

## **BGA Coplanarity Measurement by Laser Scanning Inspection Equipment**

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### **Abstract**

*In this paper BGA coplanarity Measurement by laser scanning inspection method was discussed. Chosing a right datum plane, so that the laser spot's focusing range could cover all BGA balls' relative height, is a key to success. The measuring speed and accuracy was then evaluated on a sample BGA product with 20×20 array balls by our CT300 laser scanning inspection equipment. The method was proved to be reliable. It not only extended functions of current equipment, but also had a advantage of easy and efficient operation, thus the method could be utilized by coplanarity inspection and evaluation for all kinds of BGA.*

**Keywords:** *BGA Coplanarity Measurement, Laser Scanning Inspection, Relative Height*

### **1. Introduction**

BGA Package as the highest integration density package in nature has found wide application in packaging of digital IC components with large I/O count, since its implementation to replace leaded devices in the early 1990's. Coplanarity is one of the most important quality feature of BGA, because in soldering to PCB this coplanarity can translate into open or intermittent solder connections known as "ball-in-socket" or "ball in cup"(BIC) defects named after their cross sectional shape. These defects can escape test, X-Ray and visual inspection making them difficult to prevent from entering the field. After post assembly test, assemblies with these BIC defects often fail with handling, thermal cycling or simply during shipment. Therefore, coplanarity evaluation is a necessary procedure not only in prototype development stage but also in high volume

production real-time quality control process.[1]

Evaluation of BGA coplanarity can be translate into measuring the heights of all soldering balls according to "3 point method" defined by "JEDEC Standard 95 Design Guide 4.17"[2] and solid geometry theory. To get the height of hundreds of soldering balls of BGA, several measuring methods could be utilized as being divided into contact or noncontact method. The corresponding equipments are three-coordinates measuring machine or laser scanning inspection equipment. Another noncontact method known as shadow more technique is also under research by many institutes. Because in mechanism it has a very fast measuring speed in nature since it takes and post processes the raster picture that can record the fine distinction of height change of the soldering balls, and the whole process can be finished in seconds. As to measuring with laser scanning method, a beam of laser was casted on the surface of the sample, as sample

moves in a straight line with the stage driven by linear motor. The fluctuation of the surface can be recorded by the sensor, as time interval between the light transmitting and receiving was changing as laser spot moving from one point to the next. If these points are consecutive, we can get the full 3D surface view of the sample.[3,4]

In comparison, laser scanning inspection method demonstrates a comprehensive advantage, it is mature and known to be more accurate and reliable than shadow more technique and faster in speed than contact method using three-coordinates measuring machine. For many years, laser scanning inspection has been commercialized to wide application in thick film IC technology industry, such as measuring the height of screen printing thick film line, the flatness or finish of ceramic substrates, and so on.

In this paper the coplanarity measuring experiment was implemented on a sample BGA product with 20×20 array balls by our CT300 laser scanning inspection equipment.

## 2. BGA Coplanarity Definition

A BGA coplanarity evaluation method was defined by “JEDEC Standard 95 Design Guide 4.17” as so-called “3 point method”. As illustrated in Fig.1, suppose we put a BGA sample with soldering balls down on a horizontal surface, there must be 3 highest balls contacting with the surface by gravity. The horizontal surface was defined as seating plane. According to the definition, the BGA product’s coplanarity was defined as the maximum distance of the top of soldering balls to the seating plane. From solid geometry theory, coplanarity could be easily drawn from the measured heights of all BGA soldering balls. Reference 4 and 5 had given us a comprehensive deduction of mathematical representation of coplanarity and a calculation diagram for programming.

