finds this to be a good compromise between light intensity and bulb life) of their maximum value and adjust the lens iris to achieve proper fringe contrast. Make sure the image is not saturated (bright spots with constant maximum grayscale values) or too dark (there is still a lot of room to increase the brightness before saturation). For optimal fringe contrast it is best to have the image brighter without any light saturation. The Akrometrix Studio software is capable of showing saturated light and dark pixels on the image, so that light saturation can be avoided. The Studio software also tracks an electronic iris setting (0-100%); however, the lens will still have a manual adjust that needs to be replicated between different systems.

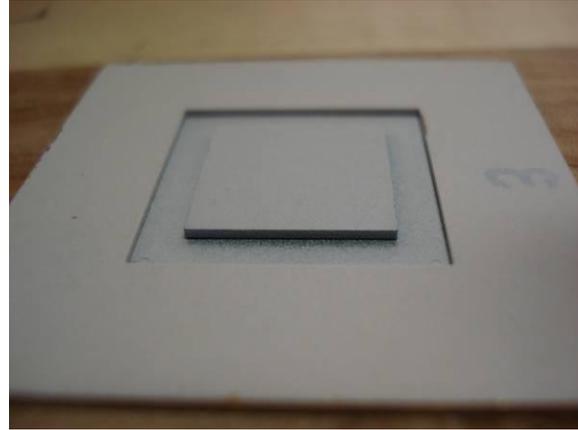
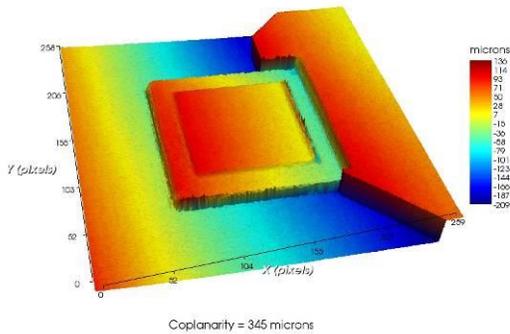
- **Sample to Grating Distance:** Maintain a reasonable distance between the sample and grating. Too close or too far can result in loss of data or inaccurate results. For consistency Akrometrix recommends jogging the sample up until it touches the grating, and then lowering it by approximately 200 mils or 5000 μm when using the 100 LPI grating, or approximately 25 mils or 625 μm when using the 300 LPI grating. Slow or medium jog speeds should be used when grating to sample contact is likely to happen. On samples that have been coated with white paint, this distance allows good fringe contrast while leaving space for sample deflection towards the grating. This also reduces the effect of out-gassing during the thermal cycle. For uncoated samples, a shorter working distance may need to be selected. The working distance for components with surfaces at varying heights, such as a die on a package, may need to be shorter to measure the lower areas while avoiding sample to grating contact. This may also require the use of a 100 LPI grating on sample sizes where the 300 LPI would typically be preferred. Again, consistency between systems is the key.
- **Phase Amplitude Threshold:** Phase amplitude threshold can be used to mask noisier regions of an ROI when measuring components or dies. Recommended phase amplitude threshold values are 1, 2, or 3. For samples that exhibit excessive out-gassing during thermal cycles, lower phase amplitude threshold values should be used to keep more data. Higher values introduce the possibility of losing good data on the sample surface, while lower values may not effectively mask the noisier areas. Akrometrix Studio tracks the phase amplitude threshold used on any given phase image. Different samples may need to use different phase amplitude thresholds, but the same form factors should always be tested with the same phase amplitude thresholds.
- **Regions of Interest (ROI):** The ideal approach for ROI selection is to size the ROI 2-3 pixels from the edge of the measured surface. This allows a nearly complete data set, while not creating any “edge effects” from pixels off the edge of a sample. This ROI choice will also decrease the need for later phase image processing. However, in some cases, the sample will move laterally inside the heating chamber. In these cases ROI selection can be selected well outside the dimensions of the part and cropped more carefully in post processing.

