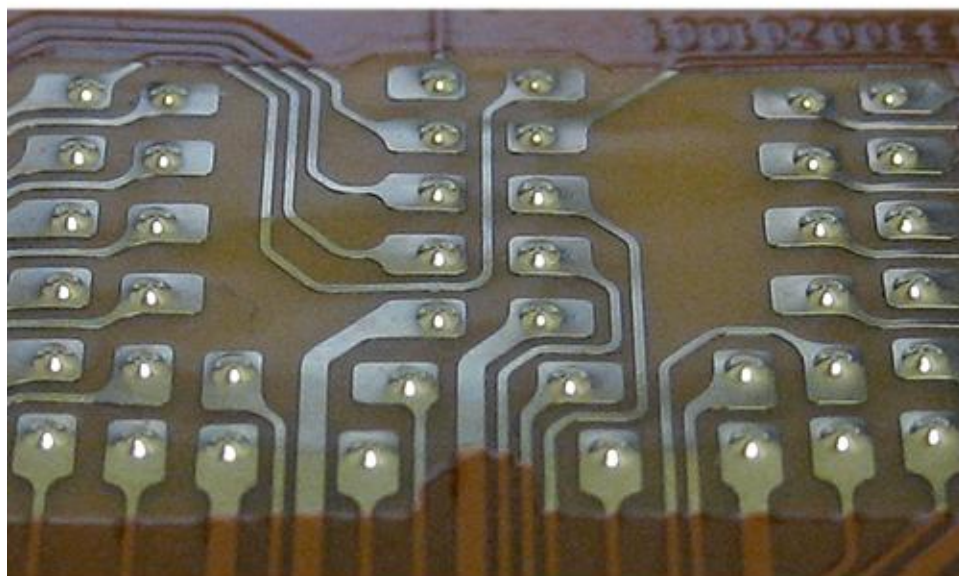


**The Importance Of
3D Profilometry & AFM Integration**



Prepared by
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INTRO:

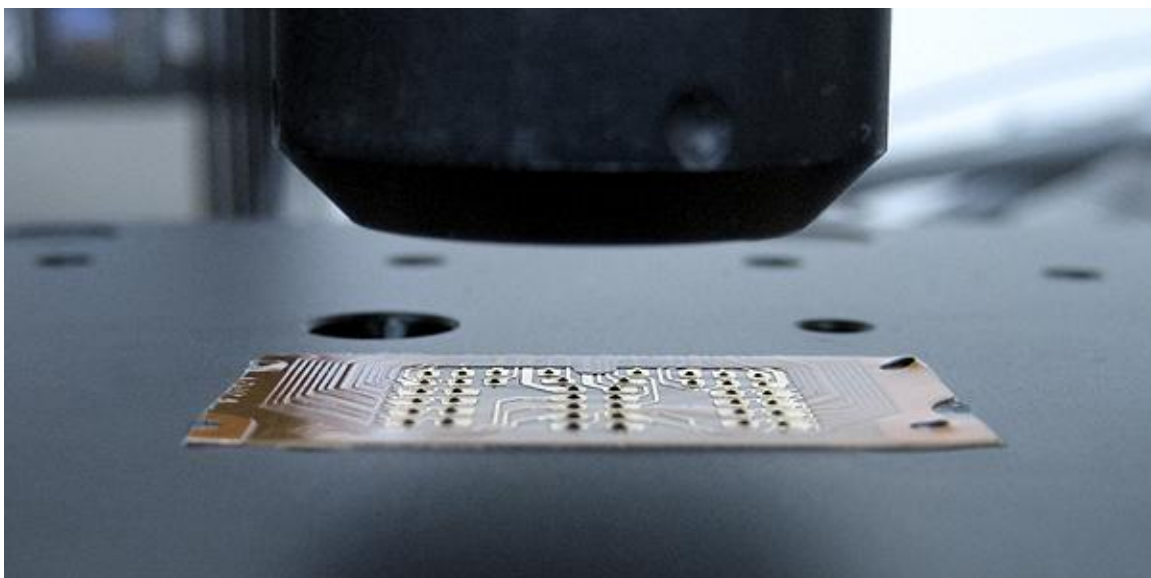
To ensure the quality levels of applications spanning across nearly all industries, most R&D units have or are in the process of obtaining or updating their instruments to include surface measurement at various range. This would ensue before an exhausting list of instrument options would have to be comparatively matched to fit user specific measurement requirements. Once the instrument is selected, it is only later that the user then identifies that their chosen instrument is not capable of broad and or expandable measurement use. It is unfortunate that only at this point most recognize the true value of a single surface measurement instrument with broad capability from Macro through Angstrom range.

