"GETTING 3D IMAGERY IN FOCUS" HOW 3D DIGITAL STITCHING IMAGERY IS REVOLUTIONIZING FAILURE ANALYSIS AND PRODUCT ANALYSIS – A USER'S PERSPECTIVE

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ABSTRACT
We live in a three dimensional world, so why has the serious exploration of the many options of generating real and pseudo 3D imagery taken until the last decade to happen? This presentation will outline the different types of 3D imagery and how they have found uses in various applications. There are several different companies making 3D vertical stitching equipment and this will show how this capability is being used in the medical, industrial, and especially the electronics industries. The presentation will include various short videos and several images of electronic components that are impossible to get without 3D stitching capability. This includes several examples of how 3D microscope system has saved 100's of thousands of dollars by catching problems and proving to the vendors that they were shipping out of spec parts. Nothing shows the problems better than a crystal clear image with measurements of the defective parts. (Remember, "He that has the best data and clear photos wins any argument"). A method of incorporating moving GIF images to find hard to see defects will be demonstrated. A short discussion on the calibration method of the 3D imaging system, the Gage R&R and accuracy studies, and the 3D rotational imaging capabilities of the system will be shown. An example of using video capture capability to show dendrite growth on components and boards will be demonstrated.

Key words: Failure Analysis, 3D Microscope stitching, human visual acuity, visual sensitivity, video capture, microscope GR&R, dendrites

INTRODUCTION
Two dimensional images have been the norm for most of recorded history. From cave wall paintings to the photos of the men walking on the moon, 2D images are what have recorded the visual history of mankind.

Only recently have there been significant innovations into three dimensional methods of capturing an image that are more realistic of what was actually being viewed at the time the image was taken.

Several companies have introduced 3D digital stitching technology and microscopes. Some of these have different capabilities and software functions, but generally they all take multiple images and combine them into one clear image. This can be done in a 2D format (horizontal and vertical images) or in a 3D format (where you are stitching the vertical images together).

Note:
The methods of capturing 3D movement will be very difficult to demonstrate in this written word format. Screen captures of the AVI and MP4 videos will only capture a single frame of the whole video and will do a poor job of portraying the moving information adequately. Only the complete presentation with the full videos will suffice for accuracy, clarity, and understanding what the 3D images are seeing. These videos will be shown during the SMTAI conference sessions.

ADVENTURES INTO 3D IMAGERY:
What has been done to bring 3D into reality and usable for everyday lives?
- Animation/Game Graphics
- Pseudo Movement 3D
- 3D Screens and Projectors
- Holograms
- Sidewalk art that looks 3D
- Vertical/Horizontal stitching

Figure 1: 3D Virtual Reality with your cell phone.

Figure 2: Pseudo Movement – A watch movement that is moving in a GIF format.

3D cameras:
3D Screens (TV's)
3D Projectors
3D movie glasses (Anaglyph and shutter glasses)

Figure 3: 3D Screens and Projectors need glasses to see the image.

PSEUDO 3D IMAGERY:
Magic Eye Images – can you see the squirrel with the acorn in the below image:

Figure 4: Magic Eye Image

HOLOGRAMS

Figure 5. Moving holograms.

Figure 6: Sidewalk drawings to represent 3D images

HOW CAN THESE 3D TECHNOLOGIES BE USED TO ENHANCE PHOTOGRAPHIC IMAGES
The background and history of watching humans inspect products have taught us that the human eye is very good at detecting slight differences in a pattern of the same thing. Inspection equipment vendors have been mimicking how humans look at objects for several years. Knowing that the human eye has the "megapixel equivalent" of about 10 megapixels, [(1)] humans are as equipped to see movement as most of the AOI production systems are. To enhance the human ability to detect differences, show more detail, or find defects, we can alternate the images with different lighting, or different images of "perfect" product.

Hunters will scan a hillside for many minutes but cannot see what they are looking for. Then suddenly something moves and now they can see it – even after it has stopped again.[(2)]

Figure 7: When the animal stops, the animal blends in with the background and can't be easily seen. When it moves, it shows up clearly. Can you see the wolf?

From previous experience with amateur astronomy, we know that there are rather unique techniques used to find hard to detect objects in an image. The comparison of images looks for something that is moving.