8 Data Analysis

- **Akrometrix Studio:** Of all the feature changes and improvements in the Akrometrix Studio software, the data analysis software (Surface Analysis) provides the largest technical advances to the TherMoiré systems. When at all possible data analysis should be performed on this new platform.
- **Units:** Z-displacement units are most commonly shown in microns.
- **Reference Plane:** LSF rotation must be applied during analysis to obtain correct coplanarity values. Choosing LSF rotation also allows concave or convex shape to be defined as in JEDEC standard JESD22B112 or JEITA standard ED-7306.
- **Gauges:** A number of gauges are available to numerically represent a given data set, with a number of added options in Studio. Coplanarity is defined as the vertical displacement difference between the highest and lowest pixel in an entire

data set. While this gauge can be noise sensitive, it is the most commonly used gauge for data comparison. Additionally, signed coplanarity can be used to show the direction of warpage.

- **Phase filtering (smooth):** To reduce noise in an image, phase filtering can be applied once to each phase image. Phase filtering will also typically change calculated gauge values; for this reason all images for a specific sample ROI or no images should be phase filtered.
- **ROI (Cropping/Partitioning):** If the global ROI was made larger than the sample, then phase images should be cropped 2-3 pixels inside the visible edge of the sample. Akrometrix Studio allows for more accurate cropping using the “view surface image” capability. Local areas on the PCB can also be partitioned for more detailed analysis of these areas. In all cases, if lens zoom is consistent, pixel dimensions for all ROIs should be the same.
- **Masking:** If there are noise or spikes in the results, they should be masked out before further analysis. This noise will substantially affect the coplanarity value since it relies on only two values among possibly millions of data points. Very small features can often be ignored if they do not cause noise in the extrema of the data set. Finally, any step heights or discontinuity in the measured surface will also need to be masked. A common example would be a package with die in the center. Both package and die can be measured, but they must be processed separately when using the shadow moiré technique. The die can be cropped out and processed as a separate region. Similarly, the surrounding substrate can be analyzed by masking the central die, thereby removing it from the 3D data. Akrometrix Studio gives much stronger masking capabilities, particularly when dealing with complex shapes or highly discontinuous surfaces.
- **Unwrapping Errors:** An unwrapping error occurs when the software cannot count between the beginning and end of a fringe. Noisier areas or step heights on the sample can cause these errors. Unwrapping errors will appear as a sudden, one fringe value height change that moves diagonally away from the source of the error. When measuring components with features containing sudden height changes, unwrapping errors can also be well hidden as surface areas that are off by a single fringe value height. A “sanity” check of local features should always be considered when processing these types of surfaces. Results should never contain unwrapping errors, as these areas contain false data. Unwrapping errors are most commonly solved by masking the problem areas that are causing the incorrect fringe counting. An example unwrapping error is shown in **Figure 4(a)**. In **Figure 4(b)** a picture of the sample shows that there is clearly a low area surrounding a central die region. When this entire area is processed these sudden height changes are not analyzed correctly with the shadow moiré technique. However, the outer area and inner die surface can both be analyzed independently by using cropping and masking.



(a) Incorrectly Analyzed Image

(b) Component Picture

Figure 4 Discontinuous Component Example

- **Scale:** A common Z-scale should be chosen for all tests in a single form factor. The range of this scale will vary per sample.
- **Graphical Output:** 3D Surface plots are the preferred graphical representation of component and die shapes.
- **Relative plots (Optional):** Relative data analysis is not standard to the average test, but should be mentioned here. This capability allows two data sets of the same size to be subtracted from one another. This subtraction gives a relative warpage change, most commonly used for the change of a single part over temperature.

9 Reporting

Akrometrix provides software for organizing graphical results into a report format. As a baseline this report should include 3D Surface plots, color legends for the Surface plots, and the coplanarity value for each plot. Addition information in the form of graphical plots and numerical gauges can be added to the report as needed. Other available graphical outputs include Color Contour plots and point to point 2D chord plots. Available gauges are numerous, particularly in Studio, and can include bow, twist, signed warpage, chord maximum, and chord minimum. Signed Warpage is implemented in Akrometrix software according to JEITA standard ED-7306. An example Akrometrix report output is shown below in **Figure 5**.