IMPORTANCE OF THE 3D METROLOGY AND AFM INTEGRATION

By integrating the AFM to the Nanovea 3D Non Contact Profilometer the result is essentially an unsurpassed surface measurement instrument. Unlike the typical Optical Microscope/AFM combination, that simply provides imaging analysis before AFM use; the Profilometer/AFM combination not only provides Microscope imaging but a measured surface analysis before AFM use. The combination of these two measurement techniques is ideally supportive of one another's function with an enhancing result. The Profilometer technique provides a larger field of vision, enabling a wider surface area to be fully measured and then identified for faster AFM analysis. Conversely, the AFM technique extends capability, enabling 3D measurement at higher lateral and vertical resolution than Profilometer range. This combination of two powerfully combined techniques provides cost and time savings, while advancing user capability and expanding possibilities for quality control research.

MEASUREMENT OBJECTIVE

To showcase this advanced capability, the Nanovea ST400 with AFM integration is used to measure a Macro area of solder bumps. Several surface parameters can automatically be calculated including the most common, Sa (average surface roughness), step height, area, planarity and many others. After investigation at the Macro level, a precisely chosen target will be identified for automatic study with AFM integration.

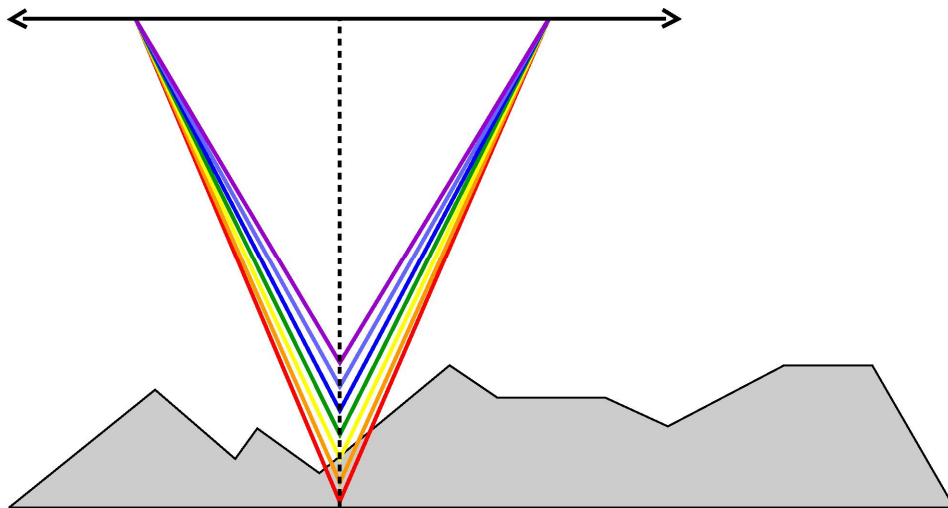


MEASUREMENT SET-UP & TIPS:

Measurement area of 42mm x 14mm was chosen to capture one entire array of solder bumps. The XY resolution was set at 4um x 4um in order to properly resolve the bumps and surrounding feature. The Optical Pen was selected based on the estimation of bump height.

MEASUREMENT PRINCIPLE:

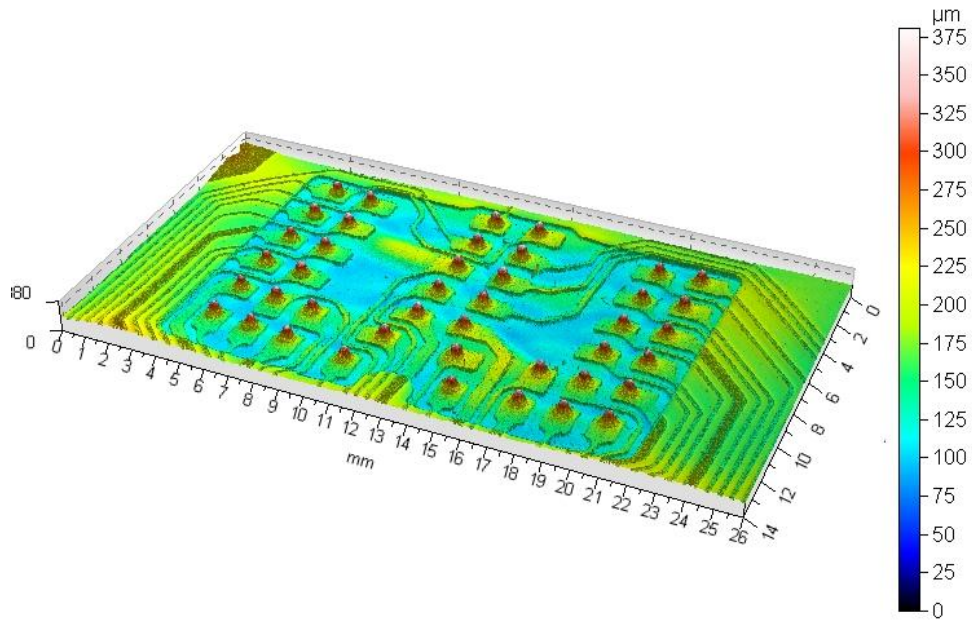
The axial chromatism technique uses a white light source, where light passes through an objective lens with a high degree of chromatic aberration. The refractive index of the objective lens will vary in relation to the wavelength of the light. In effect, each separate wavelength of the incident white light will re-focus at a different distance from the lens (different height). When the measured sample is within the range of possible heights, a single monochromatic point will be focalized to form the image. Due to the confocal configuration of the system, only the focused wavelength will pass through the spatial filter with high efficiency, thus causing all other wavelengths to be out of focus. The spectral analysis is done using a diffraction grating. This technique deviates each wavelength at a different position, intercepting a line of CCD, which in turn indicates the position of the maximum intensity and allows direct correspondence to the Z height position.



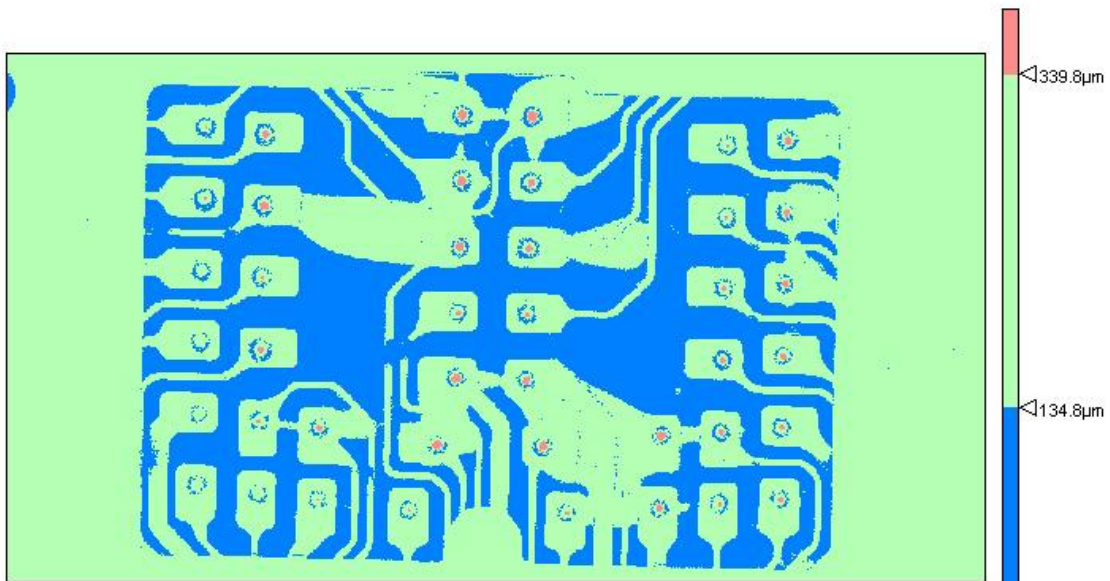
Nanovea optical pens have zero influence from sample reflectivity. Variations require no sample preparation and have advanced ability to measure high surface angles. Capable of large Z measurement ranges. Measure any material: transparent/opaque, specular/diffusive, polished/rough.