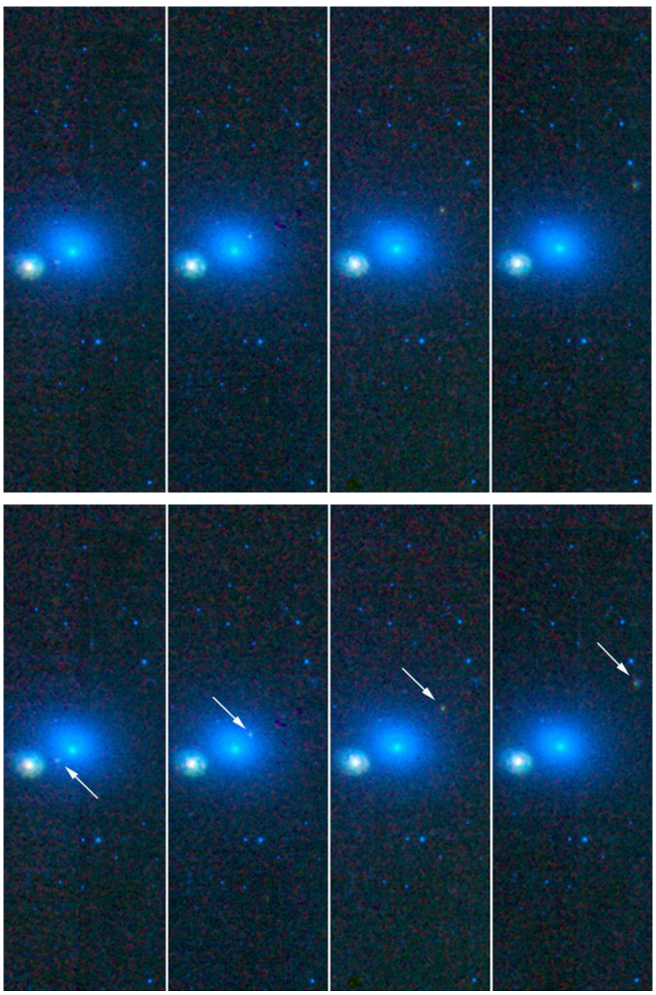

Figure 8: Tracking an object in space through movement.

The above represents consecutive images that are needed to detect the differences. It is more difficult to see something of any significance until you spot the object that moved from the proceeding image.

With this technique in mind, it was decided to see if some of these methods could be adapted to make it easier to detect hard to find defects in fields of objects that look similar.

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WHAT CAN BE DONE TO MAKE IMAGE DEFECTS MORE DETECTABLE TO THE HUMAN EYE?

From other work that has been done on image contrast and moving images, we determined that finding a way to make the image "move" would significantly increase the likelihood that the inspector can see the defect.

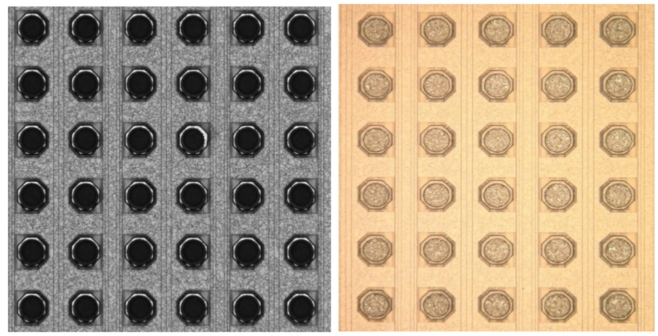

Figure 9: GIF images will alternate between the images to help make the small differences more apparent.

DEMONSTRATING EYE SENSITIVITIES TO DIFFERENCES – ALTERNATING IMAGES.

We found by researching software advantages, that Graphics Interchange Format (GIF) generators will take images and make a small file that will alternate the images. We found we would use that capability to make an image move so we would be able to detect defects that would be overlooked with the single static image.

We found that you could use the following files to make GIF's:

- Different images where lighting changes were made on same part.
- Comparison between images of similar but different parts.
- Comparison with a "good' standard image.

We investigated looking at the same image and changing the lighting to see what we could detect. In some applications this can show up differences that are detectable just with the lighting alone.