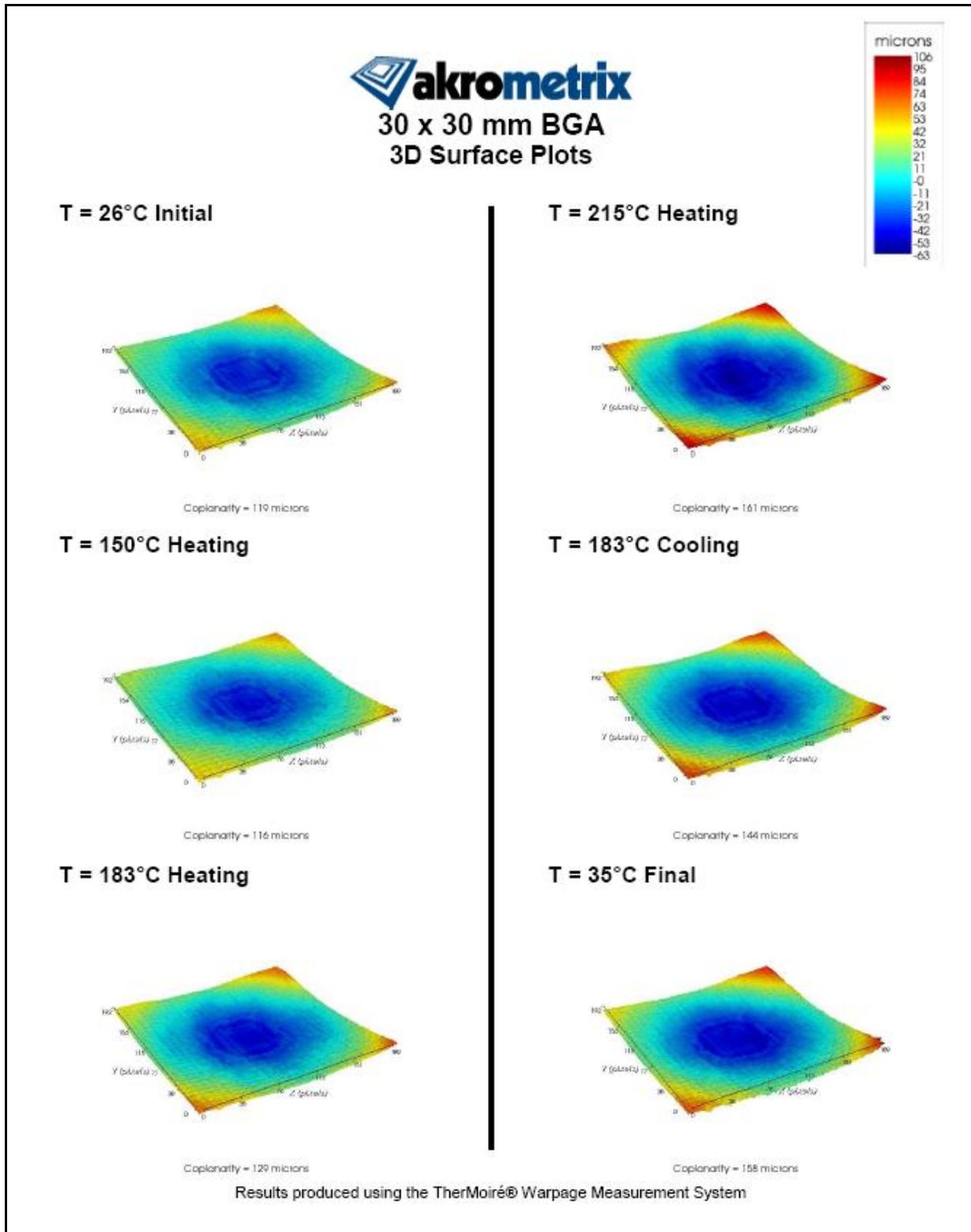


Figure 5 Akrometrix Component Report with 3D Surface Plots