3D METROLOGY RESULTS: Solder Bumps

Solder Bumps 3D Image



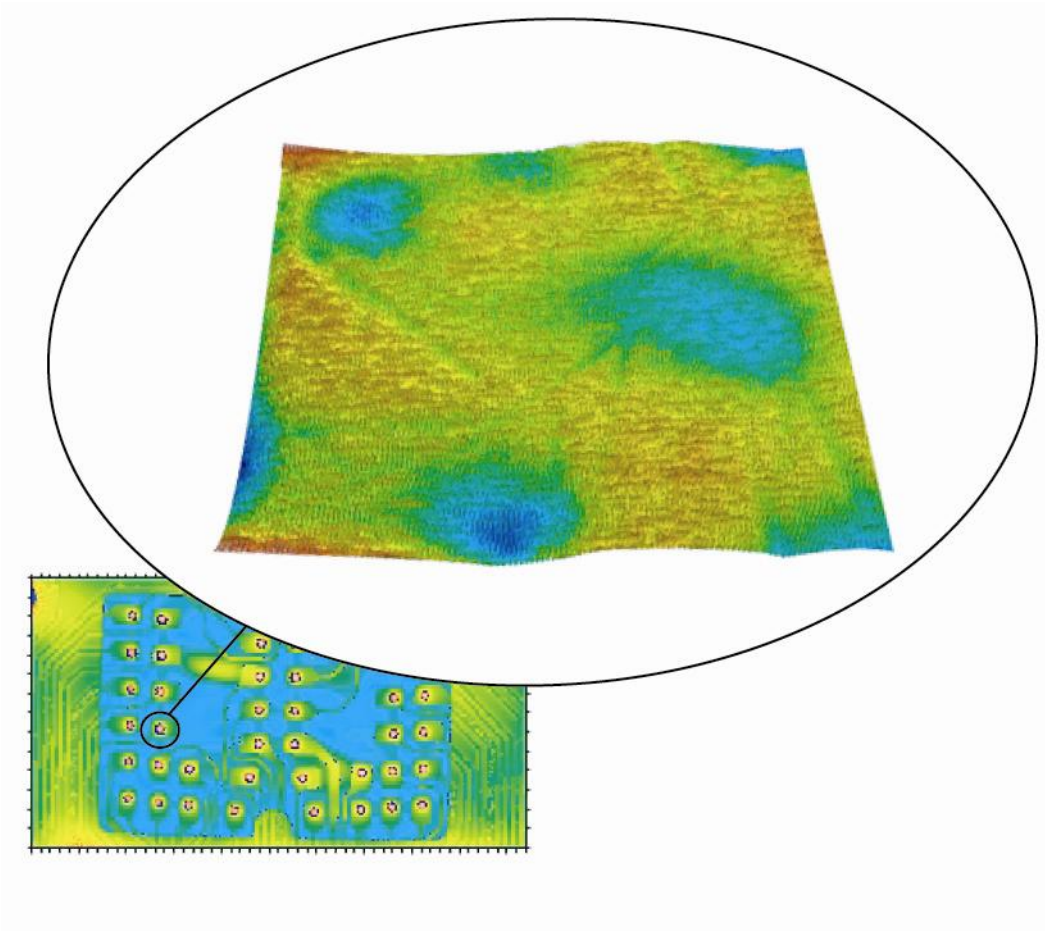
Solder Bumps Contact Surface Area



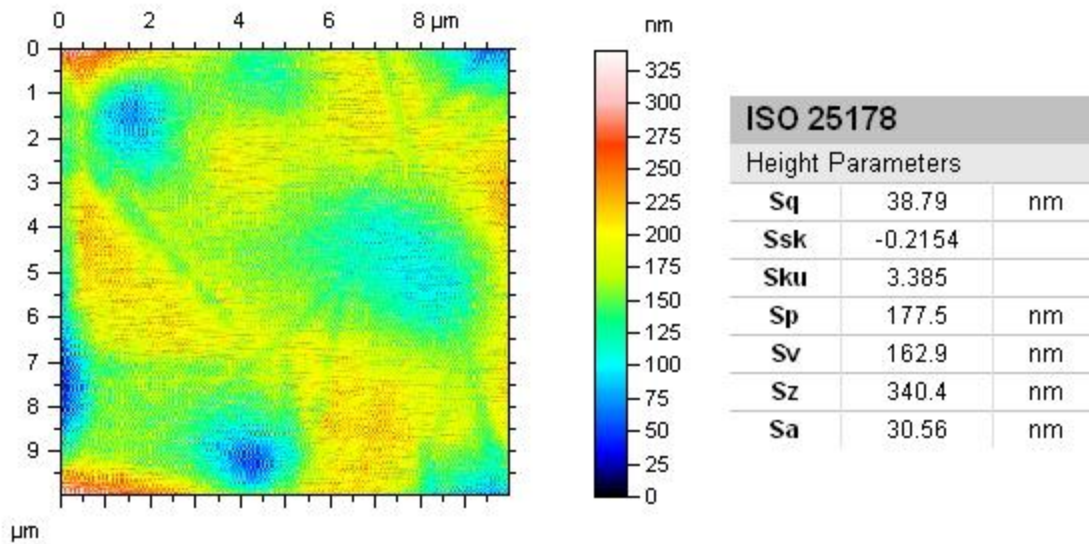
	Blue	Green	Red
Projected Area (%)	32.64	66.98	0.3746
Volume of void (%)	5.938	86.89	99.91
Volume of material (%)	94.06	13.11	0.08696
Volume of void (μm.mm2/mm2)	8.003	174.0	45.56
Volume of material (μm.mm2/mm2)	126.8	26.25	0.03966
Mean thickness of void (μm)	8.003	174.0	45.56
Mean thickness of material (μm)	126.8	26.25	0.03966

AFM RESULTS:
Solder Bumps

Solder Bump AFM Surface Measurement



Solder Bump AFM Surface Roughness



Height Parameter		Definition
Sa	Arithmetical Mean Height	<p>Mean surface roughness.</p> $Sa = \frac{1}{A} \int_A z(x,y) dx dy$
Sq	Root Mean Square Height	<p>Standard deviation of the height distribution, or RMS surface roughness.</p> $Sq = \sqrt{\frac{1}{A} \iint_A z^2(x,y) dx dy}$ <p>Computes the standard deviation for the amplitudes of the surface (RMS).</p>
Sp	Maximum Peak Height	Height between the highest peak and the mean plane.
Sv	Maximum Pit Height	Depth between the mean plane and the deepest valley.
Sz	Maximum Height	Height between the highest peak and the deepest valley.
Ssk	Skewness	<p>Skewness of the height distribution.</p> $Ssk = \frac{1}{Sq^3} \left[\frac{1}{A} \iint_A z^3(x,y) dx dy \right]$ <p>Skewness qualifies the symmetry of the height distribution. A negative Ssk indicates that the surface is composed of mainly one plateau and deep and fine valleys. In this case, the distribution is sloping to the top. A positive Ssk indicates a surface with a lot of peaks on a plane. Therefore, the distribution is sloping to the bottom.</p> <p>Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.</p>
Sku	Kurtosis	<p>Kurtosis of the height distribution.</p> $Sku = \frac{1}{Sq^4} \left[\frac{1}{A} \iint_A z^4(x,y) dx dy \right]$ <p>Kurtosis qualifies the flatness of the height distribution.</p> <p>Due to the large exponent used, this parameter is very sensitive to the sampling and noise of the measurement.</p>

CONCLUSION:

In this application, we have shown the powerful combination of the ST400 3D Non Contact Profilometer with AFM integration. A Profilometer measurement area of 42mm x 14mm was chosen to capture one entire array of solder bumps. Surface contact area was then automatically calculated. Additional automatic measurement calculations could have included height and distance, bump radius, flatness and roughness and others. Next, a specific target was chosen, solder bump tip, and the AFM was automatically set into position for Angstrom level surface analysis. This information can be used to investigate with quantifiable, reproducible and reliable results. Macro through Angstrom surface measurement can be obtained on endless research and quality control applications. With this unmatched surface measurement capability along with microscope analysis, the Nanovea Profilometer sets the standard for what should be expected when using optical surface inspection systems.