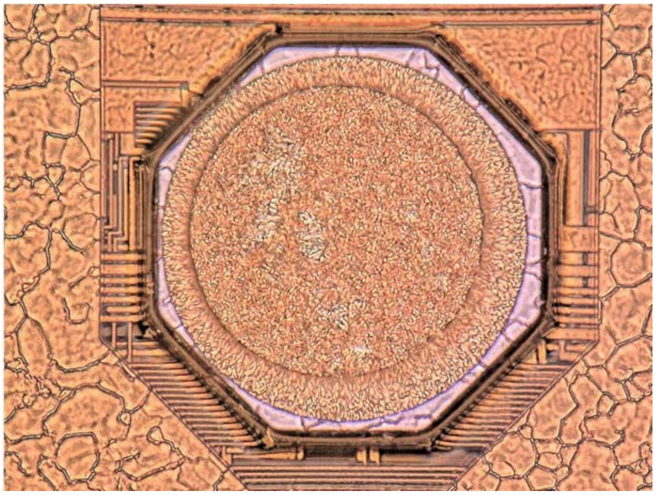

Figure 10: Photos of a gold column bump were taken with different lighting then compiled into a GIF to view the differences in gold nodules on the surface.

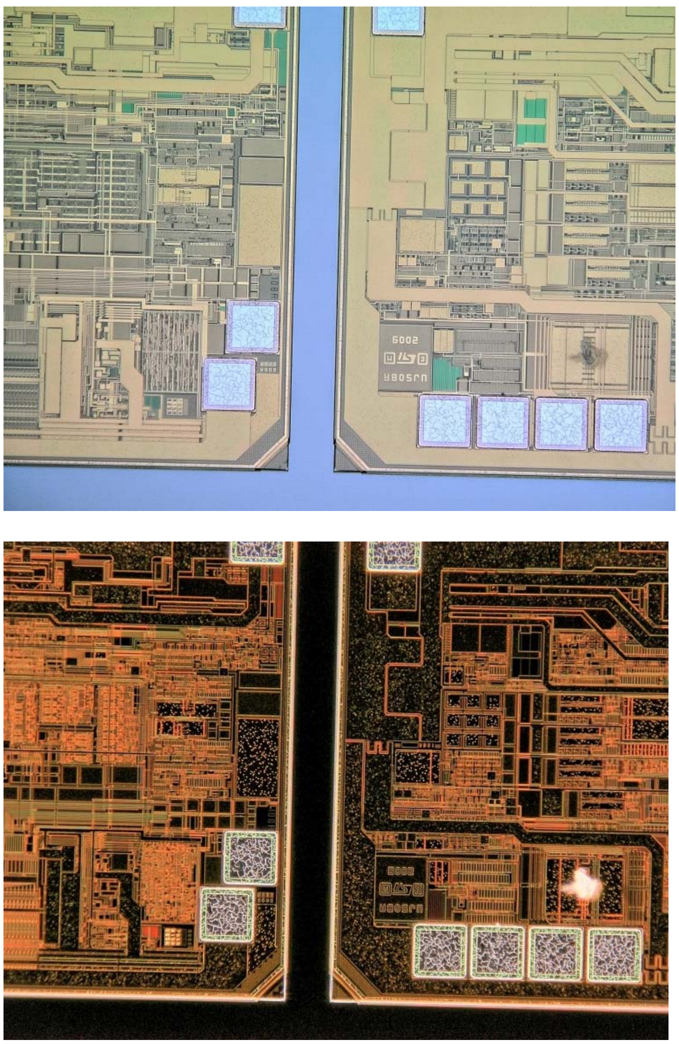

Figure 11: Alternative bright field and dark field of images shows defects clearer – Note the bottom right defect.

HOW TO USE THIS 3D TECHNOLOGY TO CAPTURE IMAGES THROUGH MICROSCOPY AND OTHER METHODS.