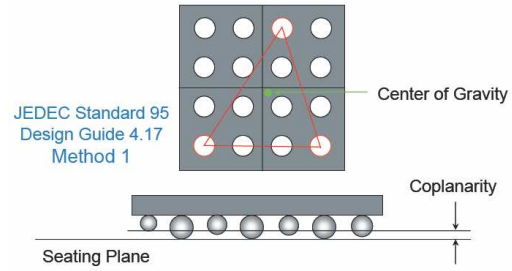


Fig.1 “3 point method” of BGA coplanarity evaluation

However, instead of precisely calculating of coplanarity according to JEDEC definition, the maximum height difference (MHD) of all soldering balls was also used to evaluate the coplanarity feature of BGA in many circumstances. It’s not difficult to prove that MHD is a more strict criteria than JEDEC defined coplanarity, so that many engineers prefer to using MHD to evaluate BGA coplanarity in many situation.

## 3. The Balls’ Relative Height Measurement

The BGA sample to be measured contains 20 × 20 array soldering balls with an absolute height of about 600 μm, and the pitch of array was 1.27mm (illustrated in Fig.2). The testing machine was CT300 Laser Scanning Measurement System manufactured by Cyberscan Corp, which has a focusing depth of 500 μm. If we use the surface of the substrate on which soldering balls were mount as the measuring datum plane, we couldn’t get the absolute height of the soldering balls in that the laser beam couldn’t focus on the top.

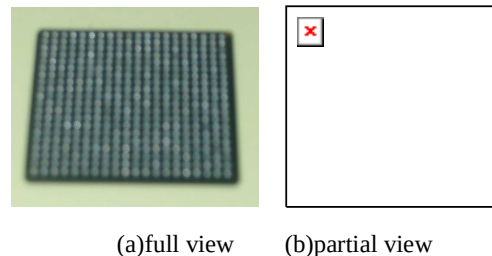


Fig.2 picture of BGA Sample to be measured

Fortunately, from the definition of coplanarity we can conclude that measuring absolute height of soldering balls is not needed. The relative height of

all soldering balls is enough to evaluate the Coplanarity of BGA. Next, the only thing we need do is to move the datum plane up  $200\text{ }\mu\text{m}$ , so that the focusing depth could cover the top half of the ball.

On CT300 the laser head was fixed, while the stage driven by linear motor could move consecutively in the X and Y direction with a step resolution of  $1\text{ }\mu\text{m}$ . As laser beam scanning on the surface of the arrayed soldering balls, it records the relative height of the points covered in the beam moving direction with a Z-direction resolution of  $0.1\text{ }\mu\text{m}$ . The precision 3D picture of the crown of the soldering balls can be drawn if we chose the maximum sampling rate when scanning the BGA in X direction and line by line in Y direction.

Considering both measuring speed and accuracy, a proper sampling rate should be chosen. In our measurement, a sampling rate of 1 data per  $5\text{ }\mu\text{m}$  in both X/Y direction were chosen. Thus we could have 100 data-collecting point around the top of the soldering ball. After the raw data had been collected, it could be saved as Microsoft Excel file

format for various data post-processing method. As illustrated in Figure 3, we could get the fitted curved surface of soldering ball crown.

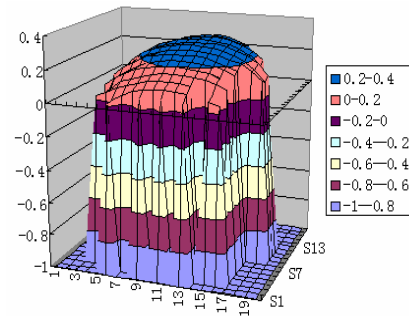


Fig.3 Fitted curved surface of soldering ball crown

#### 4. Data post-processing and the coplanarity calculation

In Microsoft Excel, we could extract the 400 highest points of all soldering balls from raw measured data.(shown in table 1.)