Examples of Microscopic failures shown with 3D imagery:

Figure 12: 3D Images of tin caps on copper columns

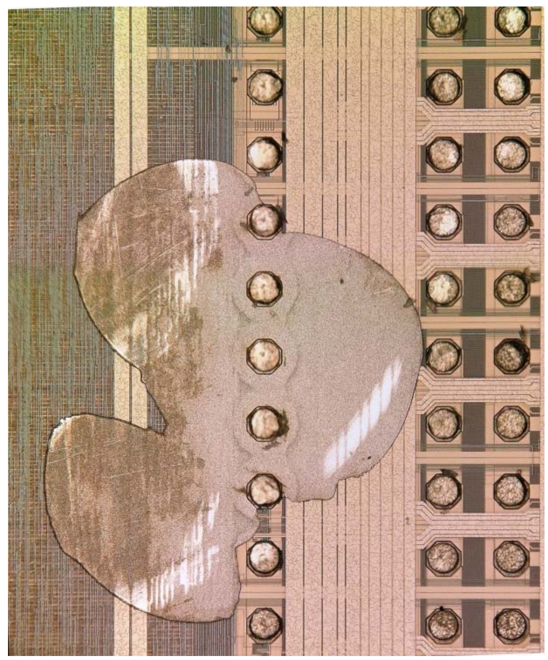

Figure13: Above is an example of a die plating defect where the photo was horizontally stitched to get the small details at high definition. .

GAGE STUDY, STABILITY AND ACCURACY:

A gage study was completed on the system to understand the accuracy and repeatability of the measurement system.

The Gage Block that was used for Z Axis studies measured 3mm x 24 mm.

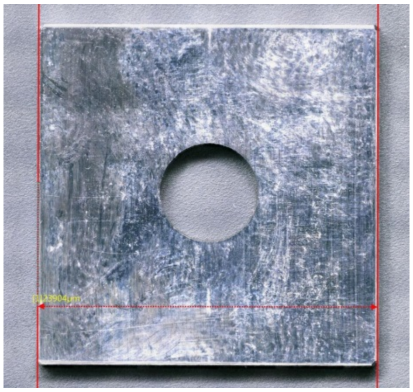

Figure 14: This is the 3mm Thick Certified Steel Standard used for the Z-Axis calibration.

Gage Block Certified thickness numbers:

Nominal	Lower Limit	Upper limit
3.0000	2.99986	3.00014
Actual	**Deviation**	**Uncertainty**
3.0000	2.99986	3.00014

With edge detection on (to help insure accuracy of the starting and ending points), the base of the microscope was measured with the focus automatically rising to the top surface of the gage block. After being colorized, the image below shows the heights achieved.

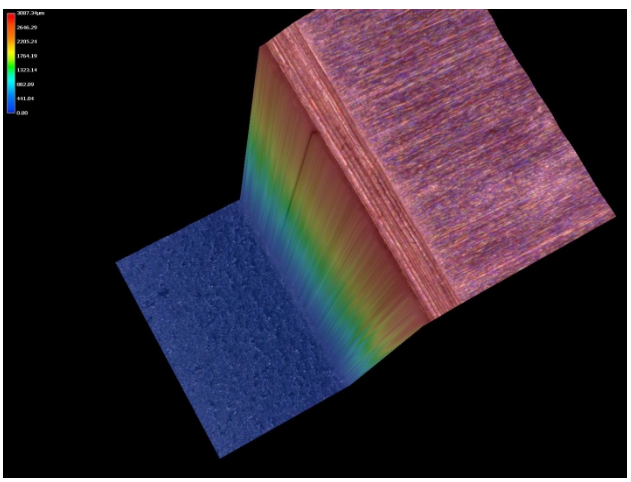

Figure 15: 3D image showing the heights. Measurements of the heights are as shown in the image below.

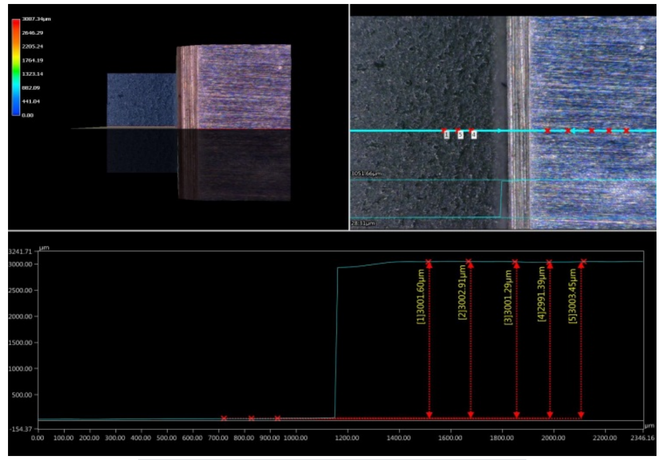

Figure 16: Vertical measurements

Z Measurement (3 mm std)	
Min	2991.39
Max	3003.45
STD	4.966
Average	3000.13

This table shows that the Z-height measurements are consistetly accurate to within 5 microns at 150 X.

CLARITY AND QUALITY OF IMAGES:

The quality the images obtained by the system is highly dependant on the level of magnifcation of the sample.

The lower the magnification, the more eratic the image is as there is not enough data being given the imager to clearly determine what it is seeing and produce adequate height measurements. Examples below show that there is a strong relationship to image quality as you go higher the magnification is up to about 150-200X. Above 200X, there is enough data to give much clearer and accurate images for measurement or image collection.

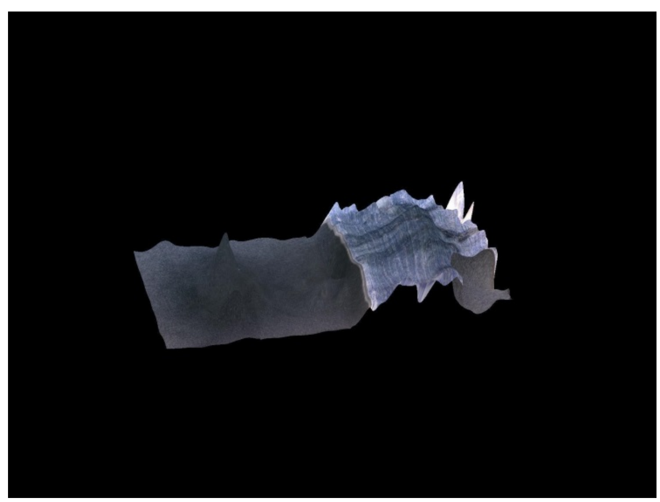

Figure 17: 20X Magnification – above – not enough data.

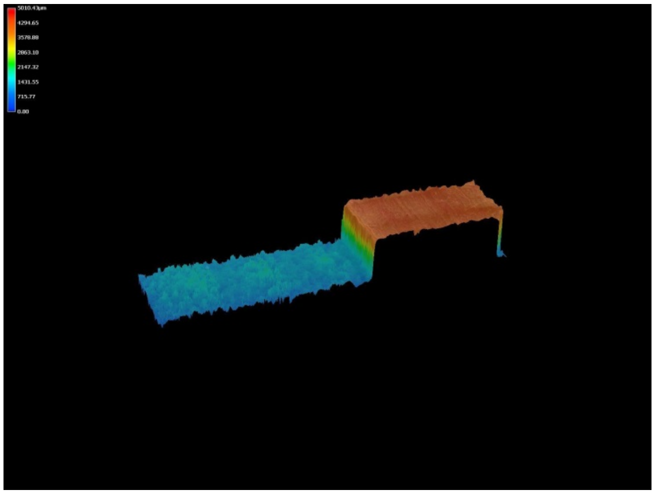

Figure 18: 50X Magnification – above – not enough data

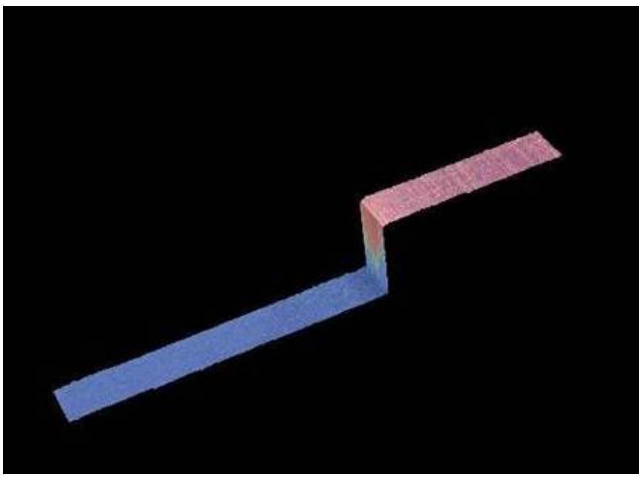

Figure 19: 150X Magnification-above-has enough data to properly measure heights.

X-Y CALIBRATION METHOD:
Calibration is done with a glass slide that is set up with various magnification levels.