Tab.1 Measured Relative Height of Balls ( $20\times 20$  Array) by CT300

| #  | A   | B   | C   | D   | E   | F   | G   | H   | I   | J   | K   | L   | M   | N   | O   | P   | Q   | R   | S   | T   |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | 298 | 303 | 297 | 294 | 285 | 294 | 303 | 292 | 310 | 310 | 311 | 310 | 313 | 325 | 315 | 310 | 302 | 313 | 306 | 302 |
| 2  | 285 | 286 | 280 | 292 | 294 | 303 | 299 | 307 | 312 | 298 | 330 | 324 | 312 | 311 | 313 | 316 | 300 | 296 | 305 | 305 |
| 3  | 294 | 288 | 286 | 291 | 304 | 308 | 316 | 333 | 328 | 355 | 324 | 331 | 335 | 333 | 330 | 239 | 319 | 309 | 301 | 297 |
| 4  | 286 | 284 | 296 | 300 | 299 | 320 | 328 | 332 | 326 | 329 | 353 | 340 | 342 | 336 | 346 | 334 | 339 | 317 | 322 | 303 |
| 5  | 275 | 281 | 298 | 301 | 308 | 320 | 326 | 336 | 344 | 342 | 347 | 335 | 347 | 333 | 332 | 332 | 326 | 319 | 312 | 303 |
| 6  | 283 | 305 | 304 | 321 | 310 | 317 | 331 | 344 | 346 | 346 | 357 | 355 | 351 | 340 | 340 | 334 | 334 | 313 | 324 | 303 |
| 7  | 282 | 302 | 305 | 313 | 313 | 329 | 337 | 347 | 351 | 357 | 359 | 358 | 360 | 352 | 350 | 341 | 331 | 326 | 314 | 320 |
| 8  | 291 | 295 | 308 | 311 | 324 | 333 | 339 | 358 | 359 | 364 | 364 | 372 | 361 | 355 | 342 | 339 | 345 | 326 | 322 | 309 |
| 9  | 285 | 299 | 307 | 316 | 329 | 342 | 346 | 356 | 344 | 367 | 369 | 372 | 363 | 376 | 356 | 365 | 338 | 330 | 318 | 312 |
| 10 | 286 | 303 | 308 | 334 | 337 | 341 | 354 | 363 | 368 | 368 | 365 | 374 | 372 | 360 | 366 | 347 | 345 | 336 | 317 | 311 |
| 11 | 343 | 326 | 382 | 355 | 365 | 367 | 378 | 382 | 381 | 382 | 387 | 383 | 373 | 356 | 370 | 346 | 339 | 324 | 309 | 302 |
| 12 | 338 | 339 | 354 | 350 | 368 | 368 | 372 | 378 | 361 | 383 | 381 | 384 | 369 | 366 | 351 | 341 | 332 | 323 | 316 | 302 |
| 13 | 323 | 335 | 358 | 356 | 361 | 366 | 369 | 377 | 374 | 374 | 372 | 369 | 360 | 364 | 365 | 344 | 355 | 333 | 309 | 295 |
| 14 | 334 | 328 | 344 | 354 | 349 | 354 | 369 | 358 | 365 | 370 | 376 | 358 | 348 | 351 | 340 | 337 | 336 | 310 | 330 | 294 |
| 15 | 324 | 332 | 335 | 346 | 345 | 340 | 351 | 353 | 360 | 356 | 359 | 359 | 357 | 347 | 334 | 326 | 328 | 314 | 292 | 301 |
| 16 | 315 | 323 | 336 | 326 | 332 | 333 | 335 | 343 | 346 | 353 | 353 | 351 | 342 | 334 | 346 | 311 | 327 | 302 | 298 | 297 |
| 17 | 328 | 320 | 320 | 326 | 326 | 344 | 335 | 332 | 335 | 350 | 339 | 338 | 332 | 331 | 322 | 316 | 318 | 301 | 320 | 287 |
| 18 | 331 | 311 | 316 | 324 | 322 | 327 | 325 | 329 | 330 | 327 | 326 | 326 | 328 | 329 | 313 | 298 | 301 | 288 | 293 | 282 |
| 19 | 336 | 316 | 319 | 312 | 308 | 331 | 322 | 317 | 316 | 321 | 324 | 313 | 312 | 315 | 301 | 289 | 310 | 288 | 283 | 275 |
| 20 | 330 | 316 | 323 | 311 | 300 | 307 | 308 | 312 | 305 | 305 | 341 | 310 | 306 | 297 | 298 | 293 | 287 | 281 | 283 | 286 |

From table 1 we can see that the highest soldering ball is  $387\text{ }\mu\text{m}$ , and the lowest is  $239\text{ }\mu\text{m}$ .