Figure 20: Glass slide with various size and space markings used to calibrate the measurements and insure accuracy.

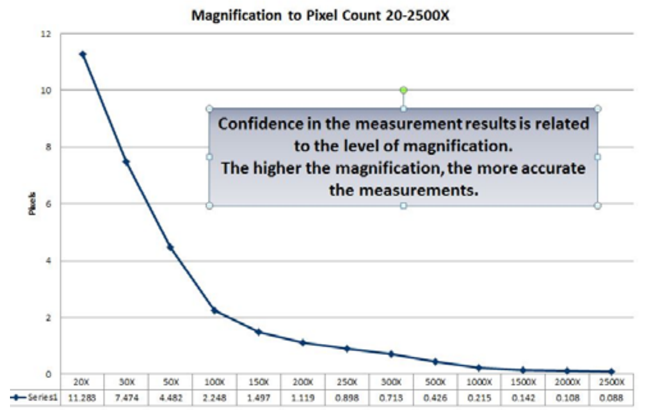

Figure 21: Hundreds of measurements were taken at magnifications from 20X up through 2500X.

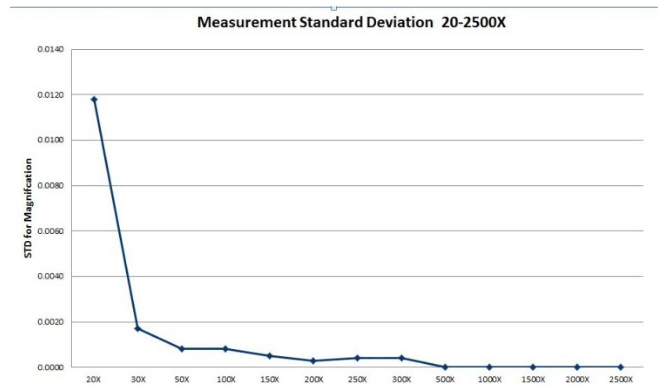

Figure 22: This shows that there is a huge measurement error when magnifying at 20X, but it gets significantly better above 100X, and is very dependable at 500X.

IMAGES THAT ARE VERY HARD TO GET WITHOUT 3D TECHNOLOGY
These images are clean and crisp, but the part to be photographed was very angular and would have been out of focus for a standard microscope. The 3D stitching capability captures hundreds of images and merges them into one clear photograph.

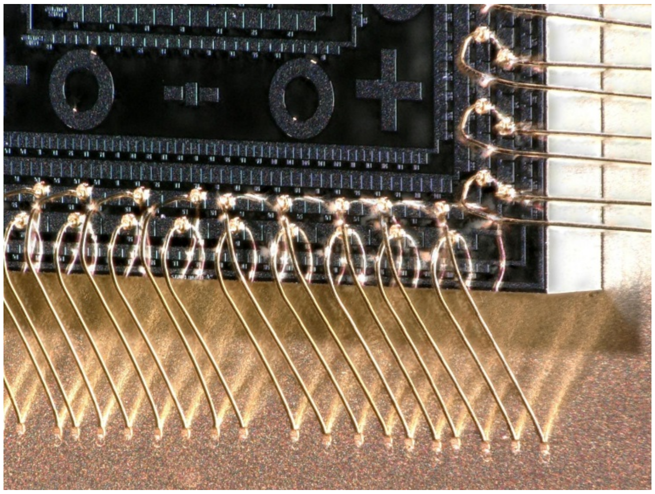

Figure 23: 3D image of wire bonds from two sides of a die showing complete loop lengths and heights.

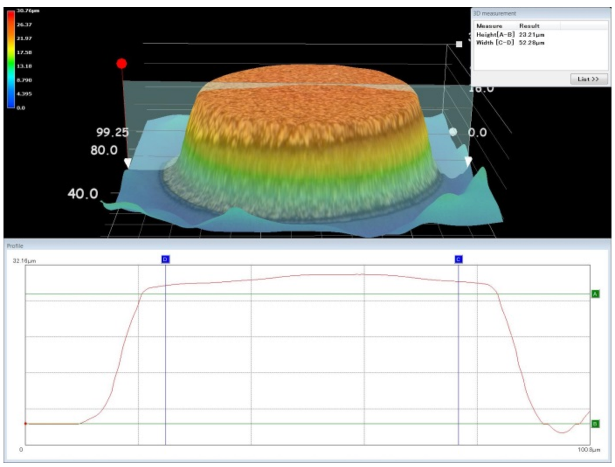

Figure 24: 3D image of a copper column bump showing measurement heights and widths.

Figure 25: Can you find the 008004 component on this penny?

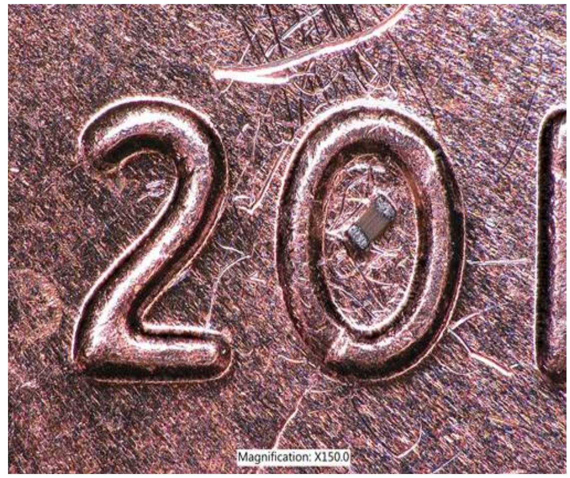

Figure 26: The 008004 component is inside the "0" in the date.

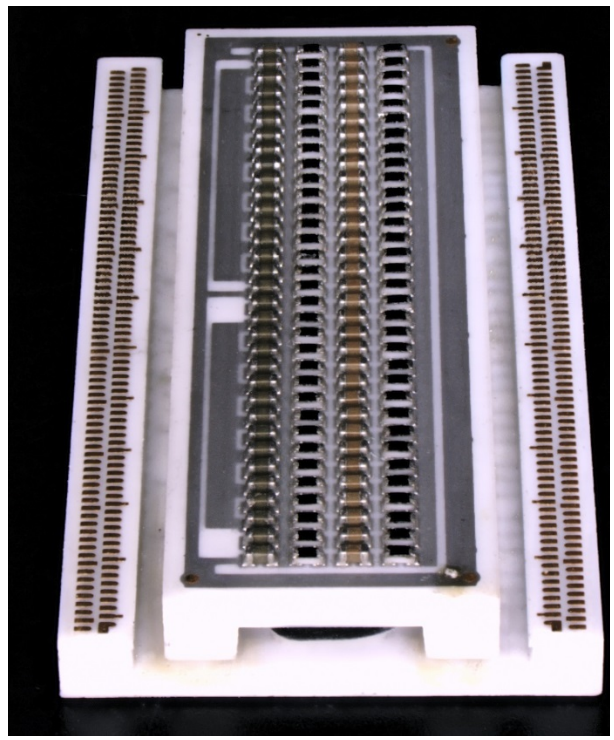

Figure 27: 3D stitched image of a two part ceramic substrate with 132 chip caps and resistors (0201's) on the backside surface – all in focus.

VIDEOS SHOWING THE STITCHING PROCESS:

The strength of the 3D stitching camera can be most easily demonstrated by viewing the videos of the optical stitching taking place on the image. (The actual videos will be shown in the presentation at the SMTAI conference).

The blurry image in the 1st photo is how the image first appears. To capture these images, the camera is focused on the lowest point of the image, and when the 3D display button begins the process of taking images quickly and compiling them into one crystal clear image within 8 seconds of total exposure time.

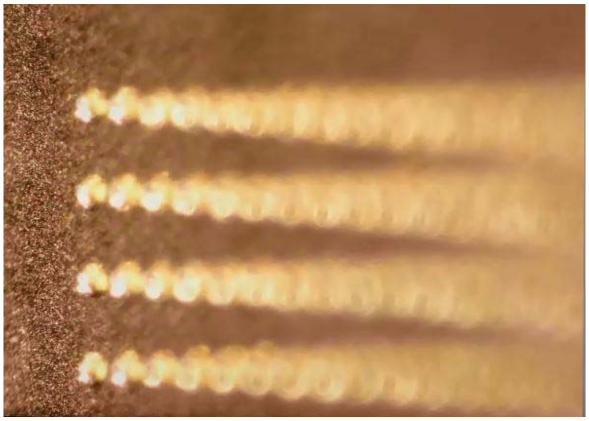

Figure 28: 3D stitching of horizontal rows of stud bumps – are blurry and out of focus as they get further away.