So the maximum height difference was  $148\text{ }\mu\text{m}$ . Given the coplanarity specification of no large than

200  $\mu$  m, This BGA sample was acceptable.

## 5 Measurement Evaluation

In order to verify the effectiveness of our measuring experiment, we re-measured the BGA sample by micron micrometer. 24 soldering balls located on the four corners (as shown in Tab.1, the squares representing the measuring location) were measured in order to adequately prove our laser scanning inspection method. The raw measuring data was shown in Tab.2.

Tab.2 Absolute height measured by micron micrometer(Unit:  $\mu$  m)

| #  | A   | B   | C   | R   | S   | T   |
|----|-----|-----|-----|-----|-----|-----|
| 1  | 599 | 600 | 595 | 614 | 602 | 598 |
| 2  | 581 | 581 |     |     | 603 | 606 |
| 3  | 599 |     |     |     |     | 602 |
| 18 | 633 |     |     |     |     | 579 |
| 19 | 627 | 609 |     |     | 579 | 566 |
| 20 | 626 | 614 | 625 | 577 | 579 | 587 |

In order for data comparison, we chose the "A1" soldering ball as the datum point whose relative height was set to zero. Then we could get the 24 soldering balls' relative height data in both measuring method. (shown in Tab.3 and Tab.4)

Tab.3 Relative height of soldering balls by LSI

| #  | A   | B   | C  | R   | S   | T   |
|----|-----|-----|----|-----|-----|-----|
| 1  | 0   | 5   | -1 | 15  | 8   | 4   |
| 2  | -13 | -12 |    |     | 7   | 7   |
| 3  | -4  |     |    |     |     | -1  |
| 18 | 33  |     |    |     |     | -6  |
| 19 | 38  | 18  |    |     | -15 | -23 |
| 20 | 32  | 18  | 25 | -17 | -15 | -12 |

Tab.4 Relative height of soldering balls by micron micrometer( Unit:  $\mu$  m)

| #  | A   | B   | C  | R   | S   | T   |
|----|-----|-----|----|-----|-----|-----|
| 1  | 0   | 1   | -4 | 15  | 3   | -1  |
| 2  | -18 | -18 |    |     | 4   | 7   |
| 3  | 0   |     |    |     |     | 3   |
| 18 | 34  |     |    |     |     | -20 |
| 19 | 28  | 10  |    |     | -20 | -33 |
| 20 | 27  | 15  | 26 | -22 | -20 | -12 |

By comparing Tab.3 and Tab.4, it's easy to see that the relative height measurement by both method coincided well with a deviation of no greater than  $\pm 10 \mu$  m. Given our micron micrometer having a precision of  $\pm 10 \mu$  m, obviously our Laser scanning inspection method has a conservative precision of no greater than  $\pm 20 \mu$  m.

As to the measuring speed, it depends on the sampling rate. A sampling rate of 1 data per  $5 \mu$  m in laser scanning direction resulted in a total measuring time of about 10 minutes according to the BGA sample mentioned above. It can be easily cut in half, if the sampling rate could be programmed in CT300 at the optimum level.

## 6 Conclusion

BGA coplanarity can be expressed by relative height of all soldering balls in a simple mathematical relation. By properly setting the focusing datum plane to make the focus depth cover the crown of every BGA soldering ball, relative height of soldering balls could be accurately recorded by laser scanning inspection equipment. This method was proved to be effective in our experiment for BGA coplanarity evaluation.

Although our laser scanning inspection equipment was designed to inspect the height of screen printing thick film pattern, the flatness or finish of ceramic substrates. The success in using it for BGA coplanarity measurement not only extended functions of the current equipment, but also had an advantage of easy and efficient operation. Therefore the method could be utilized by coplanarity inspection and evaluation for all kinds of BGA.

## Reference

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