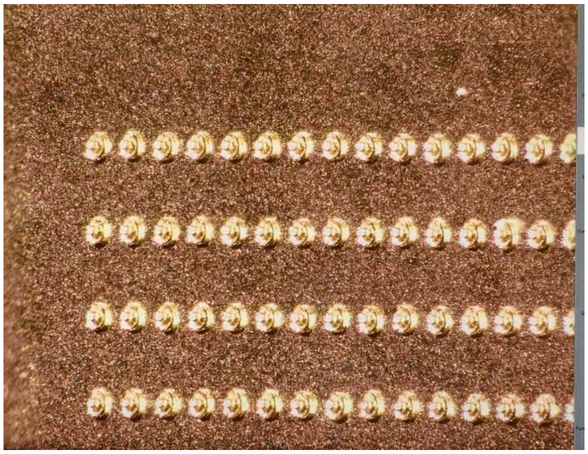

Figure 29: Above: Completed 3D image of rows of stud bumps

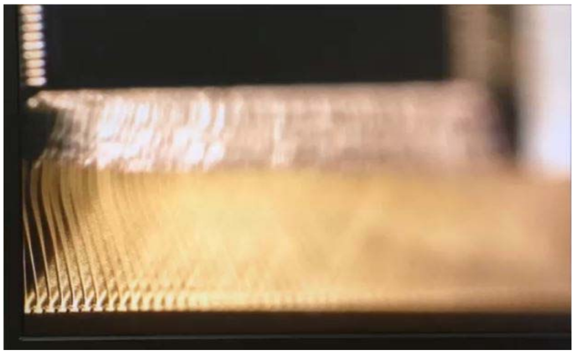

Figure 30: 3D stitching of a row of wire bonds on a die edge without stitching.

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Figure 31: Completed 3D image of a row of wire bonds

DENDRITE GROWTH STUDIES:

To evaluate the levels of incoming contamination and rate plating integrity from some vendors, we set up a classic test using a 9 volt power supply and very small electrical clips that can connect onto the boards or component leads [(3).] We placed a drop of DI water between the contacts to see if we can generate dendrites. If so, we would determine the length of time for the growth to occur to the point where it would short out to the adjacent lead or pad.

With the video capabilities on the microscope, [(4)] we were able to capture numerous short AVI movies that demonstrate the growth and time of the dendrites.

The below series of images shows the surface growth of copper dendrites (taken from the video). These occurred relatively quickly with the first dendrite that grew from the negative to the positive pad within 58 seconds and other strands continuing to grow until the voltage was being equally dissipated at 2 minutes, 14 seconds.

Figure 32: Pads and vias before start of dendrite growth

Figure 33: 1st contact with the positive pad at 58 seconds

Figure 34: Continued growth of new strands

Figure 35: Dendrite growth stopped at 2 min,14 seconds

CONCLUSIONS

3D imagery has brought significant changes to the human culture and have significant advantages over 2D images. 3D has enhanced the reality of the objects around us and enabled us to relate to them as being real and tangible.

3D has assisted us to see images that would be impossible to capture and publish in any other way.

3D videos are helping to show actual moving phenomena that show us the small details and movements in the images we are viewing.

As new technologies continue to shrink our products in the manufacturing world, the techniques we use to examine the parts, understand their construction, and detect their failures will need to evolve to see and inspect these parts. Failure Analysis techniques will migrate to more 3D detection including optical recording, acoustic 3D rendering, and 3D X-ray systems. All these techniques combined will give us a more complete understanding of the problems that face these new products.

REFERENCES

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(2) "Why Are Human Eyes So Good at Detecting Motion?" by Chandra Prakash Singh. https://www.quora.com/Why-are-human-eyes-so-good-at-detecting-motion\
(3) IPC-TM-650 Test Methods Manual, for dendritic growth due to the presence of Ionic residues.
(4) Keyence VHX-5000 system manual, Keyence Corporation,

The image below is of the KeyenceVHX-5000 3D stitching system which was used for most of the photos in this